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INTRODUCER HUB ASSEMBLY HAVING CROSS-SLIT SEAL

Abstract

An introducer hub assembly, such as an introducer hub assembly of a leadless cardiac pacemaker, including a hemostatic seal having a cross-slit configuration, is described. The hemostatic seal can be retained between a hub cap and an introducer hub. The hemostatic seal includes a first section having first slits intersecting along a longitudinal axis of the introducer hub, and a second section having second slits intersecting along the longitudinal axis. The first slits are angularly offset relative to the second slits to reduce a likelihood that fluid will leak directly through the seal. Other embodiments are also described and claimed.

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Background/Summary

[0001] This application is a continuation of U.S. patent application Ser. No. 17/877,747 filed on Jul. 29, 2022, which is a continuation of U.S. patent application Ser. No. 16/265,612 filed on Feb. 1, 2019, which claims the benefit of priority of U.S. Provisional Patent Application No. 62/628,154, filed on Feb. 8, 2018, and these applications are incorporated herein by reference in their entirety to provide continuity of disclosure.

BACKGROUND

Field

[0002] The present disclosure relates to vascular access devices. More specifically, the present disclosure relates to an introducer hub assembly including a hemostatic seal.

Background Information

[0003] Some minimally invasive surgeries of the heart and blood vessels are accomplished using catheters with specialized functions. Catheters can enter the body from a site such as the femoral or jugular vein and travel to the inside of the heart or coronary arteries to fulfill their particular purpose. Many of these catheters, due to their unique geometries, require the use of a vascular access device, such as an introducer, that provides an entryway into the cardiovascular system (or other interior cavity of the body). The introducer can include a seal to prevent blood from escaping from the body while providing the entryway.

[0004] There are a variety of existing seal types that can be incorporated into an introducer to hold blood in the body while allowing a catheter to pass through the seal into the body from an external environment. For example, some hemostasis valves can include seals that are opened by an actuation force, such as an external compressive force, to force open the seal. Larger devices can be inserted through the open seal, and then the actuation force can be removed or reversed to close the seal.

SUMMARY

[0005] Difficulty arises when medical devices of several different sizes must pass through existing introducer seals at different times. For example, an introducer may first need to seal around a guidewire, followed by a much larger secondary cardiovascular device. Existing hemostasis valves can require the operator to squeeze or otherwise force the seal open, in order to make room for larger devices to be inserted, and then stop squeezing to restore the seal to a closed state. To operate the seal in this manner, the operator is generally precluded from using their hand to perform other tasks.

[0006] In an embodiment, an introducer hub assembly includes a hemostatic seal that allows the passage of progressively larger medical devices, e.g., cardiovascular devices, without the need for an operator to actuate the seal with an external force, such as a squeeze. The seal can be retained between an introducer hub and a hub cap of the introducer hub assembly. Accordingly, the seal provides a passage from an external environment, e.g., a catheterization lab, into an internal environment, e.g., a vasculature of a patient.

[0007] In an embodiment, the seal includes a cross-slit configuration. For example, the seal can

include a first section having first slits that intersect along a longitudinal axis of the introducer hub, and a second section having second slits that intersect along the longitudinal axis. The second slits can be offset relative to the first slits. For example, the slit pairs, which may each be pairs of perpendicularly arranged cross slits, can be angularly offset such that the slits of one pair do not intersect or axially align with the slits of the other pair. In an embodiment, the angular offset of the first slits from the second slits is in a range of 40 to 50 degrees, e.g., 45 degrees. The offset cross slits can reduce a likelihood of leakage of a fluid from the internal environment by avoiding a direct pathway through the seal.

[0008] In an embodiment, the seal includes a tapered inner surface extending distally from a proximal opening at a proximal face of the seal toward a distal face of the seal. The tapered inner surface can taper toward the longitudinal axis, e.g., at an angle of 30 degrees from the longitudinal axis. The tapered inner surface can generally distribute force incurred by advancing larger objects through the seal, and direct such force in a radial direction.

[0009] The above summary does not include an exhaustive list of all aspects of the present invention. It is contemplated that the invention includes all systems and methods that can be practiced from all suitable combinations of the various aspects summarized above, as well as those disclosed in the Detailed Description below and particularly pointed out in the claims filed with the application. Such combinations have particular advantages not specifically recited in the above summary.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The novel features of the disclosure are set forth with particularity in the claims that follow. A better understanding of the features and advantages of the present disclosure will be obtained by reference to the following detailed description that sets forth illustrative implementations in which the principles of the present disclosure are utilized, and the accompanying drawings of which:

[0011] FIG. 1 is an isometric view of a leadless pacemaker system including an introducer hub assembly in accordance with the present disclosure.

[0012] FIG. 2 is a longitudinal cross-sectional view of an introducer hub assembly including a seal in accordance with the present disclosure.

[0013] FIG. 3 is an isometric view of a seal in accordance with the present disclosure.

[0014] FIG. 4 is a proximal plan view of a seal in accordance with the present disclosure.

[0015] FIG. 5 is a distal plan view of a seal in accordance with the present disclosure.

[0016] FIG. 6 is a cross-sectional side view of a seal in accordance with the present disclosure.

[0017] FIG. 7A is a longitudinal side elevation view of an introducer hub assembly in accordance with the present disclosure.

[0018] FIG. 7B is a longitudinal cross-sectional side view of the introducer hub assembly of FIG. 7A having a seal in accordance with the present disclosure.

[0019] FIGS. 8A and 8B are distal and proximal perspective views, respectively, of a seal in accordance with the present disclosure.

