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(12) **United States Patent**
Kassab

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(54) **DEVICES, SYSTEMS, AND METHODS FOR REMOVING TARGETED LESIONS FROM VESSELS**

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(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) **Int. Cl.**

A61B 17/22 (2006.01)

A61B 5/053 (2006.01)

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(52) **U.S. Cl.**

CPC *A61B 5/053* (2013.01); *A61B 5/0538* (2013.01); *A61B 5/1076* (2013.01); *A61B 5/417* (2013.01);

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(58) **Field of Classification Search**

CPC *A61B 5/0535*; *A61B 90/06*; *A61B 5/1076*; *A61B 5/417*; *A61B 5/0538*; *A61B 18/24*;

(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,871,359 A * 3/1975 Pacela 600/547
3,896,373 A 7/1975 Zelby

(Continued)

FOREIGN PATENT DOCUMENTS

EP 1 025 805 A1 8/2000
WO WO 98/35611 A1 8/1998

(Continued)

OTHER PUBLICATIONS

PCT/US2010/031553, PCT International Preliminary Report on Patentability, dated Oct. 18, 2011.

(Continued)

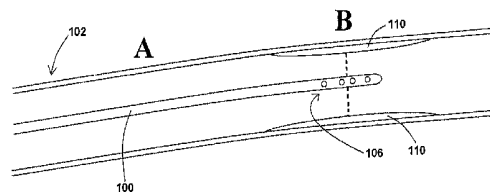
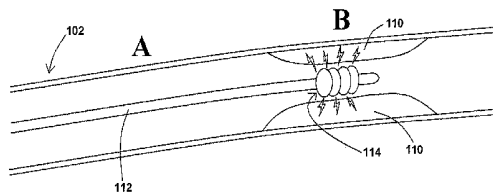
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(57) **ABSTRACT**

Devices, systems, and methods for removing targeted lesions from vessels. In at least one embodiment of a device for removing a stenotic lesion from a vessel, the device comprises a sizing portion capable of measuring a luminal size parameter when at least part of the device is positioned within a lumen of a luminal organ, a typing portion, wherein at least part of the at least one typing portion is capable of physically touching a portion of the luminal organ or a structure therein, and a treatment portion capable of removing at least part of a stenotic lesion from the luminal organ.

55 Claims, 22 Drawing Sheets



Related U.S. Application Data

of application No. 12/098,242, filed on Apr. 4, 2008, now Pat. No. 8,078,274, which is a continuation-in-part of application No. 11/891,981, filed on Aug. 14, 2007, now Pat. No. 8,114,143, which is a division of application No. 10/782,149, filed on Feb. 19, 2004, now Pat. No. 7,454,244.

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(51) **Int. Cl.**

- A61B 5/107* (2006.01)
- A61B 5/00* (2006.01)
- A61B 18/24* (2006.01)
- A61M 25/10* (2013.01)
- A61B 17/3207* (2006.01)
- A61B 18/02* (2006.01)
- A61B 17/00* (2006.01)
- A61B 18/00* (2006.01)
- A61F 2/958* (2013.01)
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(52) **U.S. Cl.**

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(58) **Field of Classification Search**

- CPC *A61B 2090/061*; *A61B 2018/0022*; *A61B 2017/00026*; *A61B 18/02*; *A61B 2017/22044*; *A61B 2017/22061*; *A61B 17/320758*; *A61B 2018/0212*; *A61B 17/320725*; *A61B 17/22004*; *A61B 2017/00084*; *A61M 25/1018*; *A61M 2025/0002*; *A61F 2/958*
- USPC 600/393, 372, 506, 547; 606/129, 127, 606/159; 604/114
- See application file for complete search history.

(56)

References Cited

U.S. PATENT DOCUMENTS

4,380,237 A	4/1983	Newbower	
4,587,975 A *	5/1986	Salo	A61B 5/0535 600/506
4,840,182 A	6/1989	Carlson	
5,058,583 A	10/1991	Geddes	
5,125,410 A	6/1992	Misono et al.	
5,209,730 A *	5/1993	Sullivan	A61M 25/0108 600/434
5,233,994 A	8/1993	Shmulewitz	
5,242,441 A *	9/1993	Avitall	606/41
5,315,996 A *	5/1994	Lundquist	600/374
5,366,443 A	11/1994	Eggers et al.	
5,425,363 A *	6/1995	Wang	600/375
5,453,576 A	9/1995	Krivitski	
5,571,162 A *	11/1996	Lin	607/122
5,665,103 A	9/1997	Lafontaine et al.	
5,697,944 A *	12/1997	Lary	606/159

5,741,214 A *	4/1998	Ouchi et al.	600/374
5,788,692 A *	8/1998	Campbell et al.	606/33
5,827,192 A	10/1998	Gopakumaran et al.	
5,842,998 A	12/1998	Gopakumaran et al.	
5,967,984 A *	10/1999	Chu et al.	600/439
5,971,933 A	10/1999	Gopakumaran et al.	
6,019,757 A *	2/2000	Scheldrup	606/49
6,112,115 A	8/2000	Feldman	
6,148,222 A *	11/2000	Ramsey, III	600/380
6,165,977 A	12/2000	Mochly-Rosen	
6,187,744 B1	2/2001	Rooney	
6,191,136 B1	2/2001	Marban	
6,270,493 B1	8/2001	Lalonde et al.	
6,325,762 B1	12/2001	Tjin	
6,354,999 B1	3/2002	Dgany et al.	
6,360,123 B1	3/2002	Kimchi	
6,398,738 B1	6/2002	Millar	
6,406,422 B1	6/2002	Landesberg	
6,471,656 B1	10/2002	Shalman et al.	
6,494,832 B1	12/2002	Feldman	
6,511,413 B2	1/2003	Landesberg	
6,514,249 B1 *	2/2003	Maguire et al.	606/41
6,545,678 B1	4/2003	Ohazama	
6,569,862 B1	8/2005	Marban	
6,926,674 B2	8/2005	Tenerz	
7,141,019 B2	11/2006	Pearlman	
7,169,107 B2	1/2007	Jersey-Willuhn et al.	
7,189,208 B1	3/2007	Beatty et al.	
7,236,820 B2	6/2007	Mabary et al.	
7,326,241 B2	2/2008	Jang	
8,114,143 B2 *	2/2012	Kassab et al.	623/1.11
2002/0016615 A1 *	2/2002	Dev et al.	607/2
2002/0183817 A1 *	12/2002	Van Venrooij et al.	607/116
2003/0013986 A1	1/2003	Saadat	
2003/0018362 A1 *	1/2003	Fellows et al.	607/5
2003/0028189 A1 *	2/2003	Woloszko et al.	606/45
2003/0191515 A1 *	10/2003	Haldeman et al.	607/119
2004/0024329 A1	2/2004	Jansen et al.	
2005/0049475 A1 *	3/2005	Gregersen	600/407
2006/0178670 A1 *	8/2006	Woloszko	A61B 18/1402 606/48
2007/0161914 A1	7/2007	Zdeblick et al.	
2008/0176271 A1	7/2008	Silver et al.	
2008/0194996 A1	8/2008	Kassab	
2008/0269581 A1	10/2008	Wood et al.	
2009/0204134 A1 *	8/2009	Kassab	606/159
2009/0210020 A1 *	8/2009	Feldman et al.	607/4
2009/0216133 A1	8/2009	Kassab	
2010/0041984 A1	2/2010	Shaplend et al.	
2012/0053441 A1 *	3/2012	Kassab	600/373
2012/0143078 A1 *	6/2012	Kassab et al.	600/547

FOREIGN PATENT DOCUMENTS

WO	WO 02/19905	3/2002
WO	WO 02/085442 A1	10/2002
WO	WO 03/092495 A1	11/2003

OTHER PUBLICATIONS

PCT/US2010/032178, PCT International Preliminary Report on Patentability, dated Nov. 3, 2011.

PCT/US04/04828, PCT Search Report and Written Opinion dated Jul. 6, 2005.

PCT/US06/05985, PCT Search Report and Written Opinion dated Aug. 8, 2007.

Supplementary European Search Report for EP Application Serial No. EP 04 71 2383 to Electro-Cat, LLC, dated Aug. 6, 2007.

Hoekstein and Inbar, "Cardiac Stroke Volume Estimation from Two Electrodes Electrical Impedance Measurements." Technion Department of Electrical Engineering Publication EE Pub No. 911, Feb. 1994.

L. Kornet, J.R.C. Jansen, E.J. Gussenhoven, M.R. Hardeman, A.P.G. Hoeks and A. Versprille, "Conductance Method for the Measurement of Cross-Sectional Areas of the Aorta," Annals of Biomedical Engineering, vol. 27, pp. 141-150, 1999.

(56)

References Cited

OTHER PUBLICATIONS

Douglas A. Hettrick, Joseph Battocletti, James Ackmann, and David C. Wartier, "Finite Element Model Determination of Correction Factors Used for Measurement of Aorta Diameter via Conductance," *Annals of Biomedical Engineering*, vol. 27, pp. 151-159, 1999.

Douglas A. Hettrick, Joseph Battocletti, James Ackmann, John Linehan, and David C. Wartier, "In Vivo Measurement of Real-Time Aortic Segmental Volume Using the Conductance Catheter," *Annals of Biomedical Engineering*, vol. 26, pp. 431-440, 1998.

International Searching Authority, International Search Report, mailed Aug. 16, 2012 (PCT/US2011/023911).

International Searching Authority, Written opinion of the International Searching Authority, mailed Aug. 16, 2012 (PCT/US2011/023911).

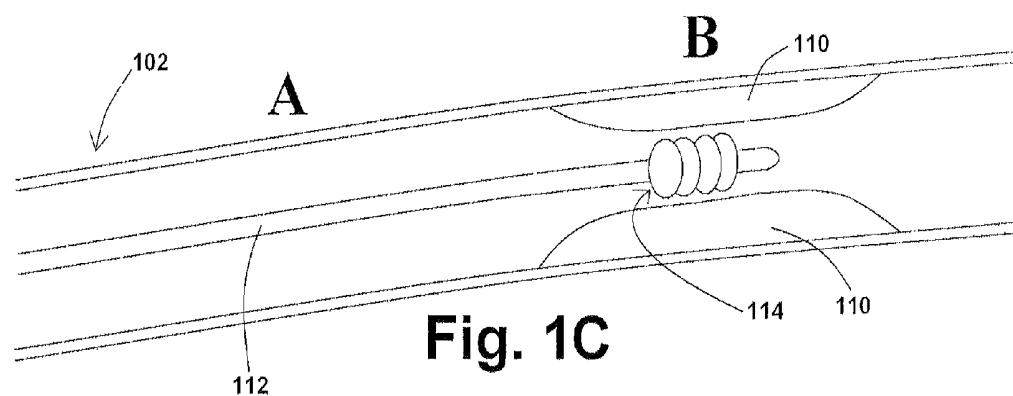
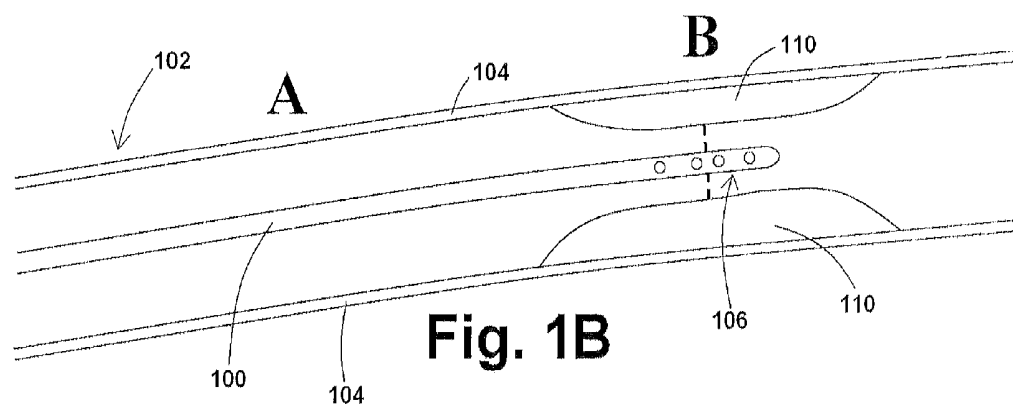
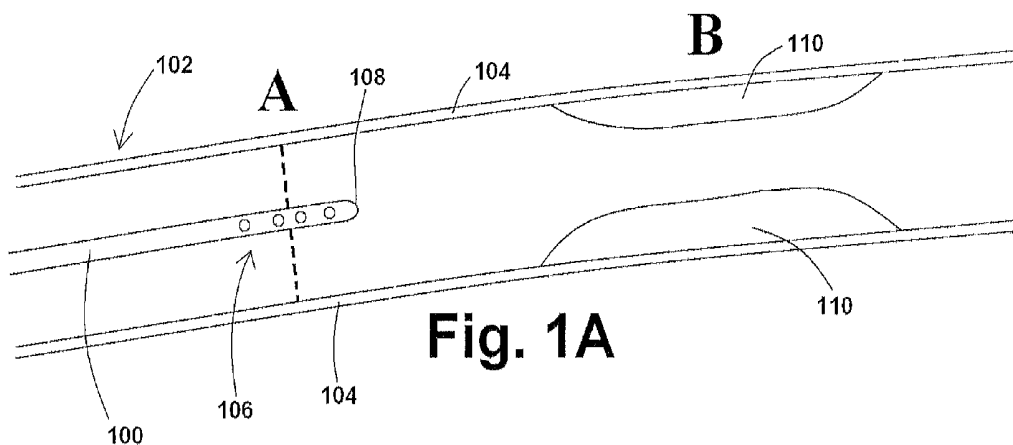
International Searching Authority, International Search Report, mailed Aug. 30, 2012 (PCT/US2011/024961).

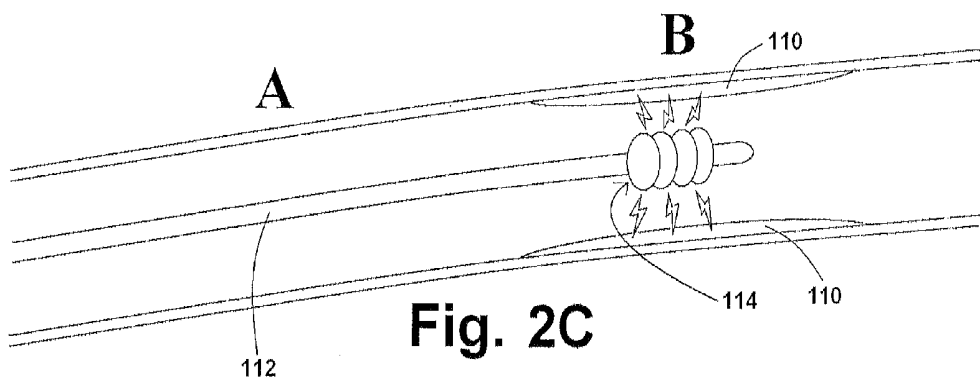
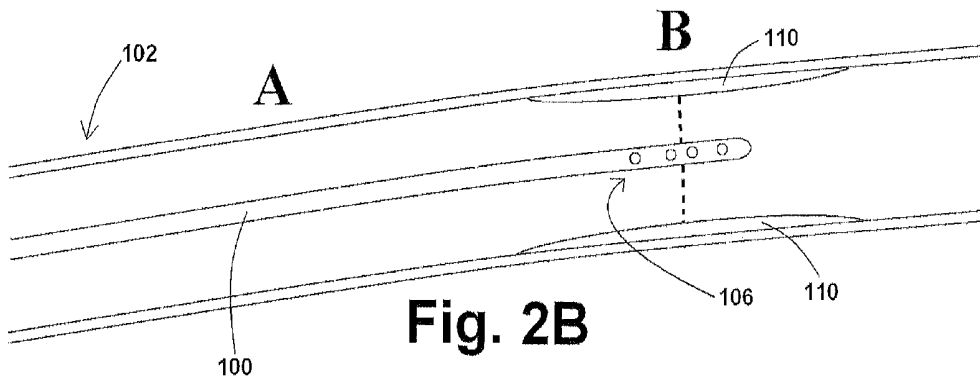
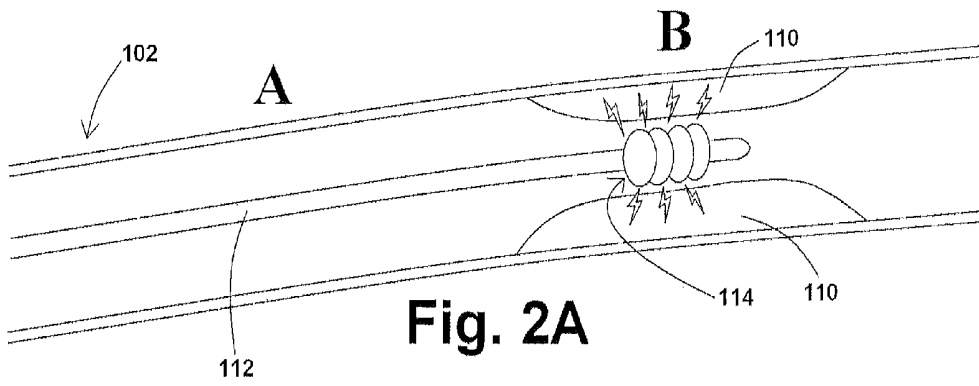
International Searching Authority, Written opinion of the International Searching Authority, mailed Aug. 30, 2012 (PCT/US2011/024961).

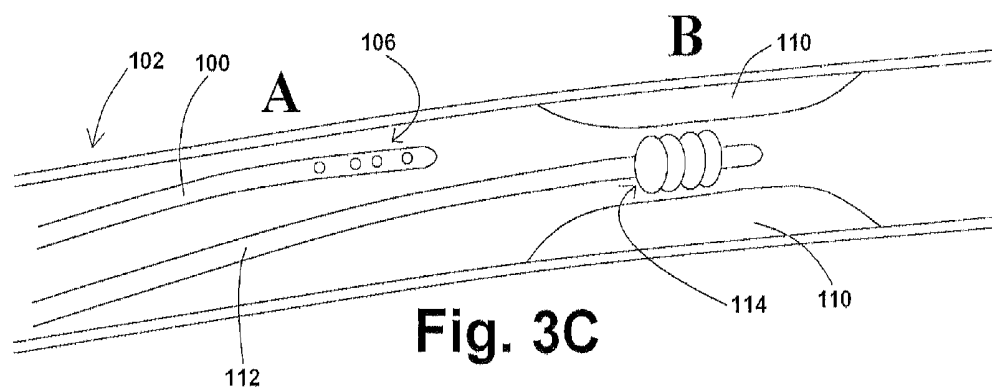
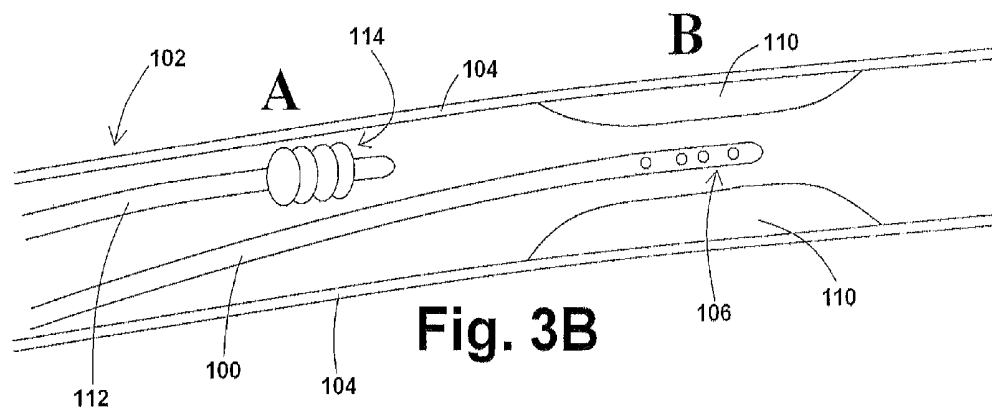
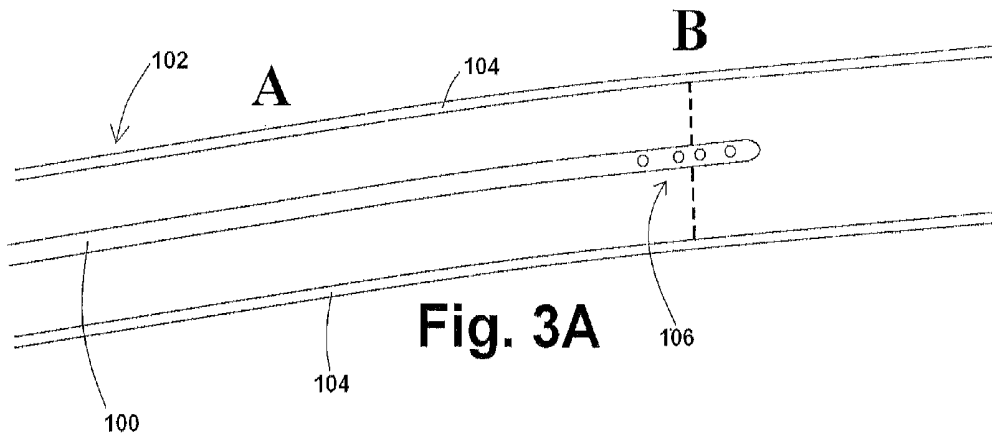
International Searching Authority, International Search Report, mailed Sep. 7, 2012 (PCT/US2011/026337).

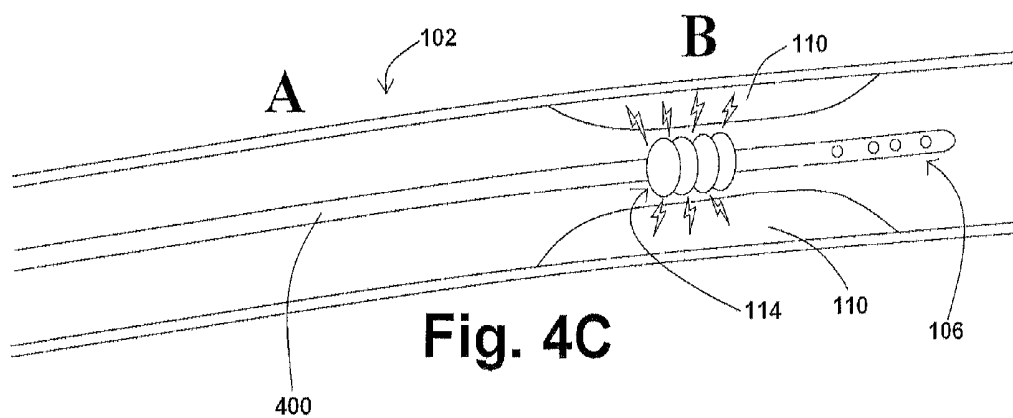
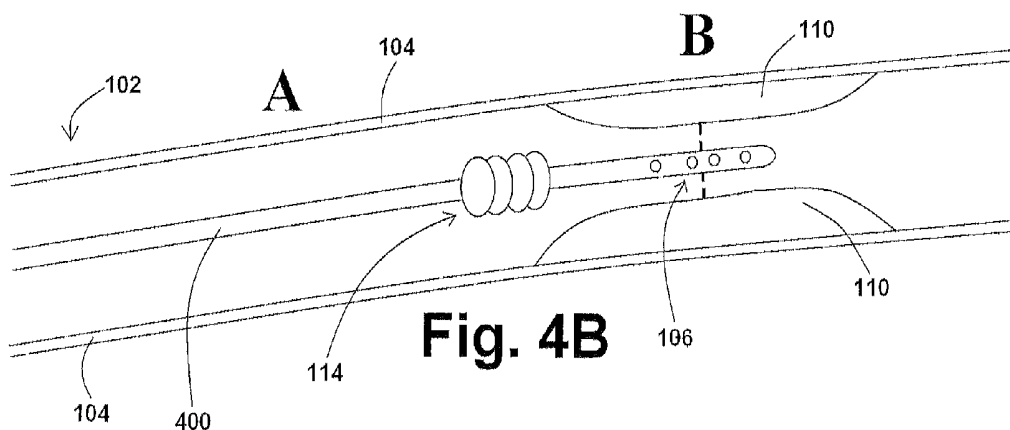
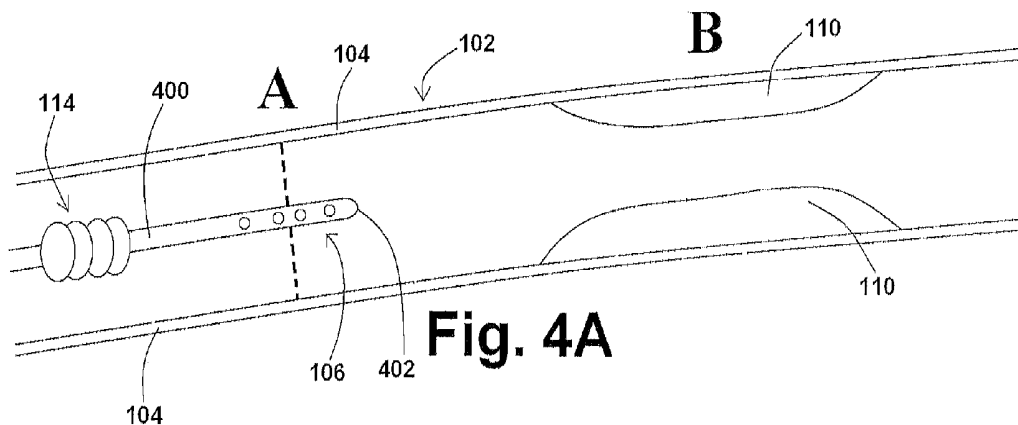
International Searching Authority, Written opinion of the International Searching Authority, mailed Sep. 7, 2012 (PCT/US2011/026337).