[0020] FIGS. 9A and 9B are a longitudinal side elevation view and a longitudinal cross-sectional side view, respectively, of a seal in accordance with the present disclosure.

[0021] FIG. 10 is a longitudinal side elevation view of a seal in accordance with the present disclosure.

[0022] FIG. 11 is a longitudinal side elevation view of a seal in accordance with the present disclosure.

[0023] FIGS. 12A and 12B are a longitudinal side elevation view and a distal plan view, respectively, of a seal in accordance with the present disclosure.

[0024] FIG. 13A is a photograph of a seal in accordance with the present disclosure.

[0025] FIG. 13B is a photograph of the seal of FIG. 13A with a secondary introducer extending therethrough in accordance with the present disclosure.

[0026] FIGS. 14A and 14B are a side elevation view and a cross-sectional side view, respectively, of a seal in accordance with the present disclosure.

[0027] FIG. 15 is a flow chart illustrating a method of manufacturing a seal in accordance with the present disclosure.

DETAILED DESCRIPTION

[0028] Embodiments describe a seal having several sections, each section including slits that extend through the respective section and intersect along a longitudinal axis. The slits of each section can be cross slits offset relative to one another. The seal can be retained between an introducer hub and a hub cap of an introducer hub assembly. The seal, however, may be used in other applications, such as in a hemostatic valve assembly, an injection port, etc. Thus, reference to the seal as being used in an introducer hub assembly is not limiting.

[0029] In various embodiments, description is made with reference to the figures. However, certain embodiments may be practiced without one or more of these specific details, or in combination with other known methods and configurations. In the following description, numerous specific details are set forth, such as specific configurations, dimensions, and processes, in order to provide a thorough understanding of the embodiments. In other instances, well-known processes and manufacturing techniques have not been described in particular detail in order to not unnecessarily obscure the description. Reference throughout this specification to “one embodiment,” “an embodiment,” or the like, means that a particular feature, structure, configuration, or characteristic described is included in at least one embodiment. Thus, the appearance of the phrase “one embodiment,” “an embodiment,” or the like, in various places throughout this specification are not necessarily referring to the same embodiment. Furthermore, the particular features, structures, configurations, or characteristics may be combined in any suitable manner in one or more embodiments.

[0030] The use of relative terms throughout the description may denote a relative position or direction. For example, “distal” may indicate a first direction along a longitudinal axis of an introducer hub assembly. Similarly, “proximal” may indicate a second direction opposite to the first direction. Such terms are provided to establish relative frames of reference, however, and are not intended to limit the use or orientation of a seal or an introducer hub assembly to a specific configuration described in the various embodiments below.

[0031] In an aspect, an introducer hub assembly is provided. The introducer hub assembly includes a passive seal. The passive seal seals and provides hemostasis without a separate sealing device and accommodates a wide range of devices that may be introduced through the introducer assembly. The seal is generally made of a compliant material, such as silicone rubber, and has the ability to expand around objects that are advanced and retracted through the seal. The compliant material further allows the seal to recover to its original state when objects are removed from the seal. In certain implementations the seal has a proximal taper and slits to aid in centering and introducing objects through the seal while providing a hemostatic seal about the object. In addition, in certain implementations, the seal material may include various additives to further aid in the recovery of the seal to its original state following removal of objects therefrom. Such additives may also promote self-healing of the seal to improve the life of the seal and/or provide lubrication of the seal to reduce the forces necessary to introduce objects through the seal. In certain implementations, the introducer hub assembly may be constructed of an over-molded hub and hub cap made of an injection-moldable plastic material with the seal constrained and providing a hermetic closure between the hub and the hub cap. Accordingly, the introducer hub assembly does not require human intervention in order to seal around a wide range of different-sized devices.

[0032] Referring to FIG. 1, an isometric view of a leadless pacemaker system including an

introducer hub assembly is shown in accordance with the present disclosure. A leadless pacemaker system **10** may be used for delivery and/or retrieval of a leadless pacemaker **12** into or from a patient, and can include an introducer hub assembly **100** in accordance with the present disclosure. The use of a system **10** for delivery and/or retrieval of a leadless pacemaker is merely intended as an example application of introducer hub assemblies in accordance with the present disclosure and primarily to provide context. It should be appreciated that introducer hub assemblies in accordance with this disclosure may be used to introduce or remove any suitable tools, medical devices, and the like into a patient and are not limited to leadless pacemaker applications.

[0033] The introducer hub assembly **100** may include an introducer sheath **102** and the system **10** may further include various catheters, such as, but not limited to, a deflectable catheter **13** and a guide catheter **14** adapted to be inserted through the introducer hub assembly **100** and, in particular, an introducer sheath **102** of the introducer hub assembly **100**. As can be understood from FIG. **1**, the guide catheter **14** may be slidably mounted on the deflectable catheter **13**. For example, the deflectable catheter **13** may extend through the guide catheter **14**. Similarly, the introducer hub assembly **100** may be slidably mounted on the guide catheter **14**. For example, the guide catheter **14** may extend through the introducer sheath **102**. A distal end of the deflectable catheter **12** may be selectively connectable to the leadless pacemaker **12** or other device, and a proximal end of the deflectable catheter **13** may include a handle **22** or similar tool by which a user may manipulate the deflectable catheter **13** or other elements of the system **10**.

[0034] The guide catheter **14**, which can extend through the introducer sheath **102** of the introducer hub assembly **100**, includes each of a distal end **15** and a proximal end **17**. The distal end **15** of the guide catheter **14** may include a protective pacemaker sheath. The proximal end **17** of the guide catheter may include a flush port **26** extending from a proximal hub **28**. The guide catheter **14** extends from both the distal and proximal ends of the introducer sheath **102**. A shaft **30** of the guide catheter **14** may also include one or more sections (not shown) having different durometers such that the reinforcement and corresponding bending resistance of the sections may be modified according to the specific application for which the system **10** is being implemented. The introducer hub assembly **100** further includes a distal end **104** and a proximal end **106**. As illustrated, the proximal end **106** of the introducer hub assembly **100** may include a flush port **108**. More particularly, a side port can extend from an exterior of an introducer hub to an interior cavity of the introducer hub, and the flush port **108** can connect to the side port to inject fluid into the interior cavity.

[0035] Referring to FIG. **2**, a longitudinal cross-sectional view of an introducer hub assembly including a seal is shown in accordance with the present disclosure. The introducer hub assembly **200** includes an introducer hub **202**, a hub cap **204** coupled to a proximal end of the introducer hub **202**, and a seal **206** retained between the hub cap **204** and the introducer hub **202**. The hub cap **204** can be coupled to the introducer hub **202** in numerous manners. For example, the hub cap **204** can be welded onto introducer hub **202**, using a thermal, adhesive, or ultrasonic weld. Similarly, the hub cap **204** can be press fit onto introducer hub **202**, or coupled to the introducer hub **202** by a snap fit feature or an external retaining ring, to name only a few possibilities.

[0036] For reference, the introducer hub **202** further defines a longitudinal axis **208**. The introducer hub assembly **200** may further include an introducer sheath **210** extending from a distal end of the introducer hub **202**. In certain implementations, one or both of the hub introducer hub **202** and the hub cap **204** are formed from a moldable plastic and are overmolded onto the seal **206** and/or the introducer sheath **210**.

[0037] In certain implementations, the seal **206** is a hemostatic seal to prevent blood from passing through the seal when the introducer sheath **210** is inserted into a vasculature. The seal **206** can be formed from silicone rubber and generally allows for objects to be inserted through the seal **206** while maintaining a hemostatic seal. The seal **206** may have a specialized geometry that allows it to seal around objects of various dimensions. For example, in certain implementations, the seal **206**

may be adapted to seal around cylindrical objects having a diameter from and including 0.035 inches to and including 0.3 inches. Notably, the seal **206** seals against such objects without requiring excessive force to advance such objects through the seal or requiring an operator to “open” the seal to make room for larger objects.

[0038] The seal **206** may include a proximal flange shaped to be received between the introducer hub **202** and the hub cap **204** when the introducer hub assembly **200** is assembled. As described below, a proximal face and/or a distal face of the seal flange **220** can be adapted to engage with, seal against, or otherwise interact with corresponding mating features of the introducer hub **202** and the hub cap **204**, respectively. For example, the seal flange **220** can press against a protrusion **227** of the hub cap **204** to form a seal along the proximal face.

[0039] The seal may include a proximal opening **216**. The proximal opening **216** may be disposed along the longitudinal axis **208**, and can align with a corresponding opening in the hub cap **204**. For example, the hub cap **204** opening can be coaxial with the opening **216** to allow a guidewire, catheter, or another device component to be inserted through the hub cap **204** and the seal **206** into an inner lumen of the introducer hub **202** and/or introducer sheath **210**.

[0040] FIGS. **3-6** are various views of a seal shown in accordance with the present disclosure. The figures illustrate like features of the seal, and thus, are described together below. In certain implementations, the seal **206** is made of one or more compliant materials, e.g., a compliant silicone material. Such material(s) may have a durometer from and including 20 Shore A to and including 40 Shore A, thereby allowing the seal **206** to stretch and seal around objects of various sizes while providing sufficient durability to withstand multiple insertions/removals and manipulation of such objects, and to enable the seal **206** to return to its original shape and state when objects are removed from the seal **206**. In certain implementations, the material of the seal **206** may also be selected to be at least one of self-healing and self-lubricating. The self-healing and self-lubricating properties of seal **206** can derive from the inclusion of various additives in the seal material to further aid in the recovery of the seal to its original state following removal of objects therefrom. Such additives may also promote self-healing of the seal to improve the life of the seal and/or provide lubrication of the seal to reduce the forces necessary to introduce objects through the seal.

[0041] The seal **206** generally includes a first, proximal section **212** and a second, distal section **214** adjacent to the proximal section **212**. The distal section **214** can extend from a distal face of the proximal section **212**. In certain implementations, one or more of the sections is substantially cylindrical. For example, the distal section **214** may be a substantially cylindrical section extending from a substantially cylindrical proximal section **212**.

[0042] The seal can include slits extending through at least one of the sections. For example, the proximal section **212** can include a set of first slits, e.g., a pair of first slits **213A**, **213B**. The slits can extend through the proximal section and intersect along the longitudinal axis **208**. Referring to FIG. **4**, slit **213A** and slit **213B** can be straight lines when viewed in an end view, and the straight lines can cross at longitudinal axis **208**. Accordingly, slits **213A**, **213B** can be cross slits. Similarly, the distal section **214** can include a second set of slits, e.g., a pair of second slits **215A**, **215B**, extending through the distal section **214** and intersecting along the longitudinal axis **208**. For example, referring to FIG. **5**, slit **215A** and slit **215B** can be straight lines when viewed in an end view, and the straight lines can cross at longitudinal axis **208**. Thus, slits **215A**, **215B** are cross slits.