* cited by examiner









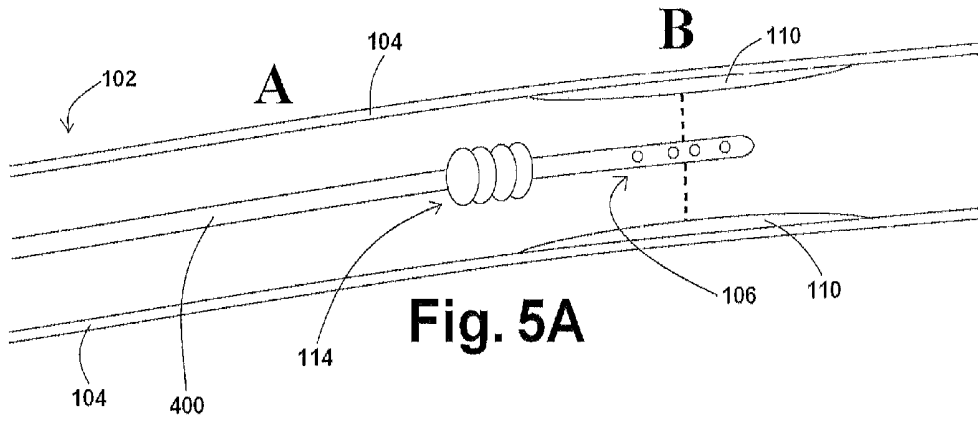


Fig. 5A

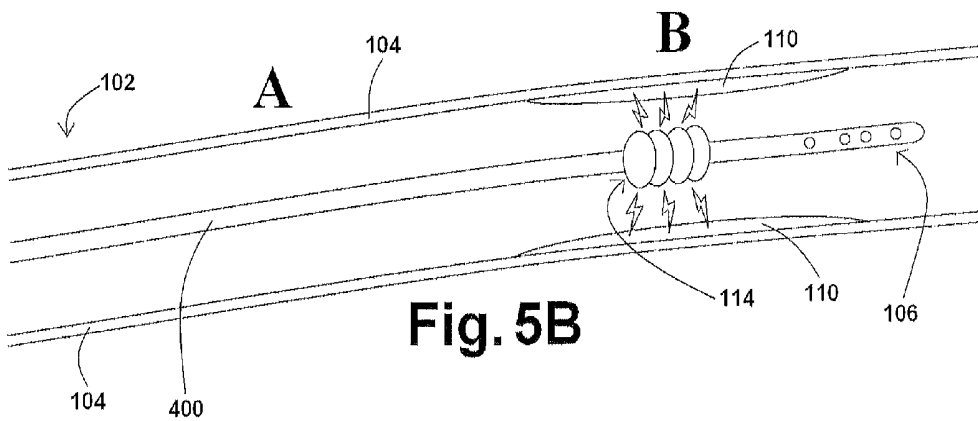


Fig. 5B

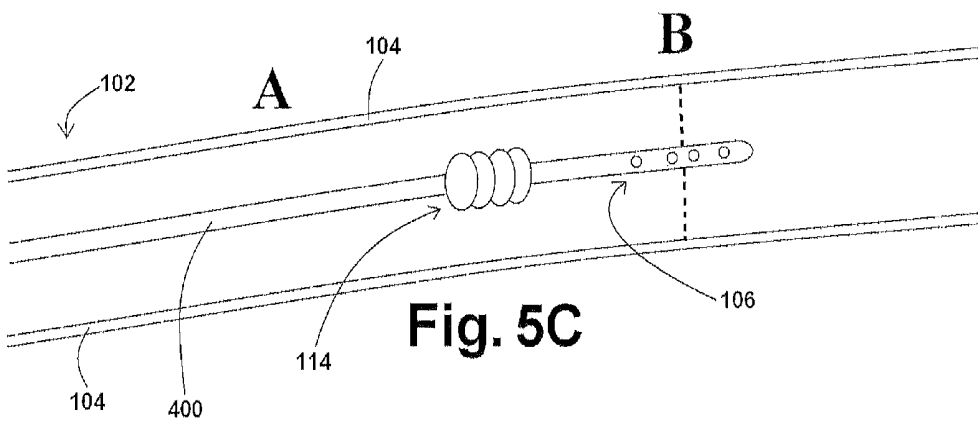


Fig. 5C

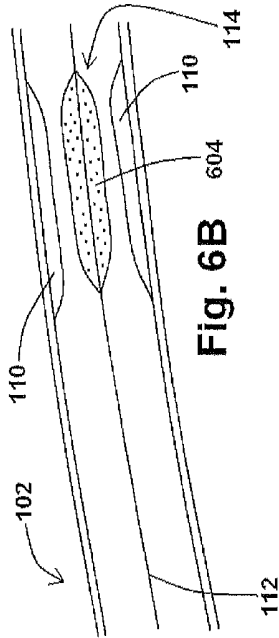


Fig. 6A

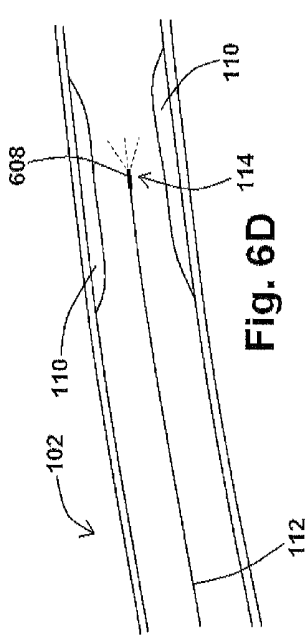


Fig. 6B

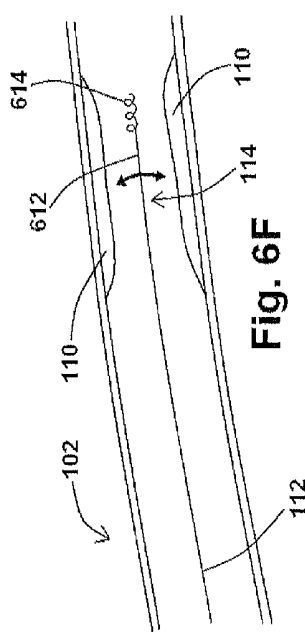


Fig. 6C

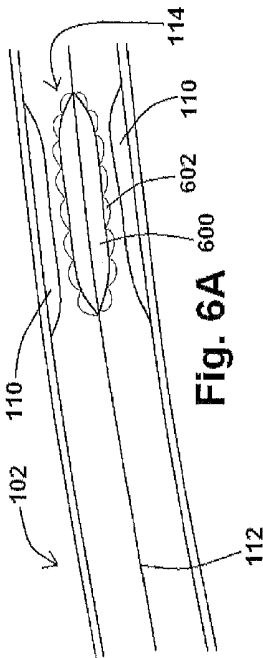


Fig. 6D

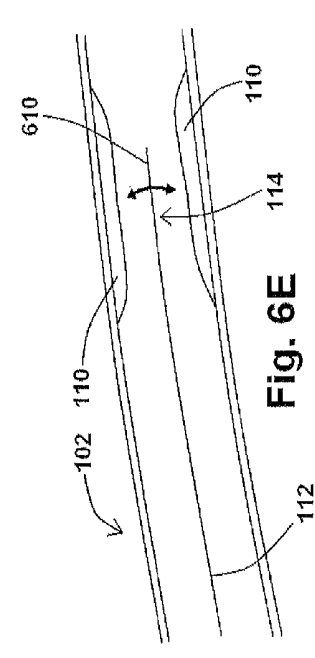
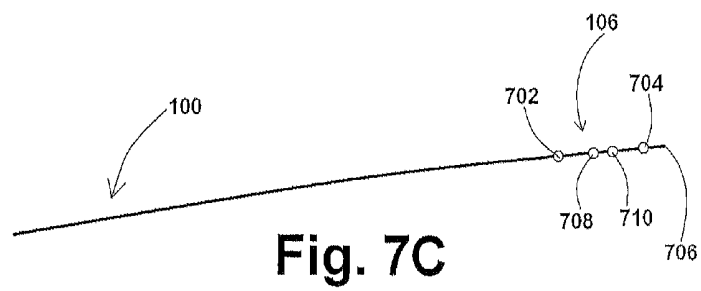
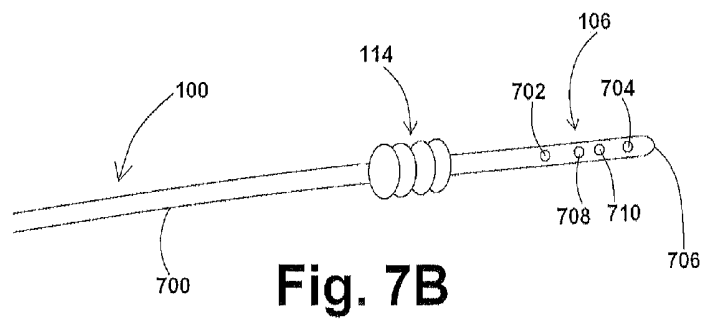
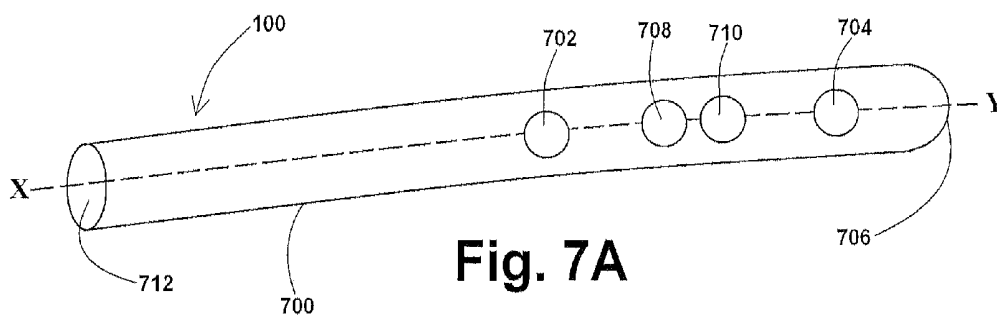
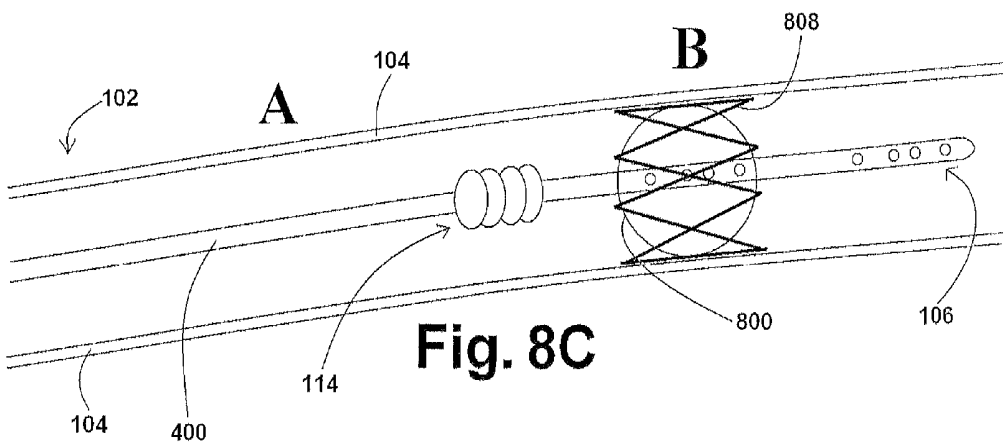
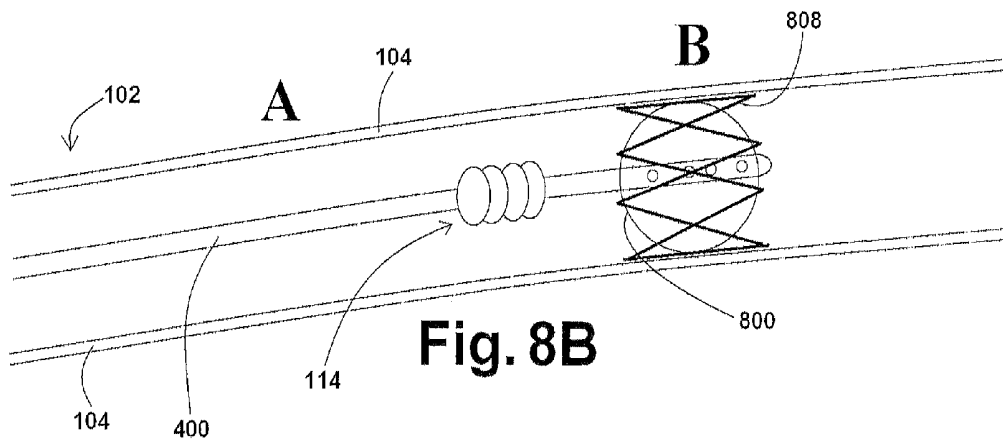
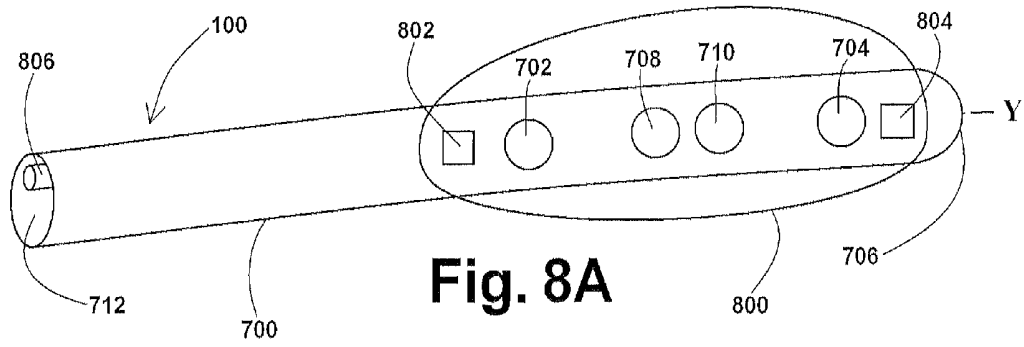