[0043] The second slits **215A**, **215B** can be in an angularly offset orientation relative to the first slits **213A**, **213B**. This is evident from the “×” orientation of the slits **213A**, **213B** in FIG. **4** relative to the “+” orientation of the slits **215A**, **215B** in FIG. **5**. More particularly, the “×” and the “+” are angularly offset because a clocking of the symbols differs with respect to a vertical line passing through the intersection point at the middle of the symbols. In certain implementations, such angular offset may be in a range of 40 to 50 degrees. For example, as shown in FIGS. **4-5**, the first slits can be offset from the second slits by an angle of 45 degrees. In other words, the cross slits can

be angularly offset with respect to each other.

[0044] Also shown in FIGS. 4-5, in certain implementations, each of the first slits **213A**, **213B** may extend perpendicular with respect to each other and each of the second slits **215A**, **215B** may similarly extend perpendicular with respect to each other. Perpendicularity refers to, for example, the angle between slit **213A** and slit **213B**, which is 90 degrees in FIG. 4. The angle between slits may vary, however. For example, the individual slits of one or more of the slit pairs may be separated by an acute and/or obtuse angle. Nonetheless, in certain implementations, no slit of the first slit pair is coplanar with a slit of the second slit pair within a plane defined by the slit of the first slit pair and the longitudinal axis **208**.

[0045] Referring to FIG. 6, in certain implementations, the slits **213A**, **213B** and **215A**, **215B** are not cut completely through the seal **206** and prevent a direct pathway for blood flow through the seal **206** when the seal **206** is each of a closed state (unused) as well as an open state (in which an object is inserted through the seal **206**). Slits **213A**, **213B** may extend from proximal face **222** to an intersection point at longitudinal axis **208** that is proximal to distal face **224** of seal **206**. Similarly, slits **215A**, **215B** may extend from distal face **224** to an intersection point at longitudinal axis that is distal to proximal face **222**. Accordingly, in an embodiment, neither slit pair extends entirely through a thickness of seal **206**. The slit pairs may overlap, however. For example, a depth of the first slit pair **213A**, **213B** may be greater than half of the seal thickness and a depth of the second slit pair **215A**, **215B** may be greater than half of the seal thickness. The first slit pair therefore overlaps a depth of the second slit pair. Although overlapping in the axial direction, the slits may not be axially aligned with each other (they may be angularly offset), and thus, the cross slit pairs may be oriented to limit the pathways along which fluids can propagate through the seal thickness.

[0046] During operation, the slits **213A**, **213B** and **215A**, **215B** in combination with the structure of the proximal and distal sections **212**, **214** make use of the elastic force provided by the material of the seal **206** and the hydrostatic pressure within the introducer hub **202** to recover the seal **206** after objects are retracted and removed from within the seal **206**. More particularly, a substantially cylindrical section of the seal **206** can use hydrostatic pressure and the elastic force provided by the material itself to recover the seal after objects are retracted and removed from the seal.

[0047] The seal **206** may include a tapered inner surface **218** extending distally from the proximal opening **216** at the proximal face **222**. The tapered inner surface **218** can taper from the proximal opening **216** toward the longitudinal axis **208**. In certain implementations, a portion of the tapered inner surface **218** may extend through at least a portion of the proximal section **212**. The first slits **213A**, **213B** can extend through at least a portion of the tapered inner surface **218**. Referring to FIG. 6, the inner surface **218** may be tapered relative to the longitudinal axis **208**. An angle θ between the inner surface **218** and the longitudinal axis **208** can define the taper of the inner surface **218**. In certain implementations, the angle θ may be in a range of 25 to 35 degrees, e.g., 30 degrees. The tapered inner surface **218** provides a recess, indentation, or lead-in in the seal flange **220**. In general, the tapered inner surface **218** helps to center objects during insertion through the seal **206**, thereby reducing a likelihood of premature damage to the seal **206**, while also reducing a likelihood of fluid leakage from the seal **206** during insertion and removal of objects through the seal **206**.

[0048] The proximal seal flange **220** can include a proximal face **222** and a distal face **230**. The proximal face **222** and the distal face **230** may include respective mating features adapted to engage with, seal against, or otherwise interact with corresponding mating features of the introducer hub **202** and the hub cap **204**, respectively. For example, in one implementation, the proximal face **222** may include a channel or a groove **226** shaped to receive a corresponding protrusion **227** (FIG. 2) of the hub cap **204**. For example, the protrusion **227** can be an annular protrusion extending distally from an inner face of hub cap **204**, and the annular protrusion may engage a corresponding annular groove **226**. Alternatively, the protrusion **227** may press against a flat face of the seal flange **220** to form a seal between the hub cap **204** and the hemostatic seal **206**. The distal face **230** may include a

tapered flange **228** shaped to align the seal **206** along the longitudinal axis and to seal against the introducer hub **202**. For example, the tapered flange **228** can be an annular protrusion that extends from the distal face **230** and tapers distally. A distal edge of the tapered flange **228** at an outer diameter of seal flange **220** is distal to a proximal edge of the tapered flange **228** at a location nearer to the distal section **214**. When the introducer hub assembly **200** is assembled, the distal face **230** may, in certain implementations, be substantially in contact with an inner surface of the introducer hub **202**, and the tapered flange **228** can press against the introducer hub **202**, such that sealing between the seal **206** and the introducer hub **202** is further improved.

[0049] Referring to FIG. 7A, a longitudinal side elevation view of an introducer hub assembly is shown in accordance with the present disclosure. The introducer hub assembly **300** includes an introducer hub **302**, a hub cap **304** coupled to a proximal end of the introducer hub **302**, and a seal retained between the hub cap **304** and the introducer hub **302**. For example, the seal may include a proximal flange that is retained between the introducer hub **302** and the hub cap **304**. For reference, the introducer hub **302** further defines a longitudinal axis **308**. The introducer hub assembly **300** may further include an introducer sheath **310** extending from a distal end of the introducer hub **302**.

[0050] Referring to FIG. 7B, a longitudinal cross-sectional side view of the introducer hub assembly of FIG. 7A having a seal is shown in accordance with the present disclosure. In certain implementations, one or both of the hub introducer hub **302** and the hub cap **304** are formed from a moldable plastic and are overmolded onto the seal **306** and/or the introducer sheath **310**. The introducer hub **302** may include a port **303** or similar opening for providing and/or extracting fluids from an interior cavity of the introducer hub **302**. For example, the port **303** can be a side port that extends from an exterior of the introducer hub **302** to the interior cavity of the introducer hub **302**, which contains at least a portion of the seal **306**. The port **303** can be in fluid communication with flush port **108** via a connecting tube.

[0051] In certain implementations, the seal **306** is formed from silicone rubber and generally allows for objects to be inserted through the seal **306** while maintaining a hemostatic seal. The seal **306** may have a specialized geometry that allows it to seal around objects of various dimensions. For example, in certain implementations, the seal **306** may be adapted to seal around cylindrical objects having a diameter from and including 0.035 inches to and including 0.3 inches. Notably, the seal **306** seals against such objects without requiring excessive force to advance such objects through the seal or requiring an operator to “open” the seal to make room for larger objects.

[0052] In certain implementations, the seal **306** is made of a compliant silicone material. Such a material may have a durometer from and including 20 Shore A to and including 40 Shore A, thereby allowing the seal **306** to stretch and seal around objects of various sizes while providing sufficient durability to withstand multiple insertions/removals and manipulation of such objects, and to enable the seal **306** to return to its original shape and state when objects are removed from the seal **306**. In certain implementations, the material of the seal **306** may also be selected to be at least one of self-healing and self-lubricating.

[0053] FIGS. 8A-9B are various views of a seal shown in accordance with the present disclosure. The figures illustrate like features of the seal, and thus, are described together below.

[0054] Referring to FIG. 8A, the seal **306** generally includes a first, proximal section **312** and a second, distal section **314** adjacent to the proximal section **312**. In certain implementations, the proximal section **312** includes a proximal flange **320** and a tapered body **321**. The tapered body **321** can be adjacent to, and extend distally from, the proximal flange **320**. The proximal flange can be retained between the hub cap and the introducer hub of an introducer hub assembly, as described above. The tapered body can be substantially conical. In an embodiment, the distal section **314** is a substantially cylindrical body adjacent to the tapered body **321**. The distal section **314** can extend distally from the tapered body **321**. A set of slits **313A**, **313B** can extend through at least the distal section **314**. In an embodiment, the slits extend into the tapered body **321**, and thus, extend through at least a portion of the proximal section **312**. The slits of seal **306** can be similar to the slits of seal

206. In certain implementations, the slits **313A**, **313B** are cross slits oriented such that they are arranged substantially perpendicular with respect to each other. The slits **313A**, **313B** may not be cut completely through the seal **306** and may prevent a direct pathway for blood flow through the seal **306** when the seal **306** is each of a closed/open state. In certain implementations, the slits **313A**, **313B** are formed using a razor or similar blade.

[0055] In an embodiment, the seal **306** can include one or more pockets **325** in the distal face **323** of the seal **306**. The distal face **323** can define the pockets. More particularly, the pockets can be voids extending proximally from the distal face **323**, and thus, provide openings in the distal face **323**. The pockets can be sized such that the distal section **314** containing the pockets is flexible.

[0056] Referring to FIG. **8B**, and FIG. **9A-9B**, the seal **306** may include a proximal opening **316** and a tapered inner surface **318** extending distally from the proximal opening **316**. The opening **316** can taper toward the longitudinal axis **308**. The tapered inner surface **318** generally distributes force incurred by advancing larger objects through the seal **306**, and directs such forces in a radial direction. In certain implementations, a portion of the tapered inner surface **318** may extend through the proximal section **312**. Slits **313A**, **313B** can extend through a portion of the tapered inner surface **318**. In general, the tapered inner surface **318** helps to center objects during insertion through the seal **306**, thereby reducing a likelihood of premature damage to the seal **306**, while also reducing a likelihood of fluid leakage from the seal **306** during insertion and removal of objects through the seal **306**.

[0057] In certain implementations, the seal **306** is made of a silicone rubber having a durometer from and including 10 Shore OO to and including 20 Shore A. In some embodiments, different areas of the seal **306** may be formed from different materials, each having a different hardness. For example, in one implementation, the proximal section **312**, including the tapered body **321**, may be formed from a material having a durometer of 20 Shore A while the distal section **314** may be formed of a material having a durometer of 30 Shore OO. In such implementations, the hard durometer of the proximal section **312** prevents excessive elongation during advancement, while the soft durometer of the distal section **314** allows it to fill gaps and easily stretch in order to maintain a seal against an object inserted through the seal **306**.