Fig. 6E





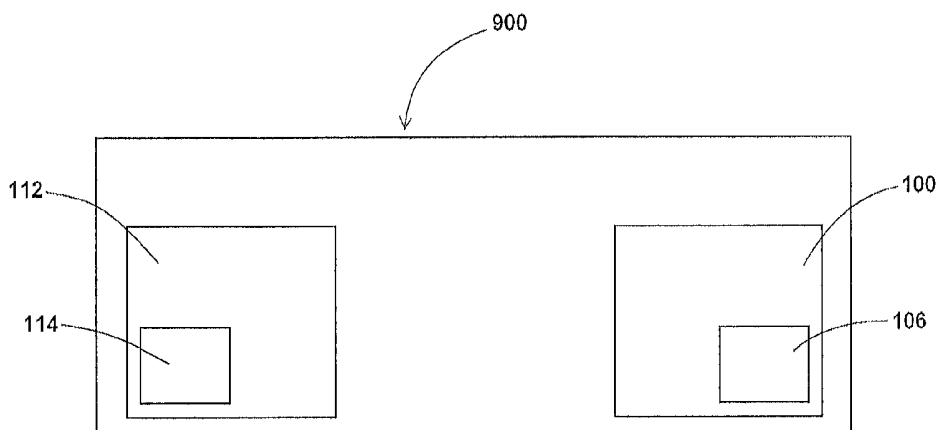


Fig. 9A

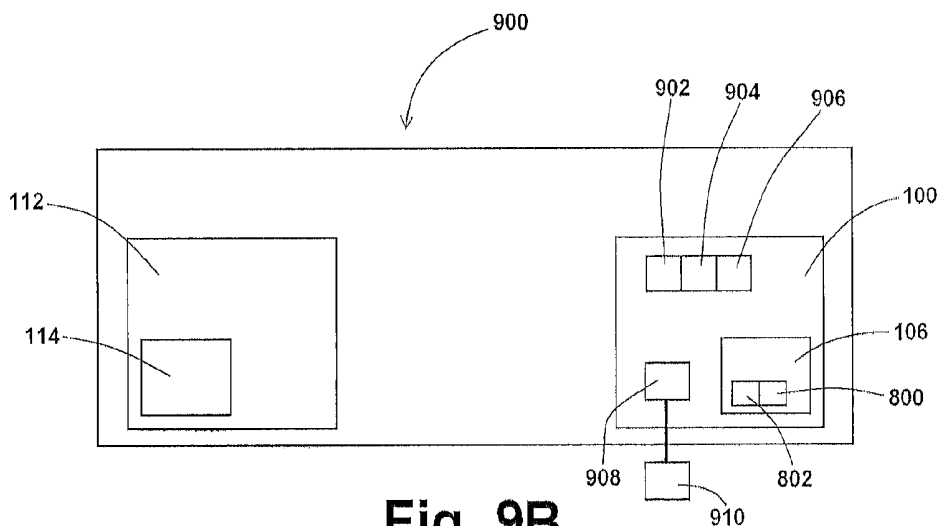


Fig. 9B

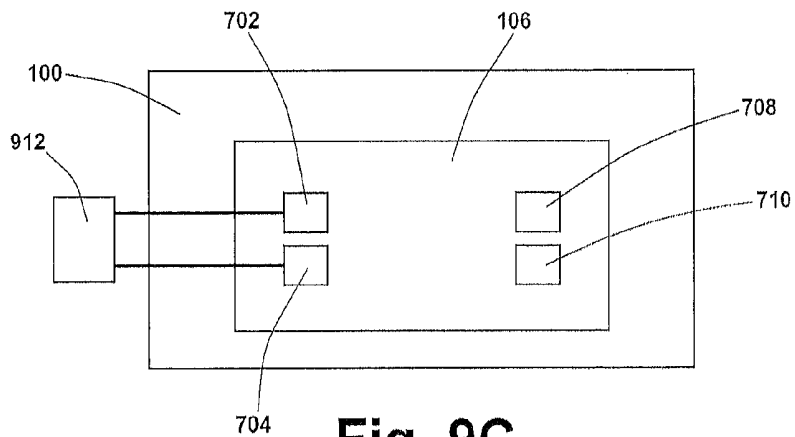
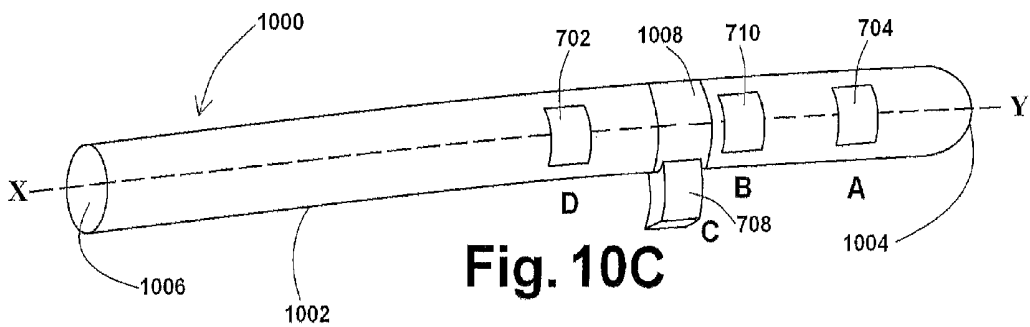
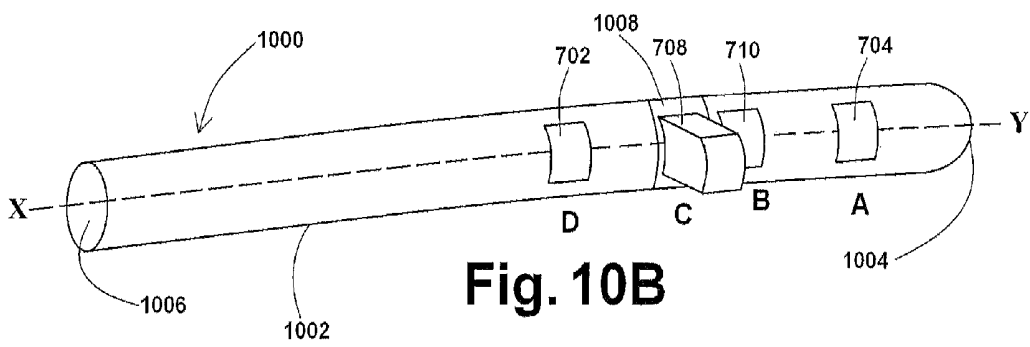
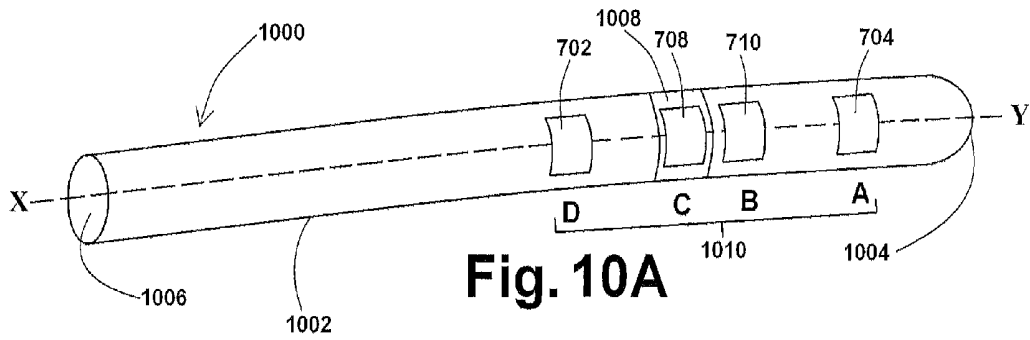
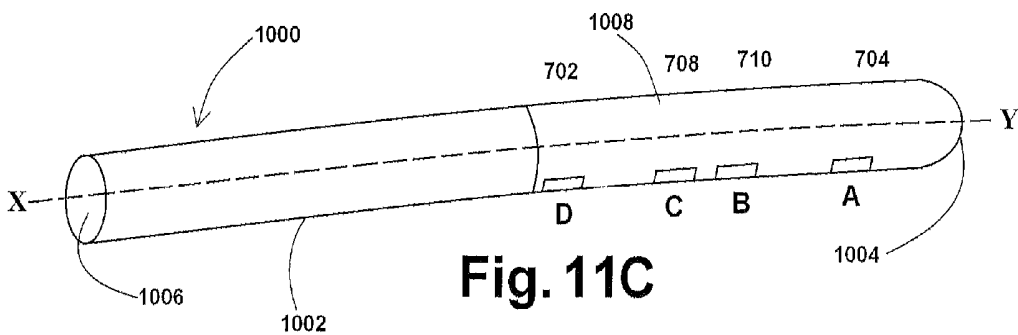
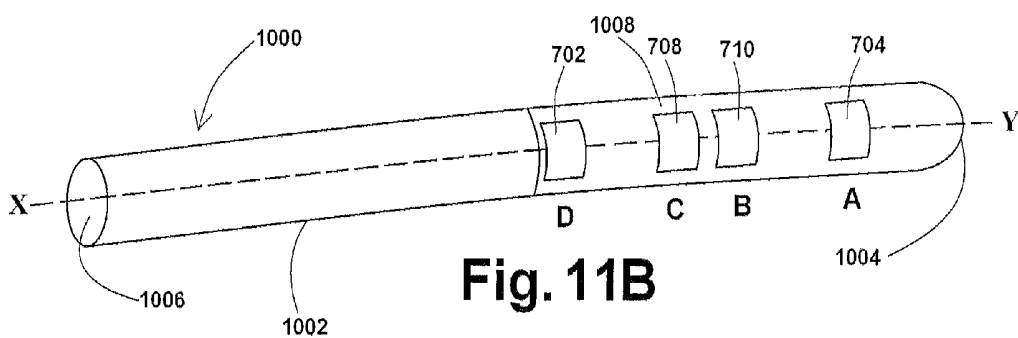
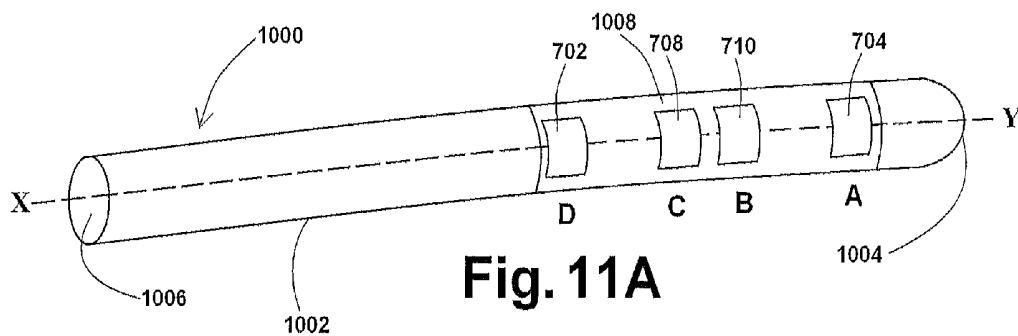
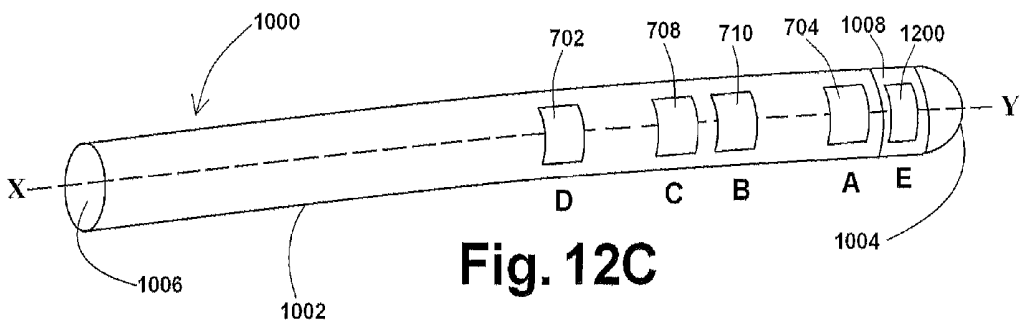
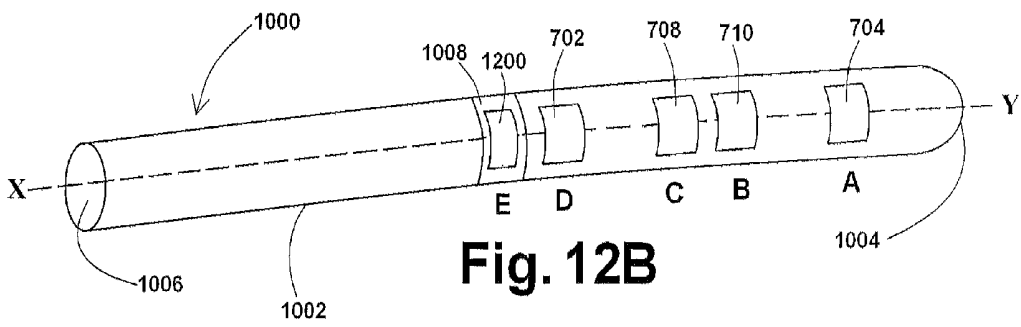
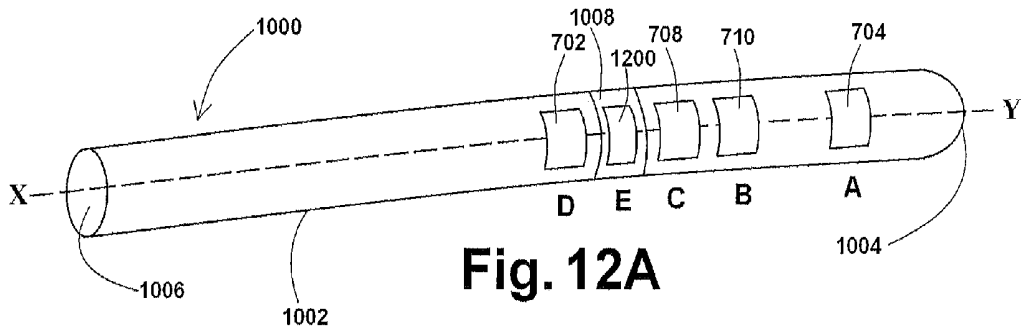
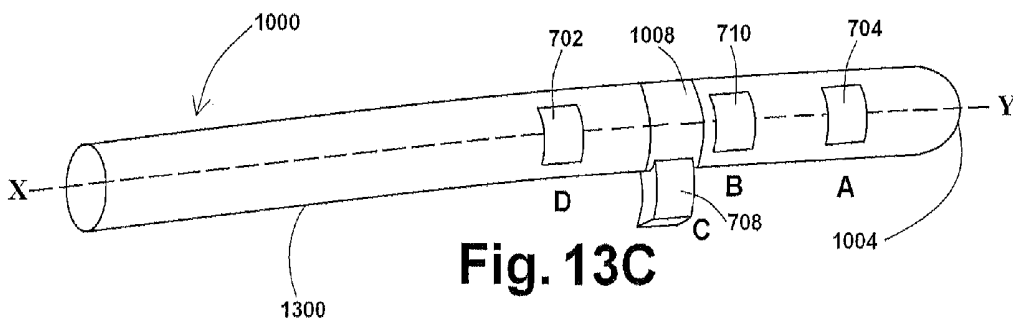
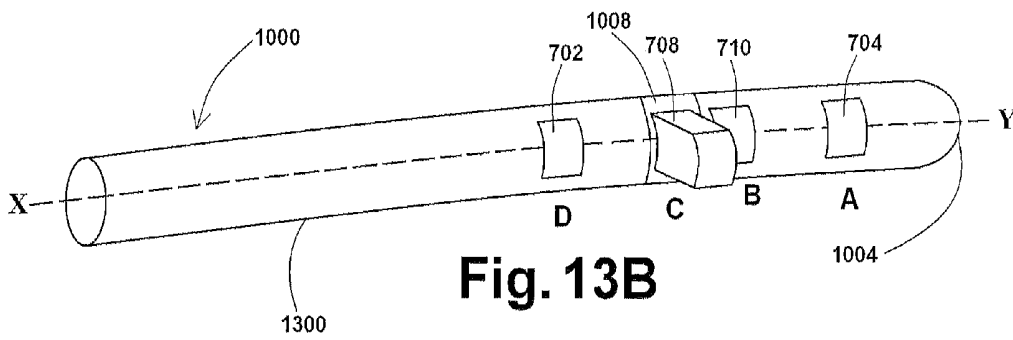
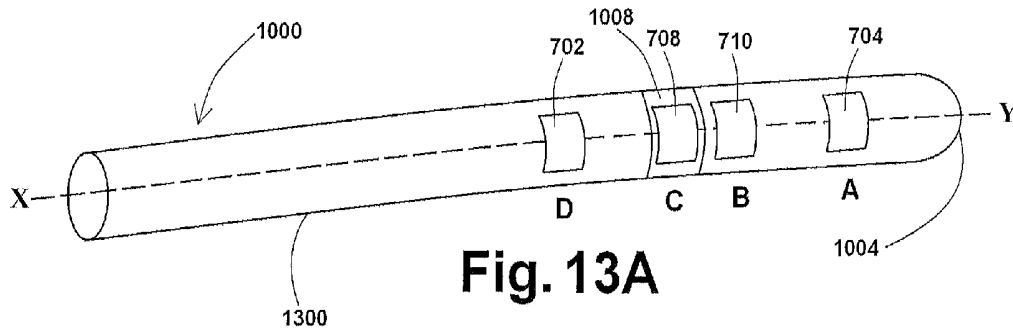


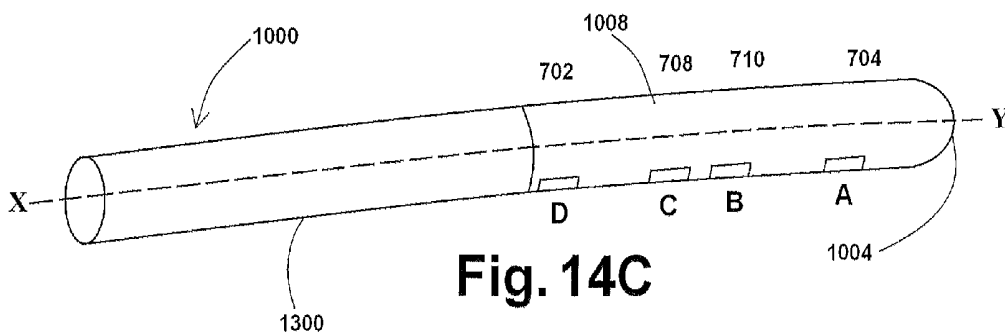
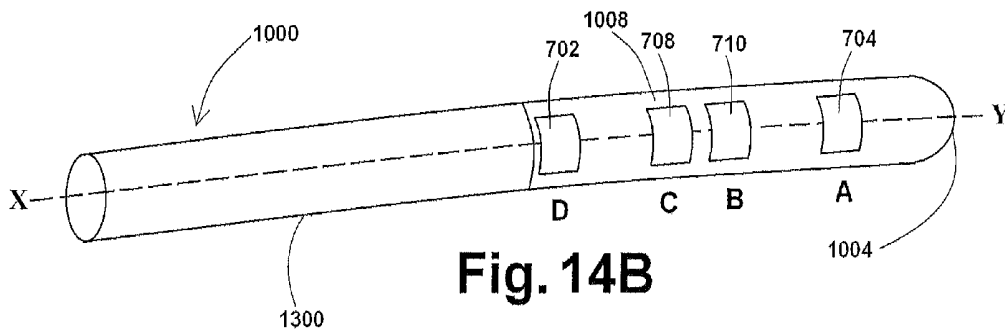
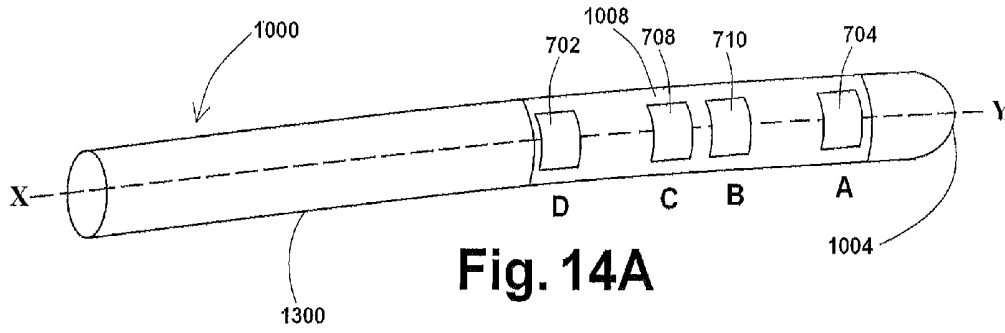
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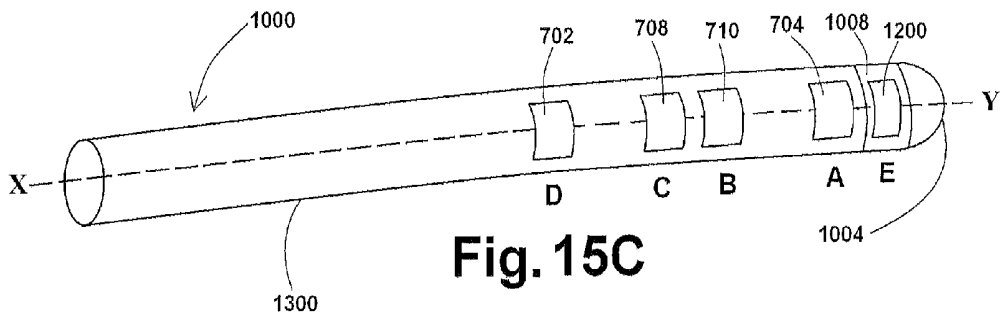
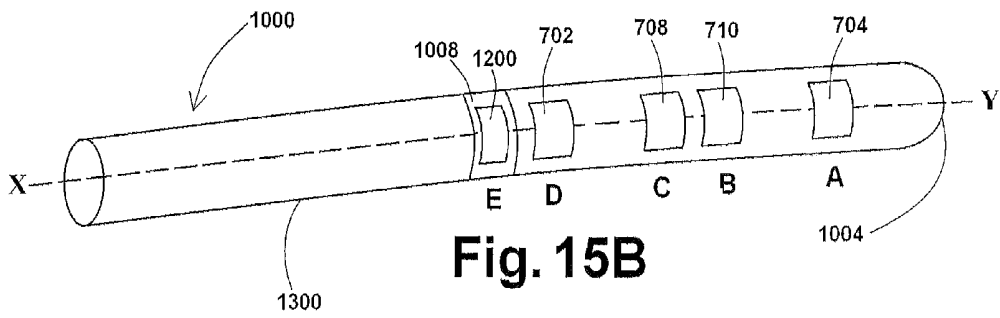
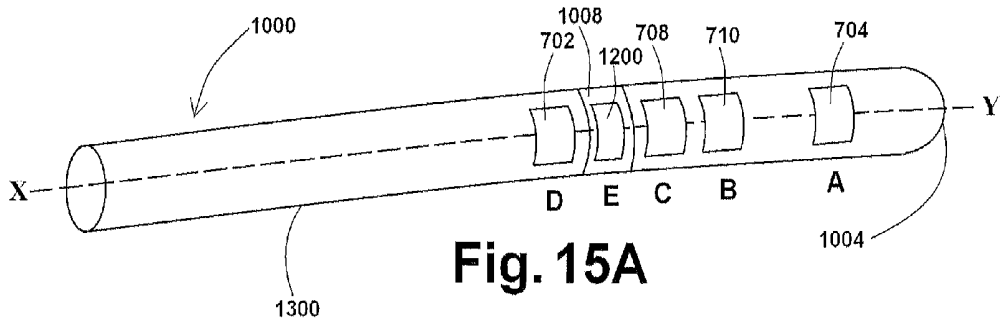


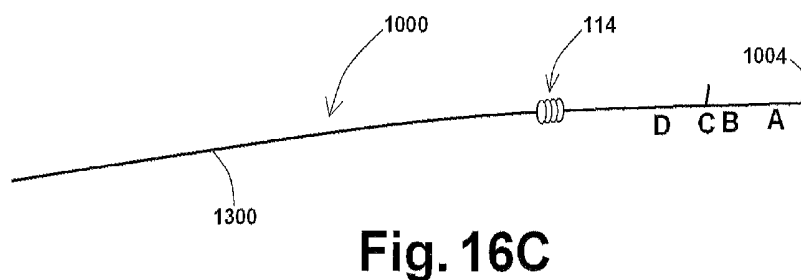
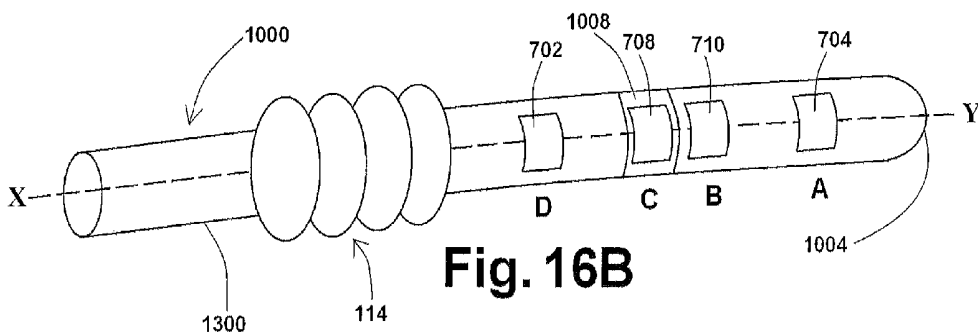
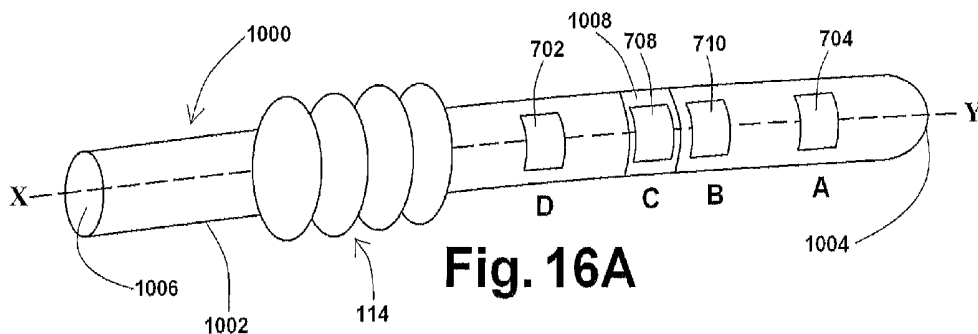


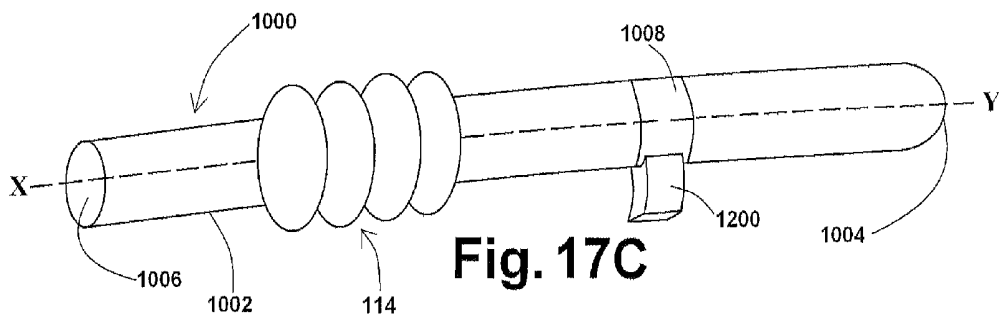
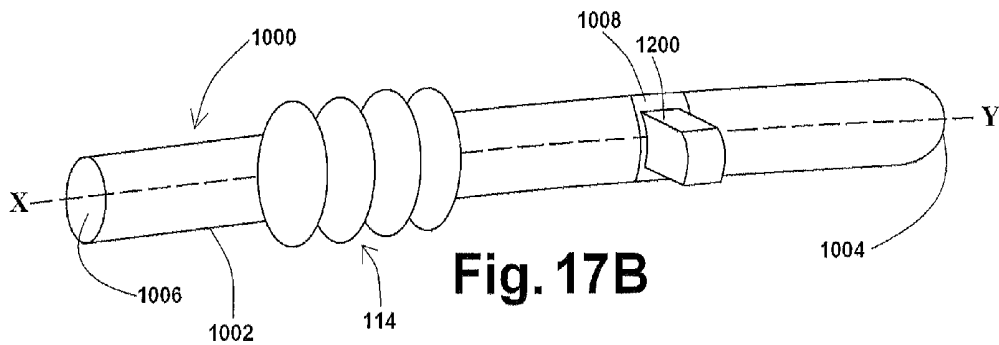
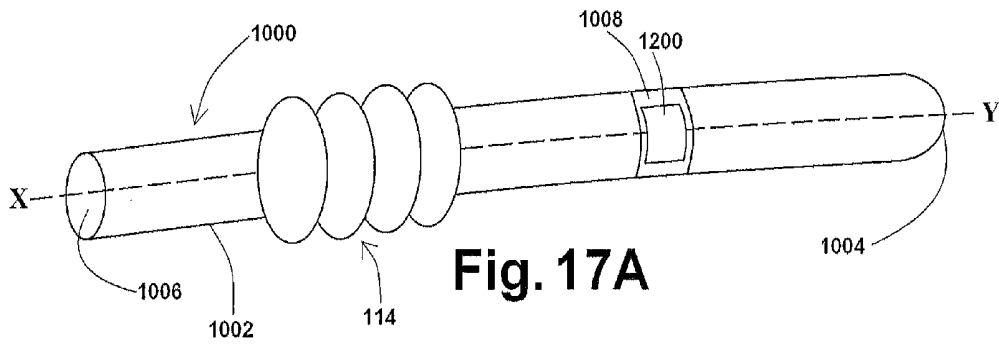