[0058] Referring to FIG. **10**, a longitudinal side elevation view of a seal is shown in accordance with the present disclosure. A seal **406** can be used in place of the seals described above (**206**, **306**) within the introducer hub assemblies described above (**200**, **300**). For the avoidance of doubt, any of the seals described herein may be used in any of the introducer hub assemblies and/or leadless pacemaker systems described herein. To improve sealing against objects inserted through them, seals in accordance with the present disclosure may include a biasing element adapted to maintain pressure and bias the distal section of the seals inward. More particularly, the biasing element can bias the slits of the seal **406** into a closed state. The biasing element can be a band, a ring, a coil, or another component that exerts a compressive force on a distal section **414**, as described below. The seal **406** includes a proximal section **412** having a tapered body **421** and the distal section **414** through which slits (not shown) extend. The seal **406** can include a biasing element **450** having an elastomeric band or an elastic ring disposed about the distal section **414**. The biasing element **450** can bias segments of the distal section **414** together. For example, the biasing element can be an annulus having an inner diameter in a relaxed state that is less than an outer diameter of the distal section **414** in a relaxed state. Thus, a press fit is formed between the annulus and the distal section, and the annulus presses radially inward on an outer surface of the distal section. During experimental testing, it was found that minimal leaking about a wire having 0.035 inches diameter was achieved through such an arrangement when a fluid stopped by the seal **406** had a pressure range of 0 pounds per square inch to 30 pounds per square inch. The tapered section **421** can be made from a material having a durometer of 20 Shore A, and the distal section **414** can be made from a material having a durometer of 30 Shore OO. The elastomeric band **450** can be formed from a material having a durometer of 20 Shore A.

[0059] Referring to FIG. 11, a longitudinal side elevation view of a seal is shown in accordance with the present disclosure. A seal **506** can be used in place of the seals described above (**206, 306, 406**) within the introducer hub assemblies described above (**200, 300**). The seal **506** can include a proximal section **512** having a tapered body **521** and a distal section **514** through which slits (not shown) extend. The seal **506** further includes a biasing element **550**, e.g., a spring element, disposed about the distal section **514** to bias segments of the distal section **514** together. Spring element **550** can be a spring coil over the cylindrical segment. The spring coil can extend over distal section **514** to the tapered body **521**. Accordingly, the spring coil can extend around the slit seal. Like the annular biasing element **450** described above, the coil **550** can wrap around the outer surface of the distal section **450** and press radially inward to close the slits of the seal.

[0060] Referring to FIG. 12A, a longitudinal side elevation view of a seal is shown in accordance with the present disclosure. A seal **606** can be used in place of the seals described above (**206, 306, 406, 506**) within the introducer hub assemblies described above (**200, 300**). The seal **606** includes a proximal section **612** having a tapered body **621** and a distal section **614** through which slits **613A, 613B** extend. In an embodiment, the seal **606** further includes magnets disposed within the distal section **614**. For example, in the side view, magnets **617A** and **617B** (indicated by hidden lines) are arranged such that the magnet axes extend parallel to longitudinal axis **308** on opposite sides of a plane containing slit **613A**. The magnets are separated in the transverse direction, however, may be located close enough to each other to attract each other in the transverse direction. The attracted magnets can apply a load against the distal section **614** that the magnets are disposed within, and thus, can bias segments of the distal section **614** together.

[0061] Referring to FIG. 12B, a distal plan view of a seal is shown in accordance with the present disclosure. Two or more magnets can be arranged about the longitudinal axis **308**. For example, four magnets may be embedded or disposed within the distal section **614** in respective quadrants. The quadrants can be defined by the cross slits **613A, 613B** that intersect along the longitudinal axis **308**. The magnets may be equally spaced, e.g., each magnet may be placed at a corner of a square reference geometry, and thus, the magnets may attract each other with approximately equal forces. The magnets can exert an overall inward force on the distal section **614** to bias the seal slits toward a closed state. In implementations of seals including magnets, the biasing force of the magnets may be varied by changing, among other things: one or more of the durometers of the material of distal section **614**; the number; the size; the shape, and/or the spacing of the magnets. Although illustrated in FIGS. 12A-12B as being cylindrical, spherical, cylindrical, rectangular, or any other suitable shape of magnet may be used. In certain implementations, the magnets may be molded into the seal. In other implementations, the magnets may be inserted after molding of the seal or otherwise coupled to the seal.

[0062] Referring to FIG. 13A, a photograph of a seal is shown in accordance with the present disclosure. A seal **706** can be used in place of the seals described above (**206, 306, 406, 506, 606**) within the introducer hub assemblies described above (**200, 300**). The photograph of the seal **706** is in an unused state. In the unused state, the cross-slits of the seal **706** can be in the closed state. More particularly, the distal section and/or the proximal section of the seal may be closed to the ingress of fluids from an external environment. As described above, a biasing element can exert a radially inward force on one or more of the seal sections to bias the slits toward the closed state in order to resist hemostatic pressure of the external environment. For example, the biasing element can apply an inward force to the distal section of the seal **706**.

[0063] Referring to FIG. 13B, a photograph of the seal of FIG. 13A with a secondary introducer extending therethrough is shown in accordance with the present disclosure. The photograph is of the seal **706** with a 0.300" secondary introducer device **707** inserted through the seal **706**. When the secondary introducer device **707** is inserted into the seal **706**, the slits expand into an open state. In the open state, the introducer device **707** can pass from a proximal end of the introducer hub assembly containing the seal **706** to the distal end of the introducer hub assembly. The expanded

seal, however, can press inward against an outer surface of the introducer device **707**. The inward pressure can form a seal between the slits and the outer surfaces. The seal resists leakage of fluids, e.g., blood, through the surface interface.

[0064] Referring to FIGS. **14A**, a side elevation view of a seal is shown in accordance with the present disclosure. A seal **806** can be used in place of the seals described above (**206**, **306**, **406**, **506**, **606**, **706**) within the introducer hub assemblies described above (**200**, **300**). The seal **806** generally includes a first, proximal section **812** and a second, distal section **814** adjacent to the proximal section **812**. In certain implementations, the proximal section **812** further includes a proximal flange **820** and a tapered body **821** and the distal section **814** is a substantially cylindrical body adjacent to the tapered body **821**.

[0065] Referring to FIGS. **14B**, a cross-sectional side view of a seal is shown in accordance with the present disclosure. The seal **806** may include a proximal opening **816** and a tapered inner surface **818** extending distally from the proximal opening **816** and tapering toward a longitudinal axis **808**. The tapered inner surface **818** generally distributes force incurred by advancing larger objects through the seal **806**, and directs such forces in a radial direction. In contrast to the slits of the previously discussed implementations, the seal **806** includes a bore **813** extending from a distal end of the tapered inner surface **818** and through the distal section **814** to a distal face **823** of the distal section **814**. The seal **806** further includes an elastomeric ring **850** disposed about the distal section **814** to impart an inward force on distal section **814** and the bore **813**. The force can bias the seal **806** into a closed state.

[0066] The distal section **814** and the proximal section **812** are composed of two different materials and, in particular, materials having different durometers. In general, the distal section **814** may be formed from a softer and/or more compliant material than the proximal section **812**. The increased compliance of the distal section **814** relative to the proximal section **812** can improve sealing of the distal section **814** about an object inserted through the bore **813**. Conversely, the proximal section **812** of the seal **806** may be formed of a harder material in order to impart additional resiliency and durability to withstand the initial insertion of such objects. For example, in certain implementations, the distal section **814** may be formed of a first silicone material having a durometer of 30 Shore A while the proximal section **812** may be formed from a second silicone material having a durometer greater than 30 Shore A, e.g., 40 Shore A or above. As in the previously discussed implementations, the materials of the seal **806** may also be selected to be at least one of self-healing and self-lubricating.

[0067] The bore **813** may generally be formed during manufacturing by first molding the distal section **814** as a solid piece and then puncturing the molded distal section **814**. In certain implementations, puncturing the distal section **814** may be performed by inserting a series of puncturing tools through the distal section **814**. In general, such tools are inserted in order of increasing diameter or width until a predetermined maximum diameter is reached. The predetermined diameter may, in certain implementations, correspond to a diameter of an object to be inserted through the seal. In certain implementations, the predetermined maximum diameter may be less than the maximum diameter of the object to improve the seal of the distal section **812** against the object when it is inserted.

[0068] Referring to FIG. **15**, a flow chart illustrating a method of manufacturing a seal is shown in accordance with the present disclosure. A flow chart **900** illustrates a manufacturing process that may be used to produce a seal, such as the seal **806** of FIGS. **14A-14B**. In general, the process includes molding the proximal and distal sections of the seal **812**, **814** to form a seal body that is then punctured. The ring **850** may be separately molded and then bonded to the seal body, thereby forming the completed seal **806**.

[0069] At operation **902**, the distal section **814** of the seal **800** is molded. For example, in certain implementations, a first material may be poured into a mold, partially filling the mold to a level corresponding to the length of the distal section. The first material may then be allowed to cure

within the mold, forming the distal section **814**. Although various materials may be used, in certain implementations, the first material may be a two-part liquid silicone rubber having a durometer of 30 Shore 00.

[0070] At operation **904**, the proximal section **812** of the seal **800** is molded. For example, in certain implementations, a second material may be poured into the mold on top of the molded distal section **814**. A cap or mold half may then be coupled to the mold in order to form the proximal face of the proximal section **812**. The cap or mold half may include a conical or similar shape in order to form the tapered inner surface **818** of the proximal section **812**. The proximal section **812** may then be left to cure as required. Accordingly, the proximal section **812** can be molded onto the distal section **814**. Again, while other materials may be used, the second material may, in certain implementations, be a two-part liquid silicone rubber having a durometer of 30 Shore A.

[0071] At operation **906**, the completed seal body is demolded. As illustrated in the photograph accompanying operation **906**, the seal body is generally a unitary or monolithic part with the proximal section **812** integrally formed with the distal section **814**.

[0072] At operation **908**, the seal body is punctured to form the bore **813** of the seal **806**. As previously noted, the process of puncturing the seal body may include the use of multiple puncturing tools. For example, as illustrated in the photographs accompanying operation **908**, the seal body may first be punctured with a first puncturing tool, e.g., a sharp needle or a rod, then subsequently punctured using a second puncturing tool, e.g., a blunt conical tool. In other implementations, needles, or rods having progressively larger diameters or widths may be used to puncture the seal body until the required bore size is achieved. For example, the first puncturing tool having a first diameter can be used to puncture the distal section of the seal, and then a second puncturing tool having a second diameter greater than the first diameter can be used to puncture the distal section.

[0073] It will be appreciated that in certain embodiments, the operations may be modified. For example, to form the seal **206** having cross-slits, a razor blade may be used. The razor blade can form two or more slits in a cross pattern, e.g., perpendicular to one another, to create the slit seal section(s).

[0074] In a separate process, the ring **850** may be molded. At operation **910**, for example, a ring material may be injected into a mold, cured, and subsequently demolded at operation **912**. In certain implementations, the ring material may be a two-part silicone rubber having a durometer of 20 Shore A. Following demolding, the ring **850** may be attached to the seal body at operation **914**. In certain implementations, the ring **850** may be bonded to the seal body using an adhesive suitable for the particular materials used to form the ring **850** and the distal section **814**. For example, silicone rubber based materials may be bonded using a silicone adhesive, such as Sil-Poxy®. Bonding of the ring **850** to the distal section **814** may further include a curing period to allow the adhesive to cure.