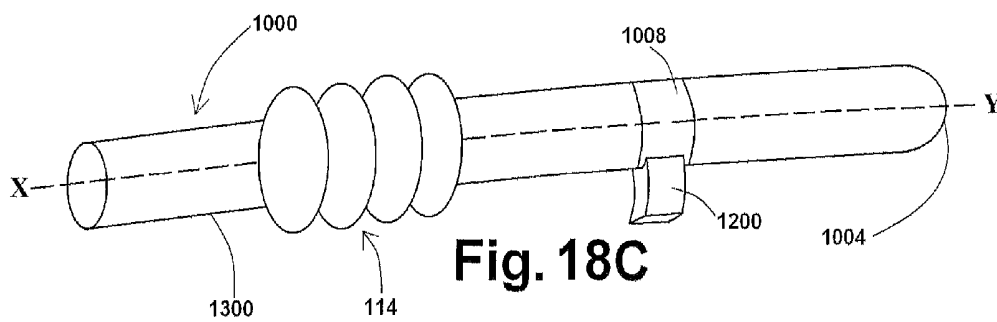
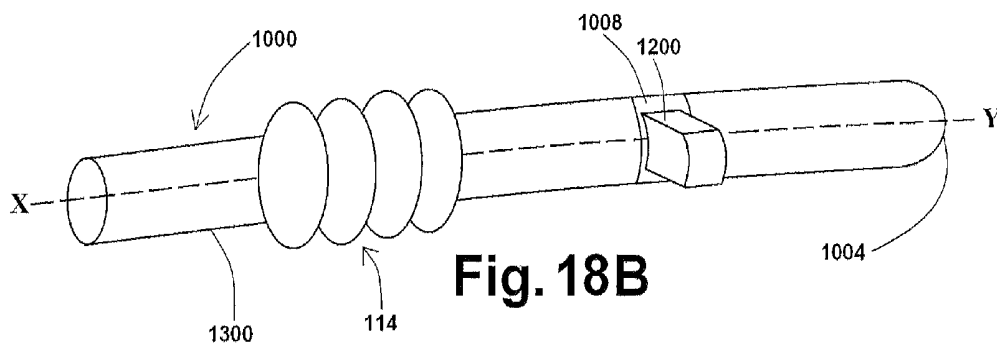
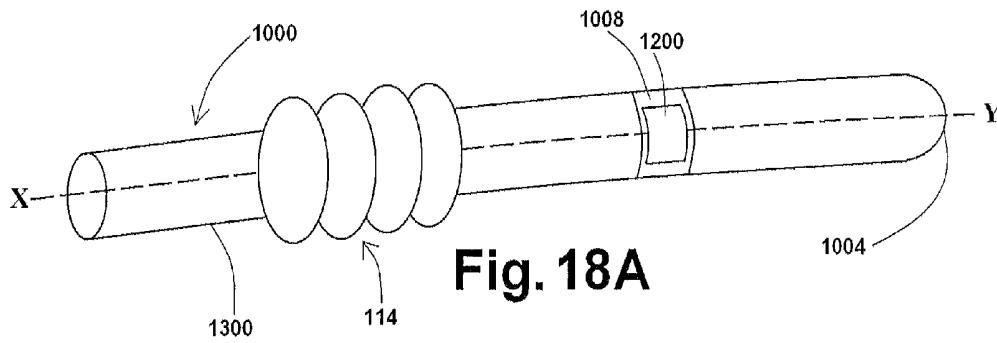


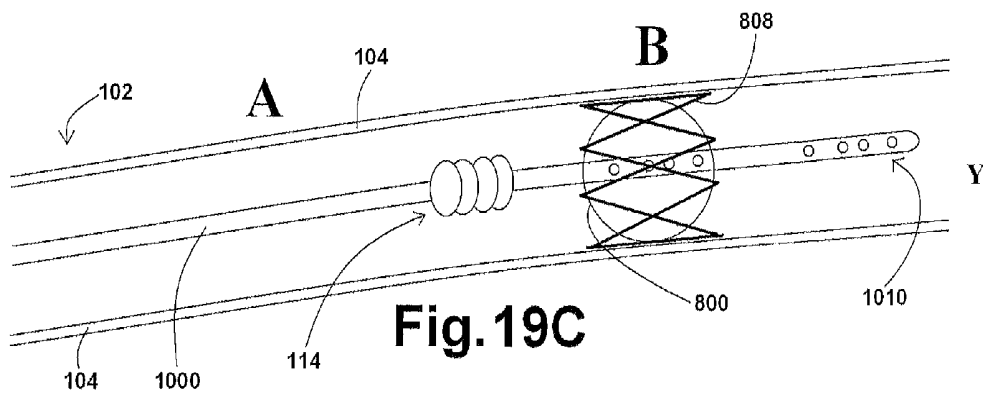
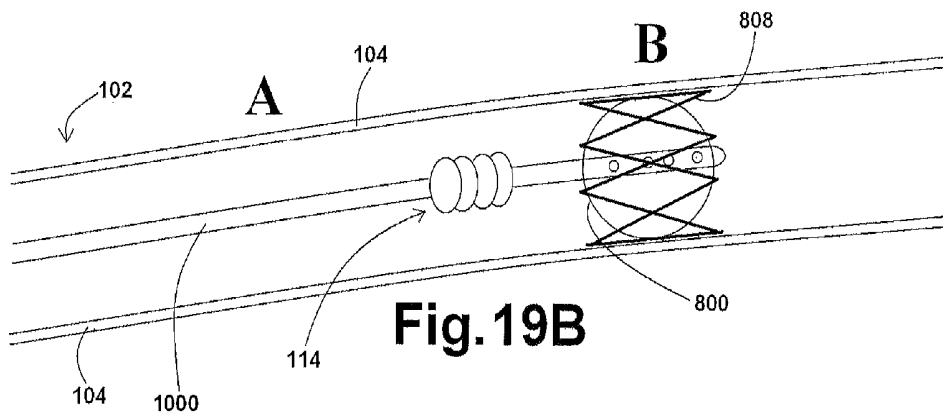
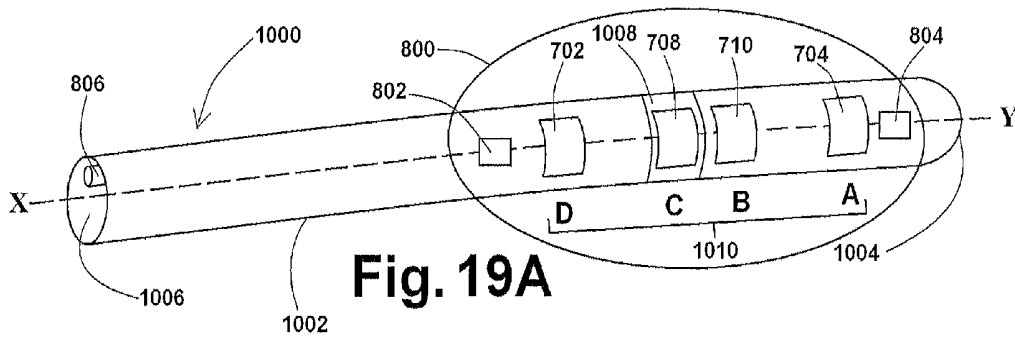












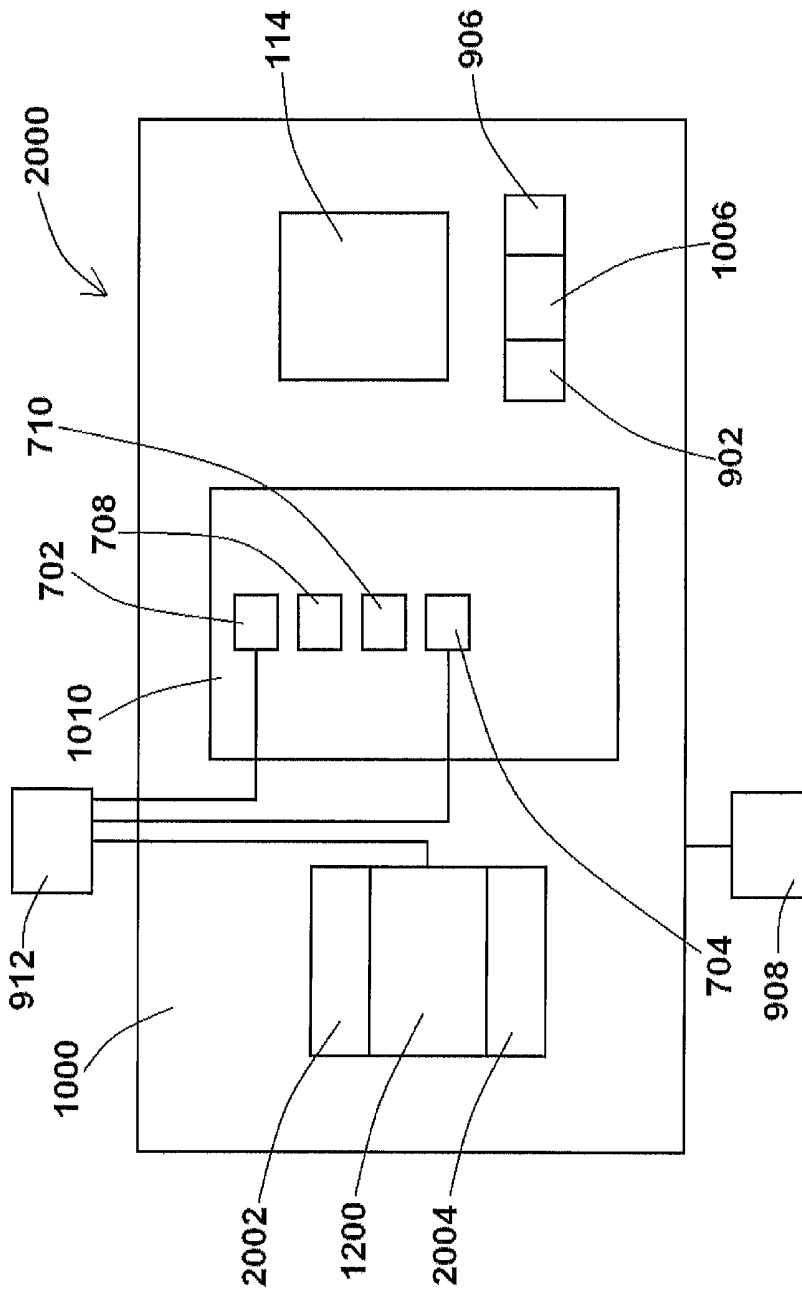


Fig. 20

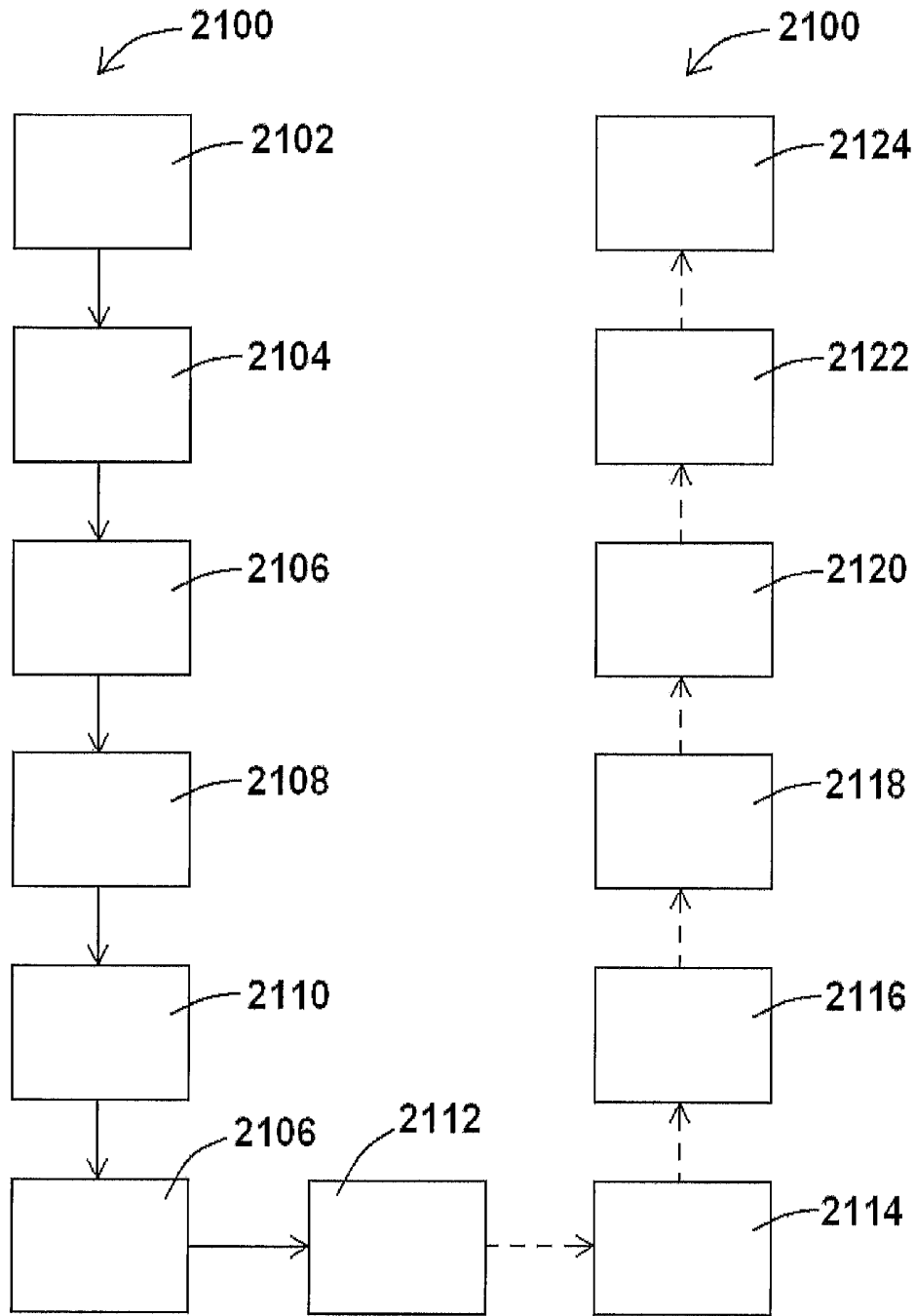


Fig. 21

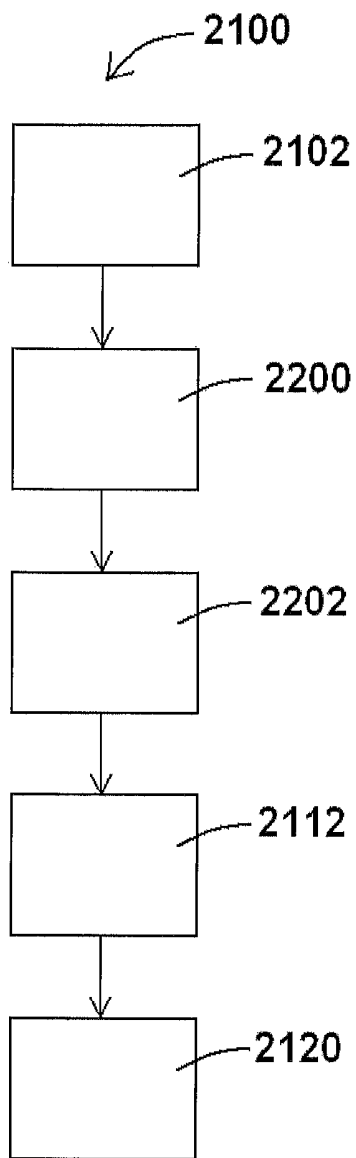


Fig. 22A

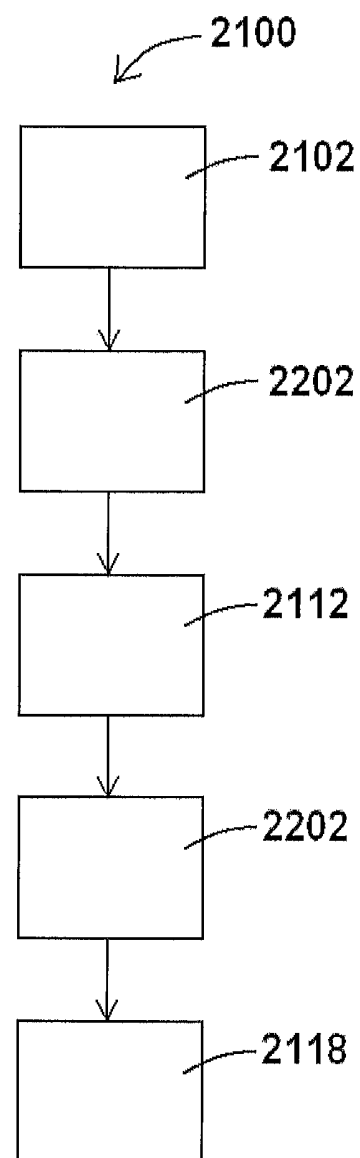


Fig. 22B

DEVICES, SYSTEMS, AND METHODS FOR REMOVING TARGETED LESIONS FROM VESSELS

PRIORITY

This U.S. Utility Patent Application is a continuation-in-part application of, and claims priority to, copending U.S. patent application Ser. No. 12/428,656, filed Apr. 23, 2009, which is a continuation-in-part application of, and claims priority to, U.S. patent application Ser. No. 12/098,242, filed Apr. 4, 2008 now U.S. Pat. No. 8,078,274, which is a continuation-in-part application of, and claims priority to, U.S. patent application Ser. No. 11/891,981, filed Aug. 14, 2007 now U.S. Pat. No. 8,114,143, which is a divisional application of, and claims priority to, U.S. patent application Ser. No. 10/782,149, filed Feb. 19, 2004, which issued as U.S. Pat. No. 7,454,244 on Nov. 18, 2008, which claims priority to U.S. Provisional Patent Application Ser. No. 60/449,266, filed Feb. 21, 2003, to U.S. Provisional Patent Application Ser. No. 60/493,145, filed Aug. 7, 2003, and to U.S. Provisional Patent Application Ser. No. 60/502,139, filed Sep. 11, 2003. The contents of each of these applications are hereby incorporated by reference in their entirety into this disclosure.

BACKGROUND

The disclosure of the present application relates generally to devices, systems, and methods for removing stenotic lesions from vessels. In at least one embodiment, the disclosure of the present application relates to methods for removing stenotic lesions from vessels involving obtaining one or more luminal size parameters of blood vessels, heart valves and other hollow visceral organs.

Coronary Heart Disease

Coronary heart disease is caused by atherosclerotic narrowing of the coronary arteries. It is likely to produce angina pectoris, heart attack or both. Coronary heart disease caused 466,101 deaths in USA in 1997 and is the single leading cause of death in America today. Approximately, 12 million people alive today have a history of heart attack, angina pectoris or both. The break down for males and females is 49% and 51%, respectively. This year, an estimated 1.1 million Americans will have a new or recurrent coronary attack, and more than 40% of the people experiencing these attacks will die as a result. About 225,000 people a year die of coronary attack without being hospitalized. These are sudden deaths caused by cardiac arrest, usually resulting from ventricular fibrillation. More than 400,000 Americans and 800,000 patients world-wide undergo a non-surgical coronary artery interventional procedure each year. Although only introduced in the 1990s, in some laboratories intra-coronary stents are used in 90% of these patients.

Stents increase minimal coronary lumen diameter to a greater degree than percutaneous transluminal coronary angioplasty (PTCA) alone according to the results of two randomized trials using the Palmaz-Schatz stent. These trials compared two initial treatment strategies: stenting alone and PTCA with "stent backup" if needed. In the STRESS trial, there was a significant difference in successful angiographic outcome in favor of stenting (96.1% vs. 89.6%).

Aortic Stenosis

Aortic Stenosis (AS) is one of the major reasons for valve replacements in adult. AS occurs when the aortic valve orifice narrows secondary to valve degeneration. The aortic valve area is reduced to one fourth of its normal size before

it shows a hemodynamic effect. Because the area of the normal adult valve orifice is typically 3.0 to 4.0 cm², an area 0.75-1.0 cm² is usually not considered severe AS. When stenosis is severe and cardiac output is normal, the mean trans-valvular pressure gradient is generally >50 mmHg. Some patients with severe AS remain asymptomatic, whereas others with only moderate stenosis develop symptoms. Therapeutic decisions, particularly those related to corrective surgery, are based largely on the presence or absence of symptoms.

The natural history of AS in the adult consists of a prolonged latent period in which morbidity and mortality are very low. The rate of progression of the stenotic lesion has been estimated in a variety of hemodynamic studies performed largely in patients with moderate AS. Cardiac catheterization and Doppler echocardiographic studies indicate that some patients exhibit a decrease in valve area of 0.1-0.3 cm² per year; the average rate of change is 0.12 cm² per year. The systolic pressure gradient across the valve may increase by as much as 10 to 15 mmHg per year. However, more than half of the reported patients showed little or no progression over a 3-9 year period. Although it appears that progression of AS can be more rapid in patients with degenerative calcific disease than in those with congenital or rheumatic disease, it is not possible to predict the rate of progression in an individual patient.

Eventually, symptoms of angina, syncope, or heart failure develop after a long latent period, and the outlook changes dramatically. After onset of symptoms, average survival is <2-3 years. Thus, the development of symptoms identifies a critical point in the natural history of AS.

Many asymptomatic patients with severe AS develop symptoms within a few years and require surgery. The incidence of angina, dyspnea, or syncope in asymptomatic patients with Doppler outflow velocities of 4 m/s has been reported to be as high as 38% after 2 years and 79% after 3 years. Therefore, patients with severe AS require careful monitoring for development of symptoms and progressive disease.

Indications for Cardiac Catheterization

In patients with AS, the indications for cardiac catheterization and angiography are to assess the coronary circulation (to confirm the absence of coronary artery disease) and to confirm or clarify the clinical diagnosis of AS severity. If echocardiographic data are typical of severe isolated AS, coronary angiography may be all that is needed before aortic valve replacement (AVR). Complete left- and right-heart catheterization may be necessary to assess the hemodynamic severity of AS if there is a discrepancy between clinical and echocardiographic data or evidence of associated valvular or congenital disease or pulmonary hypertension.

The pressure gradient across a stenotic valve is related to the valve orifice area and transvalvular flow through Bernoulli's principle. Thus, in the presence of depressed cardiac output, relatively low pressure gradients are frequently obtained in patients with severe AS. On the other hand, during exercise or other high-flow states, systolic gradients can be measured in minimally stenotic valves. For these reasons, complete assessment of AS requires (1) measurement of transvalvular flow, (2) determination of the transvalvular pressure gradient, and (3) calculation of the effective valve area. Careful attention to detail with accurate measurements of pressure and flow is important, especially in patients with low cardiac output or a low transvalvular pressure gradient.

Problems with Current Aortic Valve Area Measurements

Patients with severe AS and low cardiac output are often present with only modest transvalvular pressure gradients (i.e., <30 mmHg). Such patients can be difficult to distinguish from those with low cardiac output and only mild to moderate AS. In both situations, the low-flow state and low pressure gradient contribute to a calculated effective valve area that can meet criteria for severe AS. The standard valve area formula (simplified Hakki formula which is valve area=cardiac output/[pressure gradient]^{1/2}) is less accurate and is known to underestimate the valve area in low-flow states; under such conditions, it should be interpreted with caution. Although valve resistance is less sensitive to flow than valve area, resistance calculations have not been proved to be substantially better than valve area calculations.

In patients with low gradient stenosis and what appears to be moderate to severe AS, it may be useful to determine the transvalvular pressure gradient and calculate valve area and resistance during a baseline state and again during exercise or pharmacological (i.e., dobutamine infusion) stress. Patients who do not have true, anatomically severe stenosis exhibit an increase in the valve area during an increase in cardiac output. In patients with severe AS, these changes may result in a calculated valve area that is higher than the baseline calculation but that remains in the severe range, whereas in patients without severe AS, the calculated valve area will fall outside the severe range with administration of dobutamine and indicate that severe AS is not present.

There are many other limitations in estimating aortic valve area in patients with aortic stenosis using echocardiography and cardiac catheterization. Accurate measurement of the aortic valve area in patients with aortic stenosis can be difficult in the setting of low cardiac output or concomitant aortic or mitral regurgitations. Concomitant aortic regurgitation or low cardiac output can overestimate the severity of aortic stenosis. Furthermore, because of the dependence of aortic valve area calculation on cardiac output, any under or overestimation of cardiac output will cause inaccurate measurement of valve area. This is particularly important in patients with tricuspid regurgitation. Falsely measured aortic valve area could cause inappropriate aortic valve surgery in patients who do not need it.

Other Visceral Organs

Visceral organs such as the gastrointestinal tract and the urinary tract serve to transport luminal contents (fluids) from one end of the organ to the other end or to an absorption site. The esophagus, for example, transports swallowed material from the pharynx to the stomach. Diseases may affect the transport function of the organs by changing the luminal cross-sectional area, the peristalsis generated by muscle, or by changing the tissue components. For example, strictures in the esophagus and urethra constitute a narrowing of the organ where fibrosis of the wall may occur. Strictures and narrowing can be treated with distension, much like the treatment of plaques in the coronary arteries.

As referenced in detail above, and given the prevalence of coronary heart disease and its potential severe prognosis, the availability of various devices, systems, and methods for removing stenotic lesions from vessels in an effective fashion would be well-received by the public, including treating physicians. The disclosure of the present application provides effective devices, systems, and methods useful to remove stenotic lesions and overcome known problems regarding current treatment devices and methods and the current lack of effective devices and methods to perform the same.

BRIEF SUMMARY

In at least one exemplary embodiment of a device for insertion within a luminal organ of the present disclosure, the device comprises an elongated body having a distal body end, and at least one directional sensor positioned along the elongated body at or near the distal body end, the at least one directional sensor capable of rotation about the elongated body. In another embodiment, the elongated body is selected from the group consisting of a catheter and a wire. In yet another embodiment, the elongated body is configured to fit within a lumen of a luminal organ.

In at least one exemplary embodiment of a device for insertion within a luminal organ of the present disclosure, the device further comprises a detector positioned along the elongated body at or near the distal body end, the detector capable of measuring a luminal size parameter when at least part of the elongated body is positioned within a lumen of a luminal organ. In an additional embodiment, the detector comprises a tetrapolar arrangement of electrodes. In another embodiment, the tetrapolar arrangement of electrodes comprises two detection electrodes positioned in between two excitation electrodes. In yet another embodiment, the at least one directional sensor is at least one electrode of the tetrapolar arrangement of electrodes. In an additional embodiment, the at least one directional sensor is independent of the tetrapolar arrangement of electrodes.

In at least one exemplary embodiment of a device for insertion within a luminal organ of the present disclosure, the at least one directional sensor is further capable of extending outward from the elongated body. In another embodiment, when at least part of the elongated body is positioned within a lumen of a luminal organ, the at least one directional sensor is capable of extending outward from the elongated body to physically touch the luminal organ or a structure therein. In an additional embodiment, the at least one directional sensor is capable of obtaining a measurement from the luminal organ or the structure therein that the directional sensor is touching.

In at least one exemplary embodiment of a device for insertion within a luminal organ of the present disclosure, the at least one directional sensor is an impedance sensor, and wherein the measurement is an impedance measurement. In another embodiment, when a constant voltage is applied to the at least one directional sensor, the measurement is a current measurement indicative of electrical impedance of the luminal organ or the structure therein that the directional sensor is touching. In yet another embodiment, when a constant current is applied to the at least one directional sensor, the measurement is a voltage measurement indicative of electrical impedance of the luminal organ or the structure therein that the directional sensor is touching. In an additional embodiment, the at least one directional sensor is a thermistor, and wherein the measurement is a temperature measurement.

In at least one exemplary embodiment of a device for insertion within a luminal organ of the present disclosure, the device further comprises an extension apparatus coupled to the at least one directional sensor, the extension apparatus capable of extending the at least one directional sensor from a first position to an extended second position. In an additional embodiment, the extension apparatus is selected from the group consisting of a mechanical actuator, an electro-mechanical actuator, and a steering device. In various embodiments, the device further comprises a rotation apparatus coupled to a rotatable portion of the elongated body, the rotation apparatus capable of rotating the rotatable

portion. In another embodiment, the rotation apparatus is selected from the group consisting of a mechanical actuator, an electro-mechanical actuator, and a steering device. In yet another embodiment, when the at least one directional sensor is positioned along the elongated body on the rotatable portion, the at least one directional sensor is capable of rotation by operation of the rotation apparatus. In an additional embodiment, the rotatable portion is capable of a full 360° rotation about the elongated body.

In at least one exemplary embodiment of a device for insertion within a luminal organ of the present disclosure, the at least one directional sensor is positioned at about 45 degrees to about 90 degrees of a circumference of the elongated body. In another embodiment, the device further comprises at least one treatment portion capable of removing at least part of a stenotic lesion from a luminal organ. In yet another embodiment, the at least one treatment portion is selected from the group consisting of a cutting balloon, a cryoplasty device, a rotational atherectomy device, a laser angioplasty device, a vibrating catheter, a vibrating blade, and a vibrating drill. In an additional embodiment, the device further comprises a detector comprising a tetrapolar arrangement of electrodes positioned along the device within a balloon, wherein the electrodes are operable to measure at least one luminal parameter within the balloon at one or more stages of balloon inflation.

In at least one exemplary embodiment of a device for insertion within a luminal organ of the present disclosure, the elongated body comprises a catheter having a suction/infusion port in communication with a lumen of the catheter, wherein the catheter is configured to facilitate one or more fluid injections into a lumen of a luminal organ when at least part of the elongated body is positioned therein. In an additional embodiment, the device further comprises at least one fluid delivery source operably coupled to the lumen of the catheter, whereby one or more fluids may be injected from the at least one fluid delivery source through the lumen of the catheter, through the suction/infusion port, and into the luminal of the luminal organ. In various embodiments, the device further comprises a current/voltage source in communication with one or more of the directional sensor and the tetrapolar arrangement of electrodes, the current/voltage source capable of supplying a constant current and/or a constant voltage thereto to facilitate one or more measurements indicative of electrical impedance of the luminal organ or a structure therein. In another embodiment, the device further comprises a data acquisition and processing system operably coupled to the device, the data acquisition and processing system capable of receiving the one or more measurements from the device and calculating at least one luminal size parameter and/or determining at least one luminal organ or structure type based upon the one or more measurements. In another embodiment, the device further comprises an inflatable balloon coupled to the elongated body, the inflatable balloon capable of inflation to place a stent positioned around the inflatable balloon within a lumen of a luminal organ.

In at least one embodiment of a device for insertion within a luminal organ of the present disclosure, the device comprises an elongated body having a distal body end, the elongated body configured to fit within a lumen of a luminal organ, at least one directional sensor positioned along the elongated body at or near the distal body end, the at least one directional sensor capable of rotation about the elongated body and further capable of extension outward from the elongated body to physically touch the luminal organ or a structure therein, the at least one directional sensor operable

to obtain a measurement indicative of electrical impedance of the luminal organ or the structure therein that the directional sensor is touching, at least one detector positioned along the elongated body at or near the distal body end, the at least one detector capable of measuring a luminal size parameter when at least part of the elongated body is positioned within the lumen of the luminal organ, and at least one treatment portion capable of removing at least part of a stenotic lesion from the luminal organ.

In at least one embodiment of a device for removing a stenotic lesion from a vessel of the present disclosure, the device comprises at least one sizing portion capable of measuring a luminal size parameter when at least part of the device is positioned within a lumen of a luminal organ, at least one typing portion, wherein at least part of the at least one typing portion is capable of physically touching a portion of the luminal organ or a structure therein, and at least one treatment portion capable of removing at least part of a stenotic lesion from the luminal organ. In another embodiment, the at least one sizing portion comprises a tetrapolar arrangement of two detection electrodes positioned in between two excitation electrodes. In yet another embodiment, the at least one treatment portion is selected from the group consisting of a cutting balloon, a cryoplasty device, a rotational atherectomy device, a laser angioplasty device, a vibrating catheter, a vibrating blade, and a vibrating drill. In an additional embodiment, the at least one treatment portion comprises a balloon, and wherein the at least one sizing portion comprises at least one pressure sensor capable of detecting at least one pressure within the balloon at one or more stages of balloon inflation.

In at least one embodiment of a device for removing a stenotic lesion from a vessel of the present disclosure, the device further comprises at least one suction/infusion port in communication with at least one device lumen, the suction/infusion port operable to facilitate one or more fluid injections into the lumen of the luminal organ, and at least one fluid delivery source operably coupled to the at least device lumen, whereby one or more fluids may be injected from the at least one fluid delivery source through the at least one device lumen, through the at least one suction/infusion port, and into the lumen of the luminal organ. In another embodiment, the device further comprises a current source in communication with the two excitation electrodes, said current source operable to supply current to the two excitation electrodes to enable measurement of at least one conductance value, thereby enabling calculation of a luminal size parameter. In yet another embodiment, the device further comprises a data acquisition and processing system operably coupled to the device, the data acquisition and processing system operable to receive conductance data from the device to calculate at least one luminal parameter based upon said conductance data and to display the calculated at least one luminal parameter to facilitate operational control of the at least one treatment portion of the device.

In at least one embodiment of a system for removing a stenotic lesion of a vessel of the present disclosure, the system comprises a treatment device, the treatment device comprising at least one treatment portion capable of a removing at least part of a stenotic lesion from a luminal organ, and a sizing/typing device, the sizing/typing device comprising electrodes for measuring a first luminal size parameter when the typing/sizing device is positioned within a lumen of the luminal organ, and at least one directional sensor capable of physically touching a portion of the luminal organ or a structure therein to obtain a first vessel characteristic indicative of the luminal organ or the structure

therein. In another embodiment, the treatment device comprises a catheter, and wherein the sizing/typing device comprises a wire selected from the group consisting of a guide wire, a pressure wire, and a flow wire.

In at least one embodiment of a method of removing at least part of a stenotic lesion within a luminal organ of the present disclosure, the method comprises the steps of (a) positioning at least part of a device within a luminal organ at a first location, (b) operating the device to obtain a first luminal size parameter and a first measurement indicative of electrical impedance of the luminal organ or a structure therein that at least part of the device is physically touching at the first location, (c) moving at least part of the device to a second location within the luminal organ, (d) operating the device to obtain a second luminal size parameter and a second measurement indicative of electrical impedance of the luminal organ or the structure therein that at least part of the device is physically touching at the second location, (e) determining whether or not a stenotic lesion is present at either the first location or the second location based on one or more of the first luminal size parameter, the first measurement, the second luminal size parameter, and the second measurement, (f) if the stenotic lesion is present, moving at least part of the device having a treatment portion to a stenotic lesion location, and (g) if the stenotic lesion is present, operating the treatment portion of the device to remove at least part of the stenotic lesion. In another embodiment, the method further comprises the steps of (h) measuring a then-current luminal size parameter at the stenotic lesion location, (i) comparing the then-current luminal size parameter to either the first luminal size parameter or the second luminal size parameter that is indicative of the stenotic lesion location, and (j) if the then-current luminal size parameter does not equal a preferred luminal size parameter, repeating steps (g), (h), and (i) until the then-current luminal size parameter equals or exceeds the preferred luminal size parameter.

In at least one embodiment of a method of removing at least part of a stenotic lesion within a luminal organ of the present disclosure, the preferred luminal size parameter is determined based upon the first luminal size parameter and the second luminal size parameter. In another embodiment, steps (b) and (d) are performed in the presence of a saline injection. In yet another embodiment, the step of moving at least part of the device to a second location comprises advancing or retracting at least part of the device within the luminal organ. In at least one embodiment, the step of moving at least part of the device to a second location comprises rotating at least part of the device within the luminal organ.

In at least one embodiment of a method of removing at least part of a stenotic lesion within a luminal organ of the present disclosure, the first luminal size parameter, the second luminal size parameter, and then-current luminal size parameter(s) are obtained using a detector coupled to the device. In another embodiment, the first measurement and the second measurement are obtained using a directional sensor coupled to the device. In yet another embodiment, the step of measuring then then-current luminal size parameter at the stenotic lesion location further comprises measuring a then-current measurement indicative of electrical impedance of the luminal organ or structure therein, and wherein the step of comparing the then-current luminal size parameter to either the first luminal size parameter or the second luminal size parameter further comprises comparing either the first measurement or the second measurement to the then-current measurement. In an additional embodiment, steps (g), (h),

and (i) are repeated if the then-current luminal size parameter does not equal a preferred luminal size parameter or if the then-current measurement is indicative of electrical impedance of the stenotic lesion.

In at least one embodiment of a method of removing at least part of a stenotic lesion within a luminal organ of the present disclosure, the method further comprises the step of ceasing the operation of the treatment portion of the device when the then-current luminal size parameter equals or exceeds the preferred luminal size parameter. In another embodiment, the method further comprises the steps of selecting an appropriately-sized stent, and implanting the stent into the luminal organ.

In at least one embodiment of a method of removing at least part of a stenotic lesion within a luminal organ of the present disclosure, the method comprises the steps of positioning a device within a luminal organ, the device comprising at least one sizing portion, at least one typing portion, and at least one treatment portion, operating the at least one sizing portion of the device to obtain luminal size parameter data, operating the at least one sizing portion of the device to obtain type data indicative of electrical impedance of the luminal organ or a structure therein, and operating the at least one treatment portion at a location within the luminal organ at or near a stenotic lesion, whereby operation of the at least one treatment portion is based upon the luminal size parameter data and the type data, whereby operation of the at least one treatment portion removes at least part of the stenotic lesion. In another embodiment, the method further comprises the step of ceasing operation of the at least one treatment portion when the luminal size parameter data indicates a preferred luminal size parameter. In yet another embodiment, the method further comprises the step of ceasing operation of the at least one treatment portion when the type data is no longer indicative of electrical impedance of a stenotic lesion. In an additional embodiment, the steps of operating the at least one sizing portion and operating the at least one typing portion are performed in the presence of a saline injection.

In at least one embodiment of a method of removing at least part of a stenotic lesion within a luminal organ of the present disclosure, the method comprises the steps of (a) positioning a device within a luminal organ, the device comprising at least one typing portion and at least one treatment portion, (b) operating the at least one typing portion of the device to obtain initial type data indicative of electrical impedance of the luminal organ or a structure therein, (c) operating the at least one treatment portion if the type data is indicative of electrical impedance of a stenotic lesion to remove at least part of the stenotic lesion, and (d) operating the at least one typing portion of the device again to obtain then-current type data indicative of electrical impedance of the luminal or the structure therein, and (e) repeating steps (c) and (d) until the then-current type data does not indicate the presence of the stenotic lesion.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A shows a cross-sectional view of a vessel having a stenotic lesion and an exemplary sizing device positioned therein, according to an embodiment of the present disclosure;

FIG. 1B shows the cross-sectional view of a vessel wherein the exemplary sizing device is positioned at a second location within the vessel, according to an embodiment of the present disclosure;

FIG. 1C shows a cross-sectional view of a vessel wherein an exemplary treatment device is positioned at a second location within the vessel, according to an embodiment of the present disclosure;

FIG. 2A shows an exemplary treatment device in operation, according to an embodiment of the present disclosure;

FIG. 2B shows the exemplary sizing device is positioned at a second location within the vessel obtaining a then-current luminal size parameter, according to an embodiment of the present disclosure;

FIG. 2C shows the exemplary treatment device of FIGS. 1C and 2A in operation, according to an embodiment of the present disclosure;

FIG. 3A shows the exemplary sizing device of FIG. 2B, for example, positioned at a second location within the vessel obtaining an additional then-current luminal size parameter, according to an embodiment of the present disclosure;

FIGS. 3B and 3C show a cross-sectional views of a vessel having an exemplary sizing device and an exemplary treatment device positioned therein, according to the present disclosure;

FIG. 4A shows a cross-sectional view of a vessel having a stenotic lesion and an exemplary combination device positioned therein, according to the present disclosure;

FIGS. 4B, 5A, and 5C show cross-sectional views of a vessel wherein a sizing portion of the exemplary combination device is positioned at a second location within the vessel, according to the present disclosure;

FIGS. 4C and 5B show cross-sectional views of a vessel wherein a treatment portion of the exemplary combination device is positioned at a second location within the vessel and shown in operation, according to the present disclosure;

FIGS. 6A-6F show various embodiments of exemplary treatment portions of treatment devices, according to the present disclosure;

FIGS. 7A, 7B, and 7C show at least a portion of exemplary embodiments of sizing devices, according to the present disclosure;

FIG. 8 A shows an exemplary embodiment of a sizing device comprising a balloon coupled thereto, according to an embodiment of the present disclosure;

FIGS. 8B and 8C show exemplary embodiments of devices placing stents within a vessel, according to an embodiment of the present disclosure;

FIGS. 9A and 9B show exemplary embodiments of systems useful for removing stenotic lesions from vessels, according to the present disclosure;

FIG. 9C shows an exemplary embodiment of a sizing device of the present disclosure;

FIG. 10A shows an exemplary sizing/typing device of the present disclosure;

FIG. 10B shows an exemplary sizing/typing device of the present disclosure with an electrode extended therefrom, according to an embodiment of the present disclosure;

FIG. 10C shows an exemplary sizing/typing device of the present disclosure with an electrode extended therefrom and rotated, according to an embodiment of the present disclosure;

FIGS. 11A-11C show various embodiments of sizing/typing devices according to the present disclosure;

FIGS. 12A-12C show various embodiments of sizing/typing devices having directional sensors thereon, according to the present disclosure;

FIGS. 13A-14C show various embodiments of wire forms of sizing/typing devices according to the present disclosure;

FIGS. 15A-15C show various embodiments of wire forms of sizing/typing devices having directional sensors thereon, according to the present disclosure;

FIGS. 16A-16C show various embodiments of sizing/typing devices comprising treatment portions, according to the present disclosure;

FIGS. 17A-17C show various embodiments of sizing/typing devices having directional sensors and treatment portions thereon, according to the present disclosure;

FIGS. 18A-18C show various embodiments of wire forms of sizing/typing devices having directional sensors and treatment portions thereon, according to the present disclosure;

FIG. 19A shows an exemplary embodiment of a sizing/typing device comprising a balloon coupled thereto, according to an embodiment of the present disclosure;

FIGS. 19B and 19C show exemplary embodiments of sizing/typing devices placing stents within a vessel, according to the present disclosure;

FIG. 20 shows an exemplary embodiment of a system useful for removing stenotic lesions from vessels, according to the present disclosure; and

FIGS. 21, 22A, and 22B show steps of exemplary methods of using a sizing/typing device of the present disclosure.

DETAILED DESCRIPTION

Reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of scope is intended by the description of these embodiments.

In at least one embodiment of a method for removing a stenotic lesion of a vessel, the method comprises the steps of measuring at least two luminal parameters, determining a preferred luminal size parameter, and operating a treatment device to increase at least one of the luminal parameters.

In at least one exemplary method for removing a stenotic lesion of a vessel, the method comprises the steps of measuring a first luminal size parameter at a first location within a vessel lumen, measuring a second luminal size parameter at a second location within the vessel lumen, determining a preferred second luminal size parameter based upon the first luminal size parameter and the second luminal size parameter, and positioning a treatment device at or near the second location. In at least one method, the method further comprises the steps of operating the treatment device to increase the second luminal size parameter and measuring a then-current luminal size parameter at the second location. After the then-current luminal size parameter at the second location is measured, an exemplary method for removing a stenotic lesion of a vessel comprises the step of comparing the then-current luminal size parameter to the preferred second luminal size parameter, and if the then-current luminal size parameter does not equal the preferred second luminal size parameter, an exemplary method comprises repeating the steps of operating the treatment device to increase the second luminal size parameter, measuring another then-current luminal size parameter at the second location, and comparing the then-current luminal size parameter to the preferred second luminal size parameter. In at least one embodiment of such a method, the aforementioned three steps (essentially a feedback loop) are repeated until the then-current luminal size parameter equals the preferred second luminal size parameter.

In various embodiments of methods of the disclosure of the present application, one or more luminal size parameters

are measured. In at least one embodiment, the various luminal size parameters (the first luminal size parameter and the second luminal size parameter, for example) comprise luminal diameters. For example, and when performing an exemplary method of the disclosure of the present application to remove a vessel plaque (an exemplary stenotic lesion), a first luminal diameter may be measured at a location within the vessel, and a second luminal diameter may be measured at a second location within the vessel. In another example, the luminal size parameters may comprise luminal cross-sectional areas. In yet another example, the luminal size parameters may comprise one or more other luminal geometric calculations, including, for example, a luminal circumference, each or all of which may share one or more similar calculated components (like a luminal diameter or a luminal radius, for example).

In an exemplary embodiment of a method for removing a stenotic lesion of a vessel of the disclosure of the present application, the first location comprises a location without a stenotic lesion, and the second location comprises a location with a stenotic lesion. Alternatively, and in another exemplary embodiment, the first location comprises a location with a relatively small stenotic lesion, and the second location comprises a location with relatively large stenotic lesion. In either embodiment, or as may be with other embodiments, the luminal size parameters at the first and second locations may vary from one another.

For example, and as shown in FIG. 1A, a sizing device 100 may be positioned within the lumen of a vessel 102 at a first location "A" as shown in the figure. Sizing device 100 may then operate to determine a first luminal size parameter at location "A", for example, as shown in FIG. 1A. As shown in the figure, the first luminal size parameter (as indicated by the dotted line extending from one vessel wall 104 to another) may comprise, for example, a luminal diameter or luminal cross-sectional area. In this exemplary embodiment, sizing device 100 comprises a sizing portion 106 located at or near the distal end 108 of sizing device 100. In such an embodiment, sizing portion 106 of sizing device 100 is the portion of sizing device 100 operable to obtain one or more luminal size parameters. In addition, and as shown in FIG. 1A, sizing portion 106 of sizing device 100 is positioned at a first location within the vessel that does not have a stenotic lesion 110.

An exemplary embodiment of a sizing device 100 positioned within the lumen of a vessel 102 at a second location is shown in FIG. 1B. As shown in FIG. 1B, sizing device 100 may be introduced further within vessel 102 to a second location "B" as shown, wherein the second location is a location within vessel 102 having a stenotic lesion 110. In such an embodiment, and as shown in FIG. 1B, sizing device 100 may be operable to determine a second luminal size parameter (as indicated by the dotted line extending from sizing device 100 at second location "B"), noting that, for example, the second luminal size parameter may be relatively smaller than the first luminal size parameter if the second luminal size parameter is obtained at a portion within vessel 102 having a stenotic lesion 110. For example, sizing device 100 may obtain a first luminal diameter at location "A" and a second luminal diameter at location "B", and as shown in FIGS. 1A and 1B, the first luminal diameter would be larger than the second luminal diameter.

An exemplary embodiment of a method for removing a stenotic lesion of a vessel of the present application may comprise the step of positioning a treatment device within a vessel at or near at least one location within the vessel. As shown in FIG. 1C, a treatment device 112 is shown posi-

tioned within a lumen of a vessel 102, wherein at least one treatment portion 114 of treatment device 112 is positioned at or near a stenotic lesion 110 present within the lumen of vessel 102. Operation of treatment portion 114 of treatment device 112 is shown in FIG. 2A, with operation of the device indicated by the symbols above and below treatment portion 114. Said operation symbols are not intended to be limited to, for example, the application of electrical current—said symbols are intended merely to visually indicate operation of treatment portion 114 of treatment device 112.

After operation of treatment device 112 as shown in FIG. 2A, a determination as to the potential effectiveness of the treatment may be made by obtaining one or more luminal size parameters at the treatment site. As shown in FIG. 2B, sizing device 100 is present within the lumen of vessel 102, and is operable to obtain a then-current luminal size parameter (as indicated by the dotted line extending from sizing device 100 at second location "B"), which, as shown in the exemplary embodiment depicted in FIG. 2B, is relatively larger than the original second luminal size parameter. In this embodiment, a relatively large then-current luminal size parameter as compared to the original second luminal size parameter is indicative of at least a partially-successful stenotic lesion removal treatment, also as indicated by the smaller stenotic lesions 110 shown in FIG. 2B. A user may compare the then-current luminal size parameter to any number of other obtained luminal size parameters, including, but not limited to, the first luminal size parameter the second luminal size parameter, and a preferred second luminal size parameter, as described within example FIGS. 1A-2B and herein, as appropriate.