[0075] Any of the molding operations **902**, **904**, **910** may include a degassing operation in which the liquid material is placed in a vacuum or low pressure environment prior to or during curing. By doing so, air or similar gases may be removed from the molded parts, reducing variation and improving consistency of the final seal **806**. Also, any of the curing operations discussed above may include, among other things, placement of the part being cured into an oven or similar heated environment to speed up the curing process.

[0076] As for additional details pertinent to the present disclosure, materials and manufacturing techniques may be employed as within the level of those with skill in the relevant art. The same may hold true with respect to method-based aspects of the invention in terms of additional acts commonly or logically employed. Also, it is contemplated that any optional feature of the inventive variations described may be set forth and claimed independently, or in combination with any one or more of the features described herein. Likewise, reference to a singular item, includes the possibility that there are plural of the same items present. More specifically, as used herein and in

the appended claims, the singular forms “a,” “and,” “said,” and “the” include plural referents unless the context clearly dictates otherwise. It is further noted that the claims may be drafted to exclude any optional element. As such, this statement is intended to serve as antecedent basis for use of such exclusive terminology as “solely,” “only” and the like in connection with the recitation of claim elements, or use of a “negative” limitation. Unless defined otherwise herein, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. The breadth of the present invention is not to be limited by the subject specification, but rather only by the plain meaning of the claim terms employed.

[0077] In the foregoing specification, the invention has been described with reference to specific exemplary embodiments thereof. It will be evident that various modifications may be made thereto without departing from the broader spirit and scope of the invention as set forth in the following claims. The specification and drawings are, accordingly, to be regarded in an illustrative sense rather than a restrictive sense.

Claims

1. An introducer hub assembly, comprising: an introducer hub having a longitudinal axis defining an axial direction; a hub cap coupled to a proximal end of the introducer hub; and a hemostatic seal between the hub cap and the introducer hub, wherein the hemostatic seal includes a proximal face separated from a distal face along the longitudinal axis, wherein the hemostatic seal includes first slits intersecting along the longitudinal axis and extending distally from the proximal face to a first depth, wherein the hemostatic seal includes second slits intersecting along the longitudinal axis and extending proximally from the distal face to a second depth, and wherein the first depth of the first slits at least partly overlaps the second depth of the second slits in the axial direction.
2. The introducer hub assembly of claim 1, wherein the second slits are angularly offset relative to the first slits.
3. The introducer hub assembly of claim 1, wherein the hemostatic seal includes a seal flange having the proximal face, and a distal section extending distally from the seal flange to the distal face.
4. The introducer hub assembly of claim 3, wherein the seal flange is shaped to be retained between the hub cap and the introducer hub.
5. The introducer hub assembly of claim 3, wherein the seal flange includes a proximal mating feature shaped to engage the hub cap.
6. The introducer hub assembly of claim 5, wherein the proximal mating feature includes a groove formed in the proximal face.
7. The introducer hub assembly of claim 1, wherein the first slits are perpendicular with respect to each other, and wherein the second slits are perpendicular with respect to each other.
8. The introducer hub assembly of claim 1, wherein the first slits are angularly offset from the second slits by an angle in a range of forty to fifty degrees.
9. The introducer hub assembly of claim 1, wherein the hemostatic seal further comprises a tapered inner surface extending distally from a proximal opening at the proximal face.
10. The introducer hub assembly of claim 9, wherein the tapered inner surface tapers toward the longitudinal axis from the proximal opening, and wherein the first slits extend through the tapered inner surface.
11. A hemostatic seal, comprising: a proximal face separated from a distal face along a longitudinal axis defining an axial direction; first slits intersecting along the longitudinal axis and extending distally from the proximal face to a first depth; and second slits intersecting along the longitudinal axis and extending proximally from the distal face to a second depth, and wherein the first depth of the first slits at least partly overlaps the second depth of the second slits in the axial direction.

- 12.** The hemostatic seal of claim 11, wherein the first slits are perpendicular with respect to each other, and wherein the second slits are perpendicular with respect to each other.
- 13.** The hemostatic seal of claim 11, wherein the first slits are angularly offset from the second slits by an angle in a range of forty to fifty degrees.
- 14.** The hemostatic seal of claim 11 further comprising a tapered inner surface extending distally from a proximal opening at the proximal face.
- 15.** The hemostatic seal of claim 11 further comprising a groove formed in the proximal face of the seal flange.
- 16.** A leadless pacemaker system, comprising: a deflectable catheter; a guide catheter mounted on the deflectable catheter; and an introducer hub assembly mounted on the guide catheter, wherein the introducer hub assembly includes a hemostatic seal including a proximal face separated from a distal face along a longitudinal axis defining an axial direction, wherein the hemostatic seal includes first slits intersecting along the longitudinal axis and extending distally from the proximal face to a first depth, wherein the hemostatic seal includes second slits intersecting along the longitudinal axis and extending proximally from the distal face to a second depth, and wherein the first depth of the first slits at least partly overlaps the second depth of the second slits in the axial direction.
- 17.** The leadless pacemaker system of claim 16, wherein the first slits are perpendicular with respect to each other, and wherein the second slits are perpendicular with respect to each other.
- 18.** The leadless pacemaker system of claim 16, wherein the first slits are angularly offset from the second slits by an angle in a range of forty to fifty degrees.
- 19.** The leadless pacemaker system of claim 16, wherein the hemostatic seal further comprises a tapered inner surface extending distally from a proximal opening at the proximal face of the hemostatic seal.
- 20.** The leadless pacemaker system of claim 16 further comprising a groove formed in the proximal face.
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