For example, and using numerical values merely as an example, if a first luminal size parameter is a vessel diameter of 0.7 mm, and a second luminal size parameter at a location within a vessel 102 having at least one stenotic lesion 110 is 0.2 mm in diameter, a user may select/determine a preferred second luminal size parameter of 0.5 mm in diameter, for example. Such a larger preferred second luminal size parameter relative to the original second luminal size parameter, when achieved based upon a stenotic lesion removal treatment, would be indicative of a partial removal of a stenotic lesion 110 from the vessel 102. A user may instead decide that a preferred second luminal size parameter is equivalent to the first luminal size parameter, which, as described in this particular example, would be indicative of total or near-total removal of a stenotic lesion 110 from a vessel 102 at the treatment site.

As shown in FIG. 2C, treatment device 112 is shown re-inserted into the treatment site at or near stenotic lesion(s) 110, and is shown operating to potentially remove additional stenotic lesion(s) 110 from the treatment site. The scenario shown in FIG. 2C is indicative of a situation where a user has decided that the previously-measured then-current luminal size parameter is not equal to or within a range of an acceptable/preferred second luminal size parameter, and that the user has decided to continue treatment using treatment device 112 in attempt to remove additional stenotic lesion(s) 110 from the treatment site.

FIG. 3A shows at least a portion of a sizing device present within a vessel after completely successful treatment to remove one or more stenotic lesions. As shown in FIG. 3A, sizing device 100 is positioned within the lumen of vessel 102, whereby sizing portion 106 of sizing device 100 is positioned at or near the original second location (indicated by "B"). Sizing device 100 is shown operating to obtain a then-current luminal size parameter, and in this particular example, and assuming that the vessel has a constant diam-

eter throughout the portion shown in FIG. 3A, the then-current luminal size parameter would equal the original first luminal size parameter, indicative of complete removal of a stenotic lesion at the treatment site. In such a situation, a user may decide to cease treatment (and thus cease operation of treatment device 112) as the then-current luminal size parameter would equal to, or be within, a preferred luminal size parameter, assuming such a preferred luminal size parameter is equal to the original first luminal size parameter.

FIGS. 3B and 3C are indicative of situations where a user is using a sizing device and a treatment device, but does not completely remove one device from a vessel to use the other device. For example, and as shown in FIG. 3B, sizing portion 106 of sizing device 100 is shown positioned at or near stenotic lesion(s) 110, while at least a portion of treatment device 112 remains positioned within the lumen of vessel 102. Similarly, and as shown in FIG. 3C, treatment portion 114 of treatment device 112 is shown positioned at or near stenotic lesion(s) 110, while at least a portion of sizing device 100 remains positioned within the lumen of vessel 102.

In at least an additional embodiment of a device of the disclosure of the present application, said device comprises at least one feature indicative of a sizing device and at least one feature indicative of a treatment device. For example, and as shown in FIGS. 4A-4C, an exemplary combination device 400 comprises a sizing portion 106 located at or near the distal end of combination device 400. In addition, and as shown in the exemplary embodiments shown in FIGS. 4A-4C, an exemplary combination device 400 also comprises a treatment portion 114 positioned along combination device. As referenced within the present application, an exemplary combination device 400 may be substantially equivalent, if not completely equivalent, to an exemplary sizing device 100 of the present application comprising at least one treatment portion 114, and similarly, an exemplary combination device 400 may be substantially equivalent, if not completely equivalent, to an exemplary treatment device 112 comprising at least one sizing portion 106.

As shown in FIG. 4A, an exemplary combination device 400 is shown positioned within the lumen of a vessel 102, whereby sizing portion 106 of combination device 400 is positioned at or near a first location within vessel 102 (as indicated by "A"). Combination device 400 may then operate to determine a first luminal size parameter at location "A", for example, as shown in FIG. 4A. As shown in the figure, the first luminal size parameter (as indicated by the dotted line extending from one vessel wall 104 to another) may comprise, for example, a luminal diameter or luminal cross-sectional area. In this exemplary embodiment, combination device 400 comprises a sizing portion 106 located at or near the distal end 402 of sizing device 400. In such an embodiment, sizing portion 106 of combination device 400 is the portion of combination device 400 operable to obtain one or more luminal size parameters. In addition, and as shown in FIG. 4A, sizing portion 106 of combination device 400 is positioned at a first location within the vessel that does not have a stenotic lesion 110.

An exemplary embodiment of a combination device 400 positioned within the lumen of a blood vessel 102 at a second location is shown in FIG. 4B. As shown in FIG. 4B, combination device 400 may be introduced further within vessel 102 to a second location "B" as shown, wherein the second location is a location within vessel 102 having a stenotic lesion 110. In such an embodiment, and as shown in FIG. 4B, combination device 400 may be operable to

determine a second luminal size parameter (as indicated by the dotted line extending from combination device 400 at second location "B"), noting that, for example, the second luminal size parameter may be relatively smaller than the first luminal size parameter if the second luminal size parameter is obtained at a portion within vessel 102 having a stenotic lesion 110. For example, combination device 400 may obtain a first luminal diameter at location "A" and a second luminal diameter at location "B", and the first luminal diameter would be larger than the second luminal diameter.

An exemplary embodiment of a method for removing a stenotic lesion of a vessel of the present application may comprise the step of positioning a combination/treatment device within a vessel at or near at least one location within the vessel. As shown in FIG. 4C, combination device 400 is shown positioned within a lumen of a vessel 102, wherein at least one treatment portion 114 of combination device 400 is positioned at or near a stenotic lesion 110 present within the lumen of vessel 102. Operation of treatment portion 114 of combination device 400 is also shown in FIG. 4C, with operation of the device indicated by the symbols above and below treatment portion 114. As referenced above in connection with the operation of an exemplary treatment device 112, said operation symbols are not intended to be limited to, for example, the application of electrical current—said symbols are intended merely to visually indicate operation of treatment portion 114 of combination device 400.

As shown in FIG. 5A, combination device 400 is re-positioned within the lumen of vessel 102, and is operable to obtain a then-current luminal size parameter (as indicated by the dotted line extending from combination device 400 at second location "B"), which, as shown in the exemplary embodiment depicted in FIG. 5A, is relatively larger than the original second luminal size parameter. In this embodiment, a relatively large then-current luminal size parameter as compared to the original second luminal size parameter is indicative of at least a partially-successful treatment, also as indicated by the smaller stenotic lesions 110 shown in FIG. 5A. A user may compare the then-current luminal size parameter to any number of other obtained luminal size parameters, including, but not limited to, the first luminal size parameter the second luminal size parameter, and a preferred second luminal size parameter, as described within example FIGS. 4A-5A and herein, as appropriate.

As shown in FIG. 5B, combination device 400 is shown re-positioned within vessel 102 so that treatment portion 114 is positioned at or near stenotic lesion(s) 110, and is shown operating to potentially remove additional stenotic lesion(s) 110 from the treatment site. The scenario shown in FIG. 5B is indicative of a situation where a user has decided that the previously-measured then-current luminal size parameter is not equal to or within a range of an acceptable/preferred second luminal size parameter, and that the user has decided to continue treatment using treatment portion 114 of combination device 400 in attempt to remove additional stenotic lesion(s) 110 from the treatment site.

FIG. 5C shows at least a portion of a combination device 400 present within a vessel after completely successful treatment to remove one or more stenotic lesions. As shown in FIG. 5C, combination device 400 is re-positioned within the lumen of vessel 102, whereby sizing portion 106 of combination device 400 is positioned at or near the original second location (indicated by "B"). Combination device 400 is shown operating to obtain a then-current luminal size parameter, and in this particular example, and assuming that the vessel has a constant diameter throughout the portion

shown in FIG. 5C, the then-current luminal size parameter would equal the original first luminal size parameter, indicating of complete removal of a stenotic lesion at the treatment site. In such a situation, a user may decide to cease treatment (and thus cease operation of treatment device 112) as the then-current luminal size parameter would equal to, or be within, a preferred luminal size parameter, assuming such a preferred luminal size parameter is equal to the original first luminal size parameter.

In at least one embodiment of a treatment portion 114 of the present application, treatment portion 114 comprises a treatment portion selected from the group consisting of a cutting balloon, a cryoplasty device, a rotational atherectomy device, a laser angioplasty device, a vibrating catheter, a vibrating blade, and a vibrating drill. A common feature shared among these various treatment portion 114 compositions is that each one is operable to remove at least a portion of a stenotic lesion 110 from a vessel or luminal organ. As such, a number of other treatment portion 114 compositions either known or developed in the art may be useful in connection with the present disclosure so long as it is operable to remove at least a portion of a stenotic lesion 110 from a vessel or luminal organ. As referenced herein, the term "vessel" is intended to encompass any number of luminal organs, including blood vessels, present within an body.

FIGS. 6A-6F show various embodiments of at least part of various treatment portions 114 of exemplary treatment devices 112 of the present disclosure. FIG. 6A shows an exemplary treatment device 112 of the present disclosure positioned within a vessel 102, wherein said treatment device 112 comprises a treatment portion 114 comprising a cutting balloon 600. Cutting balloon 600, as shown in FIG. 6A, may comprise one or more cutting portions 602, said cutting portions 602 operable to physically cut a stenotic lesion 110 within a vessel 102. In at least one embodiment, cutting balloon 600 may be inflated within the lumen of a vessel 102, whereby the inflation of cutting balloon 600 allows cutting portions 602 to engage and cut a stenotic lesion 110.

Another embodiment of a treatment portion 114 of a treatment device 112 of the present disclosure is shown in FIG. 6B. As shown in FIG. 6B, treatment portion 114 comprises a cryo-balloon 604 (an exemplary cryoplasty device) capable of inflation using a relatively cold gas and/or fluid such as nitrous oxide. Inflation of cryo-balloon 604 using a cold gas and/or fluid locally reduces the temperature within a vessel 102, providing potential benefits of being able to crack and/or remove a stenotic lesion 110 within said vessel 602 using such a cryoplasty device.

An additional embodiment of an exemplary treatment device 112 of the present application is shown in FIG. 6C. As shown in FIG. 6C, treatment device 112 comprises a rotational atherectomy device 606, whereby rotation of rotational atherectomy device 606 operates to cut a stenotic lesion 110 positioned within a vessel 102.

FIG. 6D shows an embodiment of a treatment portion 114 of a treatment device 112 comprising a laser angioplasty device 608. As shown in FIG. 6D, laser angioplasty device 608 may be positioned at the distal end of treatment device 112, and is operable to emit one or more beams of light (lasers) capable of disintegrating some or all of a stenotic lesion 110.

Additional embodiments of treatment portions 114 of exemplary treatment devices 112 of the disclosure of the present application are shown in FIGS. 6E and 6F. As shown in FIG. 6E, treatment portion 114 comprises a vibrating

catheter 610 capable of vibration, for example, in the directions shown by the arrow in the figure. Vibrating catheter 610, when in operation, may physically remove some or all of a stenotic lesion 110 impacted by vibrating catheter 610. As shown in FIG. 6E, treatment portion 114 may comprise a vibrating drill 612, whereby vibrating drill 612 may operate similarly to vibrating catheter 610 as described above, and may be further operable to drill through a stenotic lesion 110 using drill tip 614.

The exemplary embodiments of treatment devices 114 shown in FIGS. 6A-6F and described herein are not intended to be an exhaustive list and/or description of treatment devices 112 of the present application, as one or more additional treatment devices 114 known in the art may be useful in one or more devices, systems, and/or methods of the present application.

As shown in FIGS. 1A and 1B, for example, a sizing device 100 is used to determine the various luminal size parameters. In at least one embodiment of at least a portion of sizing device 100, and as shown in FIG. 7A, sizing device 100 may comprise an elongated body 700 having a longitudinal axis extending from a proximal end to a distal end (as indicated by the dotted line extending from "X" to "Y" as shown in FIG. 5A). An exemplary sizing device 100 of the present disclosure may also comprise a first excitation electrode 702 and a second excitation electrode 704 positioned along the longitudinal axis of the elongated body 700 at or near a distal end 706 of the elongated body 700, and may further comprise a first detection electrode 708 and a second detection electrode 710 positioned along the longitudinal axis of the elongated body 700 in between the first excitation electrode 702 and the second excitation electrode 704. In at least one exemplary embodiment of a sizing device 100, the elongated body 700 comprises a catheter having a lumen extending along the longitudinal axis of the catheter. Furthermore, other sizing portions 106 not specifically disclosed herein but insertable within a vessel and operable to determine at least one luminal size parameter may comprise and/or be used within an exemplary device, system, and/or method of the present disclosure.

In at least one embodiment, operation of sizing device 100, sizing portion 106 of sizing device 100, or a sizing portion 106 of another device and/or system of the present disclosure, including technical operation of one or more electrodes disclosed herein to determine one or more luminal size parameters, is performed as disclosed within one or more of the patents and/or patent applications incorporated by reference herein, including, but not limited to, the disclosure of U.S. Pat. No. 7,454,244. For example, and with reference to an exemplary embodiment of a sizing portion 106 disclosed herein comprising electrodes as referenced herein, conductance of current flow through an organ lumen and organ wall and surrounding tissue is parallel; i.e.,

$$G(z, t) = \frac{CSA(z, t) \cdot C_b}{L} + G_p(z, t) \quad [1a]$$

where $G_p(z, t)$ is the effective conductance of the structure outside the bodily fluid (organ wall and surrounding tissue) at a given position, z , along the long axis of the organ at a given time, t , and C_b is the electrical conductivity of the bodily fluid which for blood generally depends on the temperature, hematocrit and orientation and deformation of blood cells, and L is the distance between the detection electrodes of sizing portion 106. Furthermore, Equation [1a]

can be rearranged to solve for an exemplary luminal size parameter, namely cross sectional area $CSA(t)$, with a correction factor, α , if the electric field is non-homogeneous, as

$$CSA(z, t) = \frac{L}{\alpha C_b} [G(z, t) - G_p(z, t)] \quad [1b]$$

where α would be equal to 1 if the field were completely homogeneous. The parallel conductance, G_p , is an offset error that results from current leakage.

FIG. 7B shows an exemplary embodiment of a sizing device **100** comprising both a treatment portion **114** and a sizing portion **106**. As shown in this exemplary embodiment, sizing portion **106** of device **100** comprises a first excitation electrode **702** and a second excitation electrode **704** positioned along elongated body **700** at or near a distal end **706** of the elongated body **700**, and further comprises a first detection electrode **708** and a second detection electrode **710** positioned along the elongated body **700** in between the first excitation electrode **702** and the second excitation electrode **704**. In this exemplary embodiment, sizing device **100**, comprising both a treatment portion **114** and a sizing portion **106**, may be substantially equivalent, if not completely equivalent, to an exemplary combination device **400** of the present application

An additional exemplary embodiment of a sizing device **100** of the disclosure of the present application is shown in FIG. 7C. As shown in FIG. 7C, sizing device **100** comprises a wire having a first excitation electrode **702**, a second excitation electrode **704**, a first detection electrode **708**, and a second detection electrode **710** positioned along the wire at or near the distal end **706** of sizing device **100**.

Exemplary sizing devices **100** of the disclosure of the present application, as referenced herein, are operable to measure various luminal size parameters. In at least one embodiment wherein the elongated body of the sizing device **100** or treatment device **112** comprises a catheter having a lumen extending along the longitudinal axis of the catheter, an exemplary method for removing a stenotic lesion of a vessel of the present application comprises the step of measuring a first luminal size parameter which comprises the steps of providing electrical current flow to the first location through the catheter, injecting a first solution of a first compound having a first conductivity into the vessel lumen at the first location through the catheter, and measuring a first conductance value at the first location. An exemplary method may further comprise the steps of injecting a second solution of a second compound having a second conductivity into the vessel lumen at the first location through the catheter, measuring a second conductance value at the first location, and calculating a first luminal size parameter based on the first conductance value, the second conductance value, the first conductivity of the first solution, and the second conductivity of the second solution. Such a method could be used to measure a second and/or subsequent luminal size parameter; noting that the location of the measuring of the conductance values may vary accordingly (for example, at a second location).

For example, and as referenced within priority U.S. Pat. No. 7,454,244 incorporated by reference in its entirety herein, at any given position, z , along the long axis of organ/vessel and at any given time, t , in the cardiac cycle,

G_p , is a constant. Hence, two injections of different concentrations and/or conductivities of an NaCl solution give rise to two equations:

$$C_1 \cdot CSA(z, t) + L \cdot G_p(z, t) = L \cdot G_1(z, t) \quad [2]$$

and

$$C_2 \cdot CSA(z, t) + L \cdot G_p(z, t) = L \cdot G_2(z, t) \quad [3]$$

which can be solved simultaneously for CSA and G_p as

$$CSA(z, t) = L \cdot \frac{[G_2(z, t) - G_1(z, t)]}{[C_2 - C_1]} \quad [4]$$

and

$$G_p(z, t) = \frac{[C_2 \cdot G_1(z, t) - C_1 \cdot G_2(z, t)]}{[C_2 - C_1]} \quad [5]$$

where subscript "1" and subscript "2" designate any two injections of different NaCl concentrations and/or conductivities. For each injection k , C_k gives rise to G_k which is measured as the ratio of the root mean square of the current divided by the root mean square of the voltage. The C_k is typically determined through in vitro calibration for the various NaCl concentrations and/or conductivities. The concentration of NaCl used is typically on the order of 0.45 to 1.8%. The volume of NaCl solution is typically about 5 ml, but sufficient to displace the entire local vascular blood volume momentarily. The values of $CSA(t)$ and $G_p(t)$ can be determined at end-diastole or end-systole (i.e., the minimum and maximum values) or the mean thereof.

In an exemplary embodiment of method for removing a stenotic lesion of a vessel of the present application, a sizing device **100** useful to measure the various luminal size parameters comprises a wire (as shown in FIG. 7C), and the treatment device **112** operable to increase at least one luminal size parameter comprises a catheter comprising at least one treatment portion **114**. In at least one embodiment, the wire comprises a first excitation electrode **702** and a second excitation electrode **704** positioned along sizing device **100**, and further comprises a first detection electrode **708** and a second detection electrode **710** positioned along sizing device **100** in between the first excitation electrode **702** and the second excitation electrode **704**.

In another exemplary embodiment of a sizing device **100**, sizing device **100** may comprise a guide wire, wherein such a guide wire may be positioned at least partially within a lumen of the catheter to guide the catheter within a vessel and to perform at least one method step of an exemplary method of the present disclosure.

In an exemplary embodiment of a treatment device **112** of the disclosure of the present application, treatment device **112** comprises at least one treatment portion **114** and at least one sizing portion **106**. In at least one embodiment, the treatment portion **114** of treatment device **112** is operable to remove at least part of a stenotic lesion. In various embodiments, an exemplary treatment portion **114** of treatment device **112** (or a sizing device **100** or a combination device **400**) may comprise a cutting balloon, a cryoplasty device, a rotational atherectomy device, a laser angioplasty device, a vibrating catheter, a vibrating blade, and a vibrating drill, exemplary embodiments of each of the same as shown in FIGS. 6A-6F and described herein.

In at least one embodiment of an exemplary sizing portion **106** of one or more devices of the present disclosure, sizing portion **106** comprises a first excitation electrode **702** and a

second excitation electrode **704** positioned along the device, and further comprises a first detection electrode **708** and a second detection electrode **710** positioned along the device in between the first excitation electrode **702** and the second excitation electrode **704**. In another embodiment wherein an exemplary treatment portion **114** comprises a balloon **800** (as shown, for example, in FIG. **8A**, discussed below), the sizing portion **106** of an exemplary device of the disclosure of the present application may comprise the same or similar configuration of electrodes. For example, and in at least one embodiment, first excitation electrode **702**, second excitation electrode **704**, first detection electrode **708**, and second detection electrode **710** may each be positioned along a treatment device **112** within balloon **800**, and wherein the then-current luminal size parameter comprises a parameter measured within balloon **800** at one or more stages of balloon **800** inflation.

In at least one additional embodiment of an exemplary device of the present application, the device comprises an exemplary treatment portion **114** comprising a balloon **800**, and further comprises an exemplary sizing portion **106** comprising at least one pressure sensor **802**. As shown in FIG. **8A**, an exemplary sizing device **100** comprises balloon **800** surrounding the various electrodes positioned along the elongated body **700** of sizing device **100**. In an exemplary embodiment, pressure sensor **802** is operable to detect at least one pressure within balloon **800** at one or more stages of balloon **800** inflation. As shown in FIG. **8A**, balloon **800** may inflate and/or deflate via inflation/deflation port **804**, allowing a gas and/or a liquid to be introduced into or removed from balloon **800** via suction/infusion tube **806**.

As described herein, a user of one or more devices comprising at least one treatment portion **114** may, at some point, decide to stop operating treatment portion **114**. The decision to stop may be for any number of reasons, including, but not limited to, achieving a preferred luminal size parameter based upon operation of treatment portion **114** on a stenotic lesion **110** within a vessel. In at least one embodiment of an exemplary method for removing a stenotic lesion of a vessel of the present disclosure, the method further comprises the step of ceasing operation of the treatment device **112** (or the treatment portion **114** of a device of the disclosure of the present application) when the then-current luminal size parameter equals the preferred second luminal size parameter. In at least one embodiment, the preferred second luminal size parameter is equal to the first luminal size parameter. In another embodiment, the preferred luminal size parameter comprises a preferred second luminal size parameter range.

In an exemplary embodiment of a method for removing a stenotic lesion of the present disclosure, the step of comparing the then-current luminal size parameter to the preferred second luminal size parameter comprises comparing the then-current luminal size parameter to the preferred second luminal size parameter range. In such a situation, and instead of a specific numerical size parameter target, the preferred luminal size parameter comprises a range of acceptable values. In an exemplary embodiment, a method for removing a stenotic lesion may comprise the step of ceasing the operation of treatment device **112** (or the treatment portion **114** of a device of the disclosure of the present application) when the then-current luminal size parameter is within the preferred second luminal size parameter range.

In at least one method for removing a stenotic lesion of the disclosure of the present application, the method further comprises the steps of selecting an appropriately-sized stent and implanting the stent into the vessel lumen. As shown in

FIG. **8B**, an exemplary device of the present application (shown as combination device **400**) comprises a balloon **800** coupled thereto, and is shown in an inflated state while positioning a stent **808** within the lumen of a vessel **102**. In another embodiment, and as shown in FIG. **8C**, combination device **400** is shown performing a similar operation, noting that in this exemplary embodiment, combination device comprises a treatment portion **114**, a sizing portion **106**, and a balloon **800** positioned around various electrodes.

In at least one method for removing a stenotic lesion of the disclosure of the present application, the method further comprises the steps of obtaining at least one additional luminal size parameter between the first position and the second position, and constructing a lumen profile based upon the second luminal size parameter and the at least one additional luminal size parameter. In such a situation, multiple luminal size parameters may be used to construct a visual profile of changes in luminal size parameter over time and/or during treatment. In an exemplary method, multiple luminal size parameters are taken at various locations, allowing for the determination of a length of a stenotic lesion to be made based upon the lumen profile.

In at least one embodiment of a system for removing a stenotic lesion of a vessel as shown in FIG. **9A**, system **900** comprises a treatment device **112** and a sizing device **100**. As referenced herein, and as shown in FIG. **9A**, treatment device **112** may comprise at least one treatment portion **114** operable to remove at least part of a stenotic lesion **110**, and an exemplary sizing device **100** may comprise at least one sizing portion **106** (including various electrodes, for example) operable to measure a first luminal size parameter when sizing device **100** is positioned at a first location, and further operable to measure a second luminal size parameter when sizing device **100** is positioned at a second location.

Any or all of the characteristics, features, elements, and/or limitations of the various devices referenced herein in connection with the above-referenced methods may apply to one or more exemplary systems of the present application. For example, and in an exemplary system **900**, treatment device **112** may comprise a catheter, and sizing device **100** may comprise a wire selected from the group consisting of a guide wire, a pressure wire, and a flow wire. Said wire, when in use, may be positioned at least partially within a lumen of the catheter.

As shown in FIG. **9B**, and in at least one embodiment of a system **900** for removing a stenotic lesion of a vessel of the present disclosure, treatment portion **114** of treatment device **112** comprises balloon **800**, and sizing portion **106** of sizing device **100** comprises at least one pressure sensor **802**. In such an embodiment, pressure sensor **802** may be operable to detect at least one pressure within balloon **800** at one or more stages of balloon inflation. In addition, and in an exemplary embodiment, pressure sensor **802** may be operable to measure a first pressure gradient and calculate at least one luminal parameter within balloon **800** based in part upon the first pressure gradient.

In at least one embodiment of a system for removing a stenotic lesion of a vessel, and as shown in FIG. **9B**, system **900** further comprises at least one suction/infusion port **902** in communication with at least one lumen **904** of sizing device **100**, said suction/infusion port **902** operable to facilitate one or more fluid injections into a treatment site. In another embodiment, and as shown in FIG. **9B**, system **900** may further comprise at least one fluid delivery source **906** operably coupled to lumen **904** of sizing device **100**, whereby one or more fluids may be injected from fluid

delivery source **906** through lumen **904** of sizing device **100**, through suction/infusion port **902**, and into the treatment site.

In an additional exemplary embodiment, system **900** may further comprise a data acquisition and processing system **908** operably coupled to sizing device **100** as shown in FIG. **9B**, whereby data acquisition and processing system **908** is operable to receive conductance data from sizing device **100**. In at least one embodiment, data acquisition and processing system **908** is further operable to calculate at least one luminal parameter based upon said conductance data. In at least another embodiment, data acquisition and processing system **908** is further operable to display the calculated at least one luminal parameter to facilitate operational control of treatment device **112**. Said parameter, along with potentially other data and/or parameters, may be displayed on, for example, a display **910** operably coupled to data acquisition and processing system **908** as shown in FIG. **9B**.

In at least one embodiment of a system for removing a stenotic lesion of a vessel, and as shown in FIG. **9C**, an exemplary sizing device **100** comprises at least one sizing portion **106**. Sizing portion **106**, as shown in the embodiment of sizing device **100** in FIG. **9C**, may comprise a first excitation electrode **702**, a second excitation electrode **704**, a first detection electrode **708**, and a second detection electrode **710**, and may further comprise a current source **912** in communication with first excitation electrode **702** and second excitation electrode **704**. In at least one embodiment, current source **912** is operable to supply current to first excitation electrode **702** and second excitation electrode **704** to facilitate measurement of at least one conductance value, thereby facilitating calculation of a luminal size parameter.

In at least one method for removing a stenotic lesion of a vessel of the disclosure of the present application, the method comprises the steps of positioning a device within a vessel lumen, the device (for example, a combination device **400** as shown in FIGS. **4A-5C**) comprising at least one sizing portion **106** and at least one treatment portion **114**, and operating sizing portion **106** of combination device **400** to obtain luminal size parameter data. An exemplary method may further comprise the steps of operating treatment portion **114** at a location within the vessel lumen at or near a stenotic lesion **110**, whereby operation of treatment portion **114** is based upon the luminal size parameter data, and whereby operation of treatment portion **114** increases the luminal size parameter data value. Such a method may further comprise the step of ceasing operation of treatment portion **114** of combination device **400** when the luminal size parameter data indicates a preferred luminal size parameter.

In at least one embodiment of a method for removing a stenotic lesion of a vessel of the disclosure of the present application, the luminal size parameter data is displayed on a display **910** (such as a computer monitor, other monitor, or LCD display, for example), and the step of operating treatment portion **114** is performed based upon the displayed luminal size parameter data. In an exemplary embodiment, the luminal size parameter data comprises a first luminal size parameter obtained at a first location within the vessel lumen, a second luminal size parameter obtained at a second location within the vessel lumen, and at least one then-current luminal size parameter obtained after initial operation of the at least one treatment portion. Said parameters may be as previously described herein regarding one or more methods of the present disclosure, and may comprise, for example, diameters and/or cross-sectional areas. In at

least one embodiment of such a method, the preferred luminal size parameter is determined based upon luminal size parameter data obtained at a location within the vessel lumen without a stenotic lesion **110**. In another embodiment, the preferred luminal size parameter is larger than luminal size parameter data obtained at a location within the vessel lumen at or near a stenotic lesion.

In at least one embodiment of a sizing portion **106** of a combination device **400** operable to facilitate performance of one or more methods of the present disclosure, sizing portion **106** comprises a first excitation electrode **702** and a second excitation electrode **704** positioned along combination device **400** at or near a distal end **706** of combination device **400**, and further comprises a first detection electrode **708** and a second detection electrode **710** positioned along combination device **400** in between first excitation electrode **702** and second excitation electrode **704**. Such an embodiment may comprise an embodiment of a device similar to or the same as the embodiment of an exemplary sizing device **100** as shown in FIG. **7B**. In addition, said combination device **400** may comprise one or more features, elements, and/or limitations of one or more other devices and/or systems (or portions thereof) referenced herein, including, but not limited to, an exemplary sizing device **100**, an exemplary treatment device **112**, and/or an exemplary system **900**.

In addition to the foregoing, and in at least one embodiment of a method for removing a stenotic lesion of a vessel of the disclosure of the present application, the step of operating the at least one sizing portion **106** may comprise obtaining multiple luminal size parameter values during the step of operating the at least one treatment portion **114**.

In at least one embodiment of a device for removing a stenotic lesion of a vessel of the disclosure of the present application, the device (for example, a combination device **400**) comprises at least one sizing portion **106** and at least one treatment portion **114**. Sizing portion **106** and/or treatment portion **114** may comprise one or more features, elements, and/or limitations of one or more other devices and/or systems (or portions thereof) referenced herein, including, but not limited to, an exemplary sizing device **100**, an exemplary treatment device **112**, and/or an exemplary system **900**.

Various additional embodiments of devices of the present disclosure are shown in FIGS. **10A-10C**. In at least one embodiment of at least a portion of a sizing/typing device **1000** of the present disclosure, and as shown in FIG. **10A**, sizing/typing device **1000** comprises an elongated body **1002** having a longitudinal axis extending from a proximal end to a distal end **1004** (as indicated by the dotted line extending from "X" to "Y" as shown in FIG. **10A**), whereby said sizing/typing device **1000** is configured to fit within a lumen of a luminal organ. An exemplary sizing/typing device **1000** of the present disclosure comprises a first excitation electrode **702** and a second excitation electrode **704** positioned along the longitudinal axis of the elongated body **1002** at or near a distal end **1004** of the elongated body **1002**, and further comprises a first detection electrode **708** and a second detection electrode **710** positioned along the longitudinal axis of the elongated body **1002** in between the first excitation electrode **702** and the second excitation electrode **704**. As shown in FIG. **10A**, second excitation electrode **704** may be referred to as electrode "A", second detection electrode **710** may be referred to as electrode "B", first detection electrode **708** may be referred to as electrode "C", and first excitation electrode **702** may be referred to as electrode "D", and are shown in an exemplary tetrapolar

arrangement. In at least one exemplary embodiment of a sizing/typing device **1000**, and as shown in FIGS. **10A** and **10B**, the elongated body **1002** comprises a catheter having a lumen **1006** extending along the longitudinal axis of the catheter.

The exemplary embodiment of at least a portion of a sizing/typing device **1000** shown in FIG. **10A**, as well as various other embodiments of sizing/typing devices **1000** of the present disclosure, comprise “directional electrodes” or “directional sensors,” meaning that they do not completely extend the entire circumference of sizing/typing devices **1000**. As shown in FIG. **10A**, an exemplary embodiment of a sizing/typing device **1000** of the present disclosure comprises directional electrodes (**702**, **708**, **710**, and **704**, for example, which may be referred to generally herein as an exemplary detector **1010**) positioned along elongated body **1002** at approximately 90° around a 360° circumference of sizing/typing device **1000**. In at least another embodiment, said electrodes (and directional sensors **1200** as referenced below) are positioned at approximately 45° around a 360° circumference of sizing/typing device **1000**. These directional electrodes, as discussed in further detail herein, allow a user of said sizing/typing device **1000** to obtain impedance measurements, for example, at a portion of a vessel instead of obtaining impedance measurements indicative of an entire circumference of a vessel at the location of said electrodes. Such measurements, and other measurements obtainable from exemplary detectors **1010** of the present disclosure, may be generally referred to as various “luminal size parameters” indicative of, for example, luminal cross-sectional areas or luminal diameters. In addition, such directional measurements overcome the problems associated with average measurements at one location within a vessel, and may identify when a vessel is not circumferentially uniform, as parts of a vessel at a single location may be calcified, fibrotic, contain lipids, or be “normal.”

As shown in FIG. **10A**, an exemplary sizing/typing device **1000** of the present disclosure comprises at least one rotatable portion **1008**. Rotatable portion **1008** allows at least one electrode of sizing/typing device **1000** to rotate around a circumference of sizing/typing device **1000**, allowing a user to obtain directional impedance measurements, for example, at various portions of a vessel wall. Rotation may be facilitated by a rotation apparatus **2002** (as shown in FIG. **20**), which may be a mechanical actuator, an electro-mechanical actuator, and/or a steering device. Rotation apparatus **2002**, in at least one embodiment, is capable of rotating rotatable portion **1008** a full 360° around elongated body **1002** (or wire **1300** as referenced below).

In an exemplary sizing/typing device **1000** of the present disclosure, at least one of electrodes A, B, C, and D is capable of extending outward from sizing/typing device **1000**. For example, and as shown in FIG. **10B**, electrode C (first detection electrode **708**) is not only positioned within rotatable portion **1008**, but also is capable of extending outward from sizing/typing device **1000**. Such an extension, for example, allows electrode C (or another electrode/sensor of the present disclosure that is capable of extending outward from a first position to an extended second position) to physically touch a vessel wall and/or a substance present within or on a vessel wall, such as a stenotic lesion or a lipid mass. Extension of C (or another electrode/sensor of the present disclosure, such as a directional sensor **1200** referenced herein) may be facilitated by an extension apparatus **2004** (as shown in FIG. **20**), which may also be a mechanical actuator, an electro-mechanical actuator, and/or a steering device.

This physical touching, as described in further detail below, provides a user of a sizing/typing device **1000** with the ability to determine what such an electrode is touching (vessel wall, lesion, etc.), so that a determination can be made as to whether or not to perform any treatment within the vessel at that particular location. For example, if an electrode/sensor of sizing/typing device **1000** extends therefrom and physically touches a vessel wall without a lesion, a user of sizing/typing device **1000** may decide not to, for example, operate a treatment device or a treatment portion of sizing/typing device **1000** at that particular location so not to damage the vessel wall. Alternatively, if an electrode/sensor of sizing/typing device **1000** extends therefrom and physically touches a stenotic lesion within a vessel wall, a user of sizing/typing device **1000** may decide to operate a treatment device or a treatment portion of sizing/typing device **1000** at that particular location to remove at least part of the lesion.

FIG. **10C** shows an exemplary embodiment of at least a portion of a sizing/typing device **1000** of the present disclosure, whereby rotatable portion **1008** has rotated from its original position shown in FIG. **10B**. In at least one embodiment, rotatable portion **1008** is capable of a full 360° rotation about sizing/typing device **1000**.

Additional embodiments of sizing/typing devices **1000** of the present disclosure are shown in FIGS. **11A-11C**. In at least one embodiment of at least a portion of a sizing/typing device **1000** of the present disclosure, and as shown in FIG. **11A**, sizing/typing device **1000** comprises an elongated body **1002** having a longitudinal axis extending from a proximal end to a distal end **1004** (as indicated by the dotted line extending from “X” to “Y” as shown in FIG. **10A**), and electrodes A, B, C, and D as referenced above. In at least the embodiment shown in FIG. **11A**, sizing/typing device **1000** comprises a rotatable portion **1008** whereby each of electrodes A, B, C, and D are present thereon. In at least another embodiment, and as shown in FIGS. **11B** and **11C**, sizing/typing device **1000** comprises a rotatable portion **1008** whereby the entire distal portion of sizing/typing device **1000** may rotate, noting that in the embodiment shown in FIG. **11A**, the most distal end is not part of rotatable portion **1008**. FIG. **11B** shows an exemplary sizing/typing device **1000** with a rotatable portion **1008** in a first position, and FIG. **11C** shows an exemplary sizing/typing device **1000** with a rotatable portion **1008** in a second position rotated from the first position.

In a situation where a user of a sizing/typing device **1000** of the present disclosure desires to have the least amount of rotatable matter, a sizing/typing device **1000** as shown in FIGS. **10A-10C** may be preferred. If the amount of rotatable matter is not of particular concern, any number of embodiments of sizing/typing devices **1000** of the present disclosure may be useful depending on the particular application.

At least another embodiment of a sizing/typing device **1000** of the present disclosure is shown in FIG. **12A**. As shown in FIG. **12A**, sizing/typing device **1000** comprises an elongated body **1002** having a longitudinal axis extending from a proximal end to a distal end **1004** (as indicated by the dotted line extending from “X” to “Y” as shown in FIG. **10A**), and further comprises electrodes A, B, C, and D as referenced herein. However, in at least the exemplary embodiment shown in FIG. **12A**, sizing/typing device **1000** comprises a directional sensor **1200**, whereby directional sensor **1200** appears along elongated body **1002** within a rotatable portion **1008** of elongated body **1002**. In at least one embodiment, directional sensor **1200** is capable of extending outward from elongated body **1000** (similar to

electrode C as shown in FIG. 10B), and is further capable of rotation about elongated body 1002 (similar to electrode C as shown in FIG. 10C). In addition, and as shown in FIGS. 12B and 12C, directional sensor 1200 may be positioned at various places along sizing/typing device 1000, such as, for example, proximal to electrodes A, B, C, and D (as shown in FIG. 12B), or distal to electrodes A, B, C, and D (as shown in FIG. 12C). In each embodiment, for example, directional sensor 1200 may be positioned along elongated body 1002 at a rotatable portion 1008 so that directional sensor 1200 may rotate as referenced herein. Furthermore, more than one directional sensor 1200 may be used in various embodiments of sizing/typing devices 1000 of the present disclosure.

In various embodiments of sizing/typing devices 1000 of the present disclosure, directional sensor 1200 is capable of extending outward to physically touch a luminal organ or a structure therein when an exemplary sizing/typing device 1000 is positioned within a lumen of a luminal organ. In additional embodiments, directional sensor 1200 is capable of obtaining a measurement from the luminal organ or the structure therein that is indicative of what directional sensor 1200 is touching. For example, if directional sensor 1200 comprises an impedance sensor, then the measurement is an impedance measurement which is indicative of what directional sensor 1200 is touching. If a constant voltage is applied to directional sensor 1200, the measurement is a current measurement, and similarly, if a constant current is applied to directional sensor 1200, the measurement is a voltage measurement. In an embodiment where directional sensor 1200 comprises a thermistor, for example, the measurement is a temperature measurement, which itself is indicative of what directional sensor 1200 is touching within the luminal organ.

Various additional embodiments of sizing/typing devices 1000 of the present disclosure are shown in FIGS. 13A-13C. As shown in FIGS. 13A-13C, sizing/typing device 1000 comprises a wire 1300, whereby electrodes A, B, C, and D are positioned directionally thereon at or near a distal end 1004 of wire 1300. In the exemplary embodiments shown therein, electrode C may rotate about wire 1300 (at rotatable portion 1008) as shown in FIG. 13C, and may extend outwardly from wire 1300 as shown in FIG. 13B. In such exemplary embodiments and other potential embodiments, electrodes A, B, C, and D may themselves comprise wire electrodes with electrode/sensor tips.

Additional embodiments of sizing/typing devices 1000 of the present disclosure are shown in FIGS. 14A-14C. As shown in FIGS. 14A-14C, sizing/typing devices 1000 comprise wires 1300, whereby rotatable portions 1008 shown therein include each of electrodes A, B, C, and D, and/or the tip of sizing devices 1000 near their respective distal ends.

FIGS. 15A-15C show additional embodiments of sizing/typing devices 1000 of the present disclosure. As shown in FIGS. 15A-15C, sizing/typing devices 1000 comprise a directional sensor 1200 within a rotatable portion 1008 of sizing/typing devices 1000 in addition to electrodes A, B, C, and D, whereby directional sensor 1200 is positioned along wire 1300 within electrodes A, B, C, and D (FIG. 15A), proximal to said electrodes (FIG. 15B), and distal to said electrodes (FIG. 15C).

Exemplary embodiments of sizing/typing devices 1000 of the present disclosure having one or more treatment portions positioned thereon are shown in FIGS. 16A-16C. As shown in FIG. 16A, sizing/typing device 1000 comprises an elongated body 1002 having a lumen therethrough, whereby a treatment portion 114 is positioned thereon proximal to

electrodes A, B, C, and D. FIG. 16B shows an exemplary sizing/typing device 1000 comprising a wire 1300 and a treatment portion 114 is positioned thereon proximal to electrodes A, B, C, and D. Treatment portions 114 of sizing/typing devices 1000 may comprise any number of treatment portions 114 referenced herein or known in the art including, but not limited to, a cutting balloon, a cryoplasty device, a rotational atherectomy device, a laser angioplasty device, a vibrating catheter, a vibrating blade, and a vibrating drill.

An additional exemplary embodiment of a sizing/typing device 1000 of the present disclosure having a treatment portion 114 thereon is shown in FIG. 16C. As shown in FIG. 16C, sizing/typing device 1000 comprises a wire 1300 having electrodes A, B, C, and D at or near a distal end 1004 of sizing/typing device 1000. In this exemplary embodiment, electrode C is capable of rotation and extension as referenced herein, whereby the rotation of electrode C allows directional impedance measurements to be obtained, and whereby the extension of electrode C from wire 1300 allows electrode C to physically touch a vessel wall or a body within a vessel wall (such as a plaque, for example), to allow a determination of the type of tissue/structure said electrode is touching. The exemplary embodiment shown in FIG. 16C comprises a treatment portion 114, so that such an embodiment of a sizing/typing device 1000 can perform three separate tasks, including sizing of a vessel, typing a vessel or vessel structure, and treatment of a vessel to, for example, remove a stenotic lesion.

Additional exemplary embodiments of sizing/typing devices 1000 of the present disclosure are shown in FIGS. 17A-18C. As shown in FIGS. 17A-17C, sizing/typing devices 1000 comprise an elongated body 1002, and directional sensor 1200 within a rotatable portion 1008 of elongated body 1002, and a treatment portion 114. FIG. 17A shows an embodiment of sizing/typing device 1000 with directional sensor 1200 at a first position, FIG. 17B shows directional sensor 1200 in an extended position, and FIG. 17C shows directional sensor 1200 in an extended position and rotated from its original position along elongated body 1002. FIGS. 18A-18C show exemplary sizing/typing devices 1000 of the present disclosure comprising a directional sensor 1200 within a rotatable portion 1008 of a wire 1300, and further comprising an exemplary treatment portion 114 of the present disclosure. FIGS. 18A, 18B, and 18C show directional sensor in an initial position, extended, and rotated, respectively.

In an exemplary embodiment of a sizing/typing device 1000 of the present disclosure wherein an exemplary treatment portion 114 comprises a balloon 800 (as shown, for example, in FIG. 19A, discussed below), electrodes A, B, C, and D may each be positioned along sizing/typing device 1000 within balloon 800, and wherein a then-current luminal size parameter (obtained by electrodes A, B, C, and D) comprises a parameter measured within balloon 800 at one or more stages of balloon 800 inflation. As shown in FIG. 19A, an exemplary sizing/typing device 1000 comprises balloon 800 surrounding the various electrodes positioned along the elongated body 1002 (or wire 1300 in a wire embodiment) of sizing/typing device 1000. In an exemplary embodiment, pressure sensor 802 is capable of detecting at least one pressure within balloon 800 at one or more stages of balloon 800 inflation. As shown in FIG. 19A, balloon 800 may inflate and/or deflate via inflation/deflation port 804, allowing a gas and/or a liquid to be introduced into or removed from balloon 800 via suction/infusion tube 806.

As shown in FIG. 19B, an exemplary sizing/typing device 1000 of the present application comprises a balloon 800 coupled thereto, and is shown in an inflated state while positioning a stent 808 within the lumen of a vessel 102. In another embodiment, and as shown in FIG. 19C, sizing/typing device 1000 is shown performing a similar procedure, noting that in this exemplary embodiment, sizing/typing device 1000 comprises a treatment portion 114, a detector 1010, and a balloon 800 positioned around various electrodes (such as a set of electrodes A, B, C, and D).

An exemplary embodiment of a system of the present disclosure is shown in FIG. 20. As shown in FIG. 20, system 2000 comprises a sizing/typing device 1000 comprising a directional sensor 1200 coupled to a rotation apparatus 2002 and an extension apparatus 2004. Detector 1010 comprises electrodes first excitation electrode 702, second excitation electrode 704, first detection electrode 708, and second detection electrode 710, whereby a current/voltage source 902 is coupled to directional sensor 1200, first excitation electrode 702, and second excitation electrode 704. Sizing/typing device 1000 may further define a lumen 1006, whereby a suction/infusion port 902 is defined at or near one end of sizing/typing device 1000, and a fluid delivery source may be coupled to sizing device 1000 at another end of said device 1000. Sizing/typing device 1000 of system 2000 may further comprise at least one treatment portion 114, and may be coupled to a data acquisition and processing system 908. Each of the aforementioned components of device 1000 and/or system 2000 may function/operate as described in the present disclosure.

Steps of using an exemplary sizing/typing device 1000 of the present disclosure are shown in FIG. 21. As shown in FIG. 21, an exemplary method 2100 of using a sizing/typing device 1000 of the present disclosure comprises the steps of positioning at least part of a sizing/typing device 1000 within a luminal organ at a first location (an exemplary positioning step 2102) and operating sizing/typing device 1000 to obtain a first luminal size parameter and a first measurement indicative of electrical impedance of the luminal organ or a structure therein that at least part of sizing/typing device 1000 is physically touching at the first location (an exemplary first operation step 2104). Step 2104 may be performed in the presence of a saline injection to optimize the output readings as referenced herein.

The first measurement indicative of electrical impedance of the luminal organ or a structure therein allows a user of sizing/typing device 1000 to know what, for example, directional sensor 1200 is touching. For example, and in an embodiment where a constant current is applied to directional sensor 1200 when directional sensor 1200 is touching the luminal organ or a structure therein (such as a plaque), a voltage can be measured and a resulting impedance can be determined based on Ohm's law ($V=I/R$, where V =voltage, I =current, and R =resistance or impedance in the case of alternating current). If instead a constant voltage is applied, a current can be measured and a resulting impedance can be determined. Physically, lipid and calcium (calcifications, such as stenotic lesions) have notably different impedance characteristics than a normal vessel wall. An exemplary study has shown that, for example, the electrical conductivities at 30 Hz for muscle, blood vessels, fat, and bone marrow (similar to a hard plaque) are 0.350, 0.32, 0.024, and 0.003 S/m. Similarly, a stenotic lesion and a normal vessel have different temperature characteristics, and in an embodiment of a sizing/typing device 1000 of the present disclosure wherein a directional sensor comprises a thermistor (temperature sensor), physically touching a vessel or a substance

therein, especially in the presence of a saline injection to optimize the results, would provide temperature data indicative of what directional sensor 1200 is physically touching. Therefore, by knowing the impedance, a user of sizing/typing device 1000 knows what directional sensor 1200 is touching at that time, which may be, for example, calcifications, lipids, fibrosis, normal tissue, plaque components, and the like. Such measurements (as well as measurements in connection with vessel sizing as referenced herein) can be made in the presence of a saline injection, for example, to standardize the impedance measurements by eliminating the variability of the conductance of blood since saline has a known conductivity. The saline injections may also be advantageous for temperature measurements (as generally referenced herein) with a thermistor to detect thermal maps in the presence of reduced viscous drag forces as compared to blood, which has a higher viscosity.

Method 2100 may further comprise the steps of moving at least part of sizing/typing device 1000 to a second location within the luminal organ (an exemplary moving step 2106), operating sizing/typing device 1000 to obtain a second luminal size parameter and a second measurement indicative of electrical impedance of the luminal organ or the structure therein that at least part of the device is physically touching at the second location (an exemplary second operation step 2108), and determining whether or not a stenotic lesion is present at either the first location or the second location based on one or more of the first luminal size parameter, the first measurement, the second luminal size parameter, and the second measurement (an exemplary determination step 2110). If a stenotic lesion is present, method 2100 may further comprise the steps of moving at least part of sizing/typing device 1000 having a treatment portion 114 to a stenotic lesion location (another exemplary moving step 2106), and operating treatment portion 114 of sizing/typing device 1000 to remove at least part of the stenotic lesion (an exemplary treatment step 2112).

In at least one embodiment of a method 2100 of the present disclosure, and as shown in FIG. 21, method 2100 comprises the steps of measuring a then-current luminal size parameter at the stenotic lesion location (an exemplary measurement step 2114), comparing the then-current luminal size parameter to either the first luminal size parameter or the second luminal size parameter that is indicative of the stenotic lesion location (an exemplary comparison step 2116), and if the then-current luminal size parameter does not equal a preferred luminal size parameter, repeating steps 2112, 2114, and 2116 until the then-current luminal size parameter equals or exceeds the preferred luminal size parameter (an exemplary repeat step 2118). In an exemplary embodiment of method 2100, the preferred luminal size parameter is determined based upon the first luminal size parameter and the second luminal size parameter.

In various embodiments of methods 2100 of the present disclosure, the step of moving at least part of the device to a second location (the first exemplary moving step 2106 referenced above) comprises advancing or retracting at least part of sizing/typing device 1000 within the luminal organ and/or comprises rotating at least part of sizing/typing device 1000 within the luminal organ. In at least one embodiment, the first luminal size parameter, the second luminal size parameter, and then-current luminal size parameter(s) are obtained using a detector 1010 coupled to sizing/typing device 1000. In an exemplary embodiment, the first measurement and the second measurement are obtained using a directional sensor 1200 coupled to sizing/typing device 1000.

In at least one embodiment of a method **2100** of the present disclosure, exemplary measurement step **2114** further comprises measuring a then-current measurement indicative of electrical impedance of the luminal organ or structure therein, and comparison step **2116** further comprises comparing either the first measurement or the second measurement to the then-current measurement. In an exemplary embodiment, steps **2112**, **2114**, and **2116** are repeated if the then-current luminal size parameter does not equal a preferred luminal size parameter or if the then-current measurement is indicative of the stenotic lesion.

In various embodiments of methods **2100** of the present disclosure as shown in FIG. **21**, method **2100** further comprises the step of ceasing the operation of treatment portion **114** of sizing/typing device **1000** when the then-current luminal size parameter equals or exceeds the preferred luminal size parameter (an exemplary treatment cessation step **2120**). In additional embodiments, method **2100** further comprises the steps of selecting an appropriately-sized stent (an exemplary stent selection step **2122**), and implanting the stent into the luminal organ (an exemplary stent implantation step **2124**).

In at least one exemplary method **2100** of the present disclosure, and as shown in FIG. **22A**, method **2100** comprises the steps of positioning a device within a luminal organ, the device comprising at least one sizing portion, at least one typing portion, and at least one treatment portion (another exemplary positioning step **2102**), operating the at least one sizing portion of the device to obtain luminal size parameter data (an exemplary sizing step **2200**), and operating the at least one typing portion of the device to obtain type data indicative of the luminal organ or a structure therein (an exemplary typing step **2202**). Method **2100** may further comprise the step of operating the at least one treatment portion at a location within the luminal organ at or near a stenotic lesion, whereby operation of the at least one treatment portion is based upon the luminal size parameter data and the type data, whereby operation of the at least one treatment portion removes at least part of the stenotic lesion (another exemplary treatment step **2112**).

In various embodiments and as shown in FIG. **22A**, methods **2100** may further comprise the step of ceasing operation of the at least one treatment portion (i) when the luminal size parameter data indicates a preferred luminal size parameter, or (ii) when the type data is no longer indicative of a stenotic lesion (additional exemplary treatment cessation steps **2120**).

In another exemplary method **2100** of the present disclosure, and as shown in FIG. **22B**, method **2100** comprises the steps of positioning a device within a luminal organ, the device comprising at least one typing portion and at least one treatment portion (an exemplary positioning step **2102**), operating the at least one typing portion of the device to obtain initial type data indicative of electrical impedance of the luminal organ or a structure therein (an exemplary typing step **2202**), operating the at least one treatment portion if the type data is indicative of a stenotic lesion to remove at least part of the stenotic lesion (an exemplary treatment step **2112**), and operating the at least one typing portion of the device again to obtain then-current type data indicative of electrical impedance of the luminal or the structure therein (an exemplary subsequent typing step **2202**). In at least one embodiment, method **2100** further comprises repeating steps **2112** and **2202** until the then-current type data does not indicate the presence of the stenotic lesion (another exemplary repeat step **2118**).

While various embodiments of devices and systems for removing targeted lesions from vessels and methods for using the same have been described in considerable detail herein, the embodiments are merely offered by way of non-limiting examples of the disclosure described herein. It will therefore be understood that various changes and modifications may be made, and equivalents may be substituted for elements thereof, without departing from the scope of the disclosure. Indeed, this disclosure is not intended to be exhaustive or to limit the scope of the disclosure.

Further, in describing representative embodiments, the disclosure may have presented a method and/or process as a particular sequence of steps. However, to the extent that the method or process does not rely on the particular order of steps set forth herein, the method or process should not be limited to the particular sequence of steps described. Other sequences of steps may be possible. Therefore, the particular order of the steps disclosed herein should not be construed as limitations of the present disclosure. In addition, disclosure directed to a method and/or process should not be limited to the performance of their steps in the order written. Such sequences may be varied and still remain within the scope of the present disclosure.

I claim:

1. A device for insertion within a luminal organ, comprising:

an elongated body having a distal body end, a fixed portion, and a rotatable portion at or near the distal body end;

at least one directional sensor positioned on the rotatable portion of the elongated body, the at least one directional sensor configured for axial rotation relative to and distinct from the fixed portion of the elongated body and operable to obtain a measurement from the luminal organ or a structure therein, wherein the measurement is indicative of less than an entire circumference of the luminal organ; and

at least one treatment portion capable of removing at least part of a stenotic lesion from a luminal organ; and an extension apparatus coupled to the at least one directional sensor, the extension apparatus capable of moving the at least one directional sensor radially relative a longitudinal axis of the elongated body between a first position and an extended second position.

2. The device of claim 1, wherein the elongated body is selected from the group consisting of a catheter and a wire.

3. The device of claim 1, wherein the elongated body is configured to fit within a lumen of a luminal organ.

4. The device of claim 1, further comprising:

a detector positioned along the elongated body at or near the distal body end, the detector capable of measuring a luminal size parameter when at least part of the elongated body is positioned within a lumen of a luminal organ.

5. The device of claim 4, wherein the detector comprises a tetrapolar arrangement of electrodes.

6. The device of claim 5, wherein the tetrapolar arrangement of electrodes comprises two detection electrodes positioned in between two excitation electrodes.

7. The device of claim 6, wherein the at least one directional sensor is at least one electrode of the tetrapolar arrangement of electrodes.

8. The device of claim 6, wherein the at least one directional sensor is independent of the tetrapolar arrangement of electrodes.

9. The device of claim 5, further comprising:
a current/voltage source in communication with one or more of the directional sensor and the tetrapolar arrangement of electrodes, the current/voltage source capable of supplying a constant current and/or a constant voltage thereto to facilitate one or more measurements indicative of electrical impedance of the luminal organ or a structure therein.
10. The device of claim 9, further comprising:
a data acquisition and processing system operably coupled to the device, the data acquisition and processing system capable of receiving the one or more measurements from the device and calculating at least one luminal size parameter and/or determining at least one luminal organ or structure type based upon the one or more measurements.
11. The device of claim 1, wherein the at least one directional sensor is further capable of extending outward from the elongated body.
12. The device of claim 11, wherein when at least part of the elongated body is positioned within a lumen of a luminal organ, the at least one directional sensor is capable of extending outward from the elongated body to physically touch the luminal organ or the structure therein.
13. The device of claim 12, wherein the at least one directional sensor is capable of obtaining the measurement from the luminal organ or the structure therein that the directional sensor is touching.
14. The device of claim 13, wherein the at least one directional sensor is an impedance sensor, and wherein the measurement is an impedance measurement.
15. The device of claim 13, wherein when a constant voltage is applied to the at least one directional sensor, the measurement is a current measurement indicative of electrical impedance of the luminal organ or the structure therein that the directional sensor is touching.
16. The device of claim 13, wherein when a constant current is applied to the at least one directional sensor, the measurement is a voltage measurement indicative of electrical impedance of the luminal organ or the structure therein that the directional sensor is touching.
17. The device of claim 13, wherein the at least one directional sensor is a thermistor, and wherein the measurement is a temperature measurement.
18. The device of claim 1, wherein the extension apparatus is selected from the group consisting of a mechanical actuator, an electro-mechanical actuator, and a steering device.
19. The device of claim 1, further comprising
a rotation apparatus coupled to the rotatable portion of the elongated body, the rotation apparatus capable of rotating the rotatable portion.
20. The device of claim 19, wherein the rotation apparatus is selected from the group consisting of a mechanical actuator, an electro-mechanical actuator, and a steering device.
21. The device of claim 19, wherein when the at least one directional sensor is positioned along the elongated body on the rotatable portion, the at least one directional sensor is capable of rotation by operation of the rotation apparatus.
22. The device of claim 19, wherein the rotatable portion is capable of a full 360° rotation about the elongated body.
23. The device of claim 1, wherein the at least one directional sensor is positioned at about 45 degrees to about 90 degrees of a circumference of the elongated body.
24. The device of claim 1, wherein the at least one treatment portion is selected from the group consisting of a

- cutting balloon, a cryoplasty device, a rotational atherectomy device, a laser angioplasty device, a vibrating catheter, a vibrating blade, and a vibrating drill.
25. The device of claim 1, further comprising:
a detector comprising a tetrapolar arrangement of electrodes positioned along the device within a balloon, wherein the electrodes are operable to measure at least one luminal parameter within the balloon at one or more stages of balloon inflation.
26. The device of claim 1, wherein the elongated body comprises a catheter having a suction/infusion port in communication with a lumen of the catheter, wherein the catheter is configured to facilitate one or more fluid injections into a lumen of a luminal organ when at least part of the elongated body is positioned therein.
27. The device of claim 26, further comprising:
at least one fluid delivery source operably coupled to the lumen of the catheter, whereby one or more fluids may be injected from the at least one fluid delivery source through the lumen of the catheter, through the suction/infusion port, and into the luminal of the luminal organ.
28. The device of claim 1, further comprising:
an inflatable balloon coupled to the elongated body, the inflatable balloon capable of inflation to place a stent positioned around the inflatable balloon within a lumen of a luminal organ.
29. A device for insertion within a luminal organ, comprising:
an elongated body having a distal body end, a fixed portion, and a rotatable portion at or near the distal body end, the elongated body configured to fit within a lumen of a luminal organ;
at least one directional sensor positioned on the rotatable portion of the elongated body, the at least one directional sensor configured for axial rotation relative to and distinct from the fixed portion of the elongated body and further capable of moving between a first position and an extended second position, the at least one directional sensor extending outward from the elongated body and toward the luminal organ or a structure therein when in the extended second position to facilitate physically touching the same, the at least one directional sensor operable to obtain a measurement from the luminal organ or the structure therein, wherein the measurement is indicative of less than an entire circumference of the luminal organ and indicative of electrical impedance of the luminal organ or the structure therein when the directional sensor is touching the luminal organ or the structure therein;
at least one detector positioned along the elongated body at or near the distal body end, the at least one detector capable of measuring a luminal size parameter when at least part of the elongated body is positioned within the lumen of the luminal organ;
an extension apparatus coupled to the at least one directional sensor, the extension apparatus capable of moving the at least one directional sensor radially relative a longitudinal axis of the elongated body between a first position and an extended second position; and
at least one treatment portion capable of removing at least part of a stenotic lesion from the luminal organ.
30. A device for removing a stenotic lesion from a vessel, comprising:
an elongated body having a fixed portion and a rotatable portion;
at least one sizing portion comprising a directional sensor capable of measuring a luminal size parameter when at

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least part of the device is positioned within a lumen of a luminal organ, at least part of the at least one sizing portion positioned on the rotatable portion of the elongated body, wherein the portion of the at least one sizing portion on the rotatable portion is configured for axial rotation relative to and distinct from the fixed portion of the elongated body and operable to obtain a measurement from the luminal organ or a structure therein, wherein the measurement is indicative of less than an entire circumference of the luminal organ;

at least one typing portion, wherein at least part of the at least one typing portion is capable moving to an extended position outward from the device and further capable of physically touching a portion of the luminal organ or a structure therein upon extension from the device;

an extension apparatus coupled to the at least one directional sensor, the extension apparatus capable of moving the at least one directional sensor radially relative a longitudinal axis of the elongated body between a first position and an extended second position; and

at least one treatment portion capable of removing at least part of a stenotic lesion from the luminal organ.

31. The device of claim 30, wherein the at least one sizing portion comprises a tetrapolar arrangement of two detection electrodes positioned in between two excitation electrodes.

32. The device of claim 31, further comprising:

a current source in communication with the two excitation electrodes, said current source operable to supply current to the two excitation electrodes to enable measurement of at least one conductance value, thereby enabling calculation of a luminal size parameter.

33. The device of claim 30, wherein the at least one treatment portion is selected from the group consisting of a cutting balloon, a cryoplasty device, a rotational atherectomy device, a laser angioplasty device, a vibrating catheter, a vibrating blade, and a vibrating drill.

34. The device of claim 30, wherein the at least one treatment portion comprises a balloon, and wherein the at least one sizing portion comprises at least one pressure sensor capable of detecting at least one pressure within the balloon at one or more stages of balloon inflation.

35. The device of claim 30, further comprising:

at least one suction/infusion port in communication with at least one device lumen, the suction/infusion port operable to facilitate one or more fluid injections into the lumen of the luminal organ; and at least one fluid delivery source operably coupled to the at least device lumen, whereby one or more fluids may be injected from the at least one fluid delivery source through the at least one device lumen, through the at least one suction/infusion port, and into the lumen of the luminal organ.

36. The device of claim 30, further comprising:

a data acquisition and processing system operably coupled to the device, the data acquisition and processing system operable to receive conductance data from the device to calculate at least one luminal parameter based upon said conductance data and to display the calculated at least one luminal parameter to facilitate operational control of the at least one treatment portion of the device.

37. A system for removing a stenotic lesion of a vessel, the system comprising:

a treatment device, the treatment device comprising at least one treatment portion capable of a removing at least part of a stenotic lesion from a luminal organ; and

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a sizing/typing device separate from the treatment device, the sizing/typing device comprising:

an elongated body having a distal body end, a fixed portion, and a rotatable portion at or near the distal body end;

electrodes positioned along the elongated body for measuring a first luminal size parameter when the typing/sizing device is positioned within a lumen of the luminal organ,

at least one directional sensor positioned on the rotatable portion of the elongated body and configured for axial rotation relative to and distinct from the fixed portion of the sizing/typing device and configured to physically touch a portion of the luminal organ or a structure therein and operable to obtain a first vessel characteristic indicative of the luminal organ or the structure therein, wherein the measurement is indicative of less than an entire circumference of the luminal organ, and

an extension apparatus coupled to the at least one directional sensor, the extension apparatus capable of moving the at least one directional sensor radially relative a longitudinal axis of the elongated body between a first position and an extended second position.

38. The system of claim 37, wherein the treatment device comprises a catheter, and wherein the sizing/typing device comprises a wire selected from the group consisting of a guide wire, a pressure wire, and a flow wire.

39. A method of removing at least part of a stenotic lesion within a luminal organ, the method comprising the steps of:

(a) positioning at least part of a device within a luminal organ at a first location, the device comprising an elongated body having a distal body end with at least one directional sensor positioned on a rotatable portion thereof at or near the distal body end, the at least one directional sensor configured for axial rotation relative to and distinct from a fixed portion of the elongated body and operable to obtain a measurement from the luminal organ or a structure therein, wherein the measurement is indicative of less than an entire circumference of the luminal organ, and wherein the device further comprises an extension apparatus coupled to the at least one directional sensor, the extension apparatus capable of moving the at least one directional sensor radially relative a longitudinal axis of the elongated body between a first position and an extended second position;

(b) operating the device to obtain a first luminal size parameter and a first measurement indicative of electrical impedance of the luminal organ or a structure therein that at least part of the device is physically touching at the first location;

(c) moving at least part of the device to a second location within the luminal organ;

(d) operating the device to obtain a second luminal size parameter and a second measurement indicative of electrical impedance of the luminal organ or the structure therein that at least part of the device is physically touching at the second location;

(e) determining whether or not a stenotic lesion is present at either the first location or the second location based on one or more of the first luminal size parameter, the first measurement, the second luminal size parameter, and the second measurement;

(f) if the stenotic lesion is present, moving at least part of the device having a treatment portion to a stenotic

lesion location, the treatment portion capable of removing at least part of the stenotic lesion from the luminal organ; and

(g) if the stenotic lesion is present, operating the treatment portion of the device to remove at least part of the stenotic lesion. 5

40. The method of claim 39, further comprising the steps of:

(h) measuring a then-current luminal size parameter at the stenotic lesion location; 10

(i) comparing the then-current luminal size parameter to either the first luminal size parameter or the second luminal size parameter that is indicative of the stenotic lesion location; and

(j) if the then-current luminal size parameter does not equal a preferred luminal size parameter, repeating steps (g), (h), and (i) until the then-current luminal size parameter equals or exceeds the preferred luminal size parameter. 15

41. The method of claim 40, wherein the step of measuring then then-current luminal size parameter at the stenotic lesion location further comprises measuring a then-current measurement indicative of electrical impedance of the luminal organ or structure therein, and wherein the step of comparing the then-current luminal size parameter to either the first luminal size parameter or the second luminal size parameter further comprises comparing either the first measurement or the second measurement to the then-current measurement. 20

42. The method of claim 41, wherein steps (g), (h), and (i) are repeated if the then-current luminal size parameter does not equal a preferred luminal size parameter or if the then-current measurement is indicative of electrical impedance of the stenotic lesion. 25

43. The method of claim 40, further comprising the step of:

ceasing the operation of the treatment portion of the device when the then-current luminal size parameter equals or exceeds the preferred luminal size parameter. 35

44. The method of claim 40, further comprising the steps of:

selecting an appropriately-sized stent; and
implanting the stent into the luminal organ. 40

45. The method of claim 39, wherein the preferred luminal size parameter is determined based upon the first luminal size parameter and the second luminal size parameter. 45

46. The method of claim 39, wherein steps (b) and (d) are performed in the presence of a saline injection.

47. The method of claim 39, wherein the step of moving at least part of the device to a second location comprises advancing or retracting at least part of the device within the luminal organ. 50

48. The method of claim 39, wherein the step of moving at least part of the device to a second location comprises rotating at least part of the device within the luminal organ. 55

49. The method of claim 39, wherein the first luminal size parameter, the second luminal size parameter, and then-current luminal size parameter(s) are obtained using a detector coupled to the device.

50. The method of claim 39, wherein the first measurement and the second measurement are obtained using the at least one directional sensor or another directional sensor coupled to the device. 60

51. A method for removing at least part of a stenotic lesion from a luminal organ, the method comprising the steps of:

positioning a device within a luminal organ, the device comprising an elongated body having a distal body end 65

and having at least one sizing portion, at least one typing portion, and at least one treatment portion, at least one of the at least one sizing portion and/or the at least one typing portion at or near the distal body end and comprising at least one directional sensor positioned on a rotatable portion of the elongated body and configured for axial rotation relative to and distinct from a fixed portion of the elongated body and operable to obtain a measurement from the luminal organ or a structure therein, wherein the measurement is indicative of less than an entire circumference of the luminal organ, and wherein the device further comprises an extension apparatus coupled to the at least one directional sensor, the extension apparatus capable of moving the at least one directional sensor radially relative a longitudinal axis of the elongated body between a first position and an extended second position;

operating the at least one sizing portion of the device to obtain luminal size parameter data;

operating the at least one sizing portion of the device to obtain type data indicative of electrical impedance of the luminal organ or a structure therein; and

operating the at least one treatment portion capable of removing at least part of a stenotic lesion from the luminal organ at a location within the luminal organ at or near the stenotic lesion, whereby operation of the at least one treatment portion is based upon the luminal size parameter data and the type data, whereby operation of the at least one treatment portion removes at least part of the stenotic lesion.

52. The method of claim 51, further comprising the step of:

ceasing operation of the at least one treatment portion when the luminal size parameter data indicates a preferred luminal size parameter.

53. The method of claim 51, further comprising the step of:

ceasing operation of the at least one treatment portion when the type data is no longer indicative of electrical impedance of a stenotic lesion.

54. The method of claim 51, wherein the steps of operating the at least one sizing portion and operating the at least one typing portion are performed in the presence of a saline injection.

55. A method of removing at least part of a stenotic lesion from a vessel, the method comprising the steps of:

(a) positioning a device within a luminal organ, the device comprising an elongated body having a distal body end and having at least one typing portion and at least one treatment portion, the at least one typing portion at or near the distal body end comprising at least one directional sensor positioned on a rotatable portion of the elongated body and configured for axial rotation relative to and distinct from a fixed portion of the elongated body and operable to obtain a measurement from the luminal organ or a structure therein, wherein the measurement is indicative of less than an entire circumference of the luminal organ, and wherein the device further comprises an extension apparatus coupled to the at least one directional sensor, the extension apparatus capable of moving the at least one directional sensor radially relative a longitudinal axis of the elongated body between a first position and an extended second position;

(b) operating the at least one typing portion of the device to obtain initial type data indicative of electrical impedance of the luminal organ or a structure therein;

- (c) operating the at least one treatment portion capable of removing at least part of a stenotic lesion from the luminal organ if the type data is indicative of electrical impedance of the stenotic lesion to remove at least part of the stenotic lesion; and 5
- (d) operating the at least one typing portion of the device again to obtain then-current type data indicative of electrical impedance of the luminal or the structure therein; and
- (e) repeating steps (c) and (d) until the then-current type 10 data does not indicate the presence of the stenotic lesion.

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专利名称(译)	用于从血管移除目标病变的装置，系统和方法		
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摘要(译)

用于从血管移除目标病变的装置，系统和方法。在用于从血管移除狭窄病变的装置的至少一个实施例中，所述装置包括尺寸部分，当所述装置的至少一部分位于管腔器官的腔内时，所述尺寸调整部分能够测量腔尺寸参数，打字部分其中至少一个打字部分的至少一部分能够物理地接触管腔器官的一部分或其中的结构，以及能够从管腔器官移除至少部分狭窄病变的治疗部分。

