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Removal device and removal system

Abstract

A removal device and a removal system are configured to effectively remove an object in a body lumen while suppressing damage to another device. The removal device includes an elongated shaft part, and a cutting part fixed to a distal portion of the shaft part. The proximal portion of the cutting part includes a ring-shaped cutting blade, and a surface of the cutting part on which the cutting blade is positioned is inclined relative to center axis of the shaft part at an angle greater than 0 degrees and less than 90 degrees.

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Background/Summary

CROSS-REFERENCES TO RELATED APPLICATIONS (1) This application is a continuation of U.S. patent application Ser. No. 17/016,847 filed on Sep. 10, 2020, which is a continuation of International Application No. PCT/JP2019/007440 filed on Feb. 27, 2019, which claims priority to Japanese patent Application No. 2018-045179 filed on Mar. 13, 2018, the entire content of all three of which is incorporated herein by reference.

FIELD OF THE INVENTION
(1) This invention generally relates to a removal device and a removal system that remove an object in a body lumen.
BACKGROUND DISCUSSION
(2) When a thrombus is formed in a blood vessel, it is difficult for blood to flow to a periphery side of the thrombus. This prevents oxygen and nutrition from sufficiently reaching the periphery, and there is a danger of necrosis of cell tissue that has become depleted of oxygen. Therefore, for example, U.S. Pat. No. 8,366,735 describes a device that aspirates and removes thrombi by a sheath connected to an aspirating pump. This device is provided with a separator that can protrude from a tip opening of the sheath. The separator is provided to a distal portion of a wire that penetrates through the sheath, and has an outer diameter larger than that of the wire. An operator causes the separator to protrude from the tip opening of the sheath and moves the separator in the front-back direction to allow the thrombi to be led into the sheath.
SUMMARY
(3) However, in a case where a thrombus is hard and large, the device described in U.S. Pat. No. 8,366,735 cannot lead the thrombus into the sheath.
(4) Disclosed here is a removal device and a removal system that can effectively remove an object

in a body lumen while suppressing damage to another device.
(5) According to one aspect, a removal device that is positionable in a living body comprises an elongated shaft part, a cutting part, and an expandable part. The elongated shaft part possesses a proximal portion and a distal portion at opposite axial ends of the elongated shaft part, with the elongated shaft part possessing a center axis and being axially movable in a distal direction and a proximal direction. The cutting part is fixed to the distal portion of the shaft part so that the cutting part and the elongated shaft part move together when the elongated shaft part is axially moved in the distal direction and the proximal direction, wherein the cutting part includes a distal portion and a proximal portion. The cutting part includes a cutting blade surface to be brought into contact with objects in the living body during axial movement of the cutting part in the proximal direction to cut the objects, wherein the cutting blade surface faces towards the proximal portion of the elongated shaft part and is inclined relative to the center axis of the elongated shaft part at an angle of more than 0 degrees and less than 90 degrees. The expandable part is fixed to the shaft part or the cutting part, and the expandable part includes a plurality of gaps that pass through the expandable part. The expandable part includes a release opening that passes through the expandable part and that is larger than the plurality of gaps to allow one of the objects that has entered an interior of the expandable part by way of the gaps is able to flow out of the interior of the expandable net by way of the release opening.
(6) Another aspect involves a removal device that is positionable in a living body comprises: an elongated shaft part possessing a proximal portion and a distal portion at opposite axial ends of the elongated shaft part, and an expandable net fixed to the elongated shaft part. The expandable net includes a plurality of gaps that pass through the expandable net. The expandable net also includes a release opening that passes through the expandable net, with the release opening being larger than the gaps so that an object that has entered an interior of the expandable net by way of the gaps is able to be released out of the interior of the expandable net by way of the release opening.
(7) According to another aspect, a removal system for removing objects from a living body during an object removal operation comprises an elongated sheath, an elongated shaft part, a cutting part, and an expandable net. The elongated sheath includes a lumen possessing a distal end that is open and a proximal end that is open, with the lumen in the elongated sheath being connectable to an aspirating device that produces an aspiration force in the lumen to draw the objects into the lumen in the elongated sheath and toward the proximal end of the elongated sheath. The elongated shaft part possesses a proximal portion and a distal portion at opposite axial ends of the elongated shaft part, and the elongated shaft part possesses a center axis. The cutting part is fixed to the distal portion of the elongated shaft part so that the cutting part and the elongated shaft part move together when the elongated shaft part is axially moved, with the elongated shaft part and the cutting part being positionable in the lumen of the elongated shaft part and being axially movable relative to the elongated shaft part. The cutting part includes a distal portion and a proximal portion, with the proximal portion of the cutting part including an inclined cutting surface to cut the objects, and wherein the inclined cutting surface is inclined relative to the center axis of the elongated shaft part at an angle of more than 0 degrees and less than 90 degrees. The expandable net is fixed to the cutting part or the elongated shaft part so that axial movement of the elongated shaft part results in axial movement of the expandable net. The expandable net includes a plurality of gaps that pass through the expandable net, and also includes a release opening that passes through the expandable net and is larger than the gaps so that one of the objects that has entered an interior of the expandable net by way of the gaps during the object removal operation is able to flow out of the interior of the expandable net by way of the release opening.
(8) The removal device and the removal system configured as above insert the cutting part into the body lumen and then pull the shaft part to allow the cutting blade to cut an object in the body lumen. The cutting blade having a ring shape receives a part of an object having a three-dimensional shape in an inside of the ring, and is thus easy to be caught by the object. Therefore,

the removal device and the removal system can effectively cut and remove the object by the cutting blade that is difficult to slip with respect to the object. The surface on which the cutting blade is positioned is inclined relative to the center axis of the shaft part at an angle of less than 90 degrees, so that the cutting blade is difficult to damage another device, for example, the sheath, when moving to the proximal side.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a plan view illustrating a removal system according to a first embodiment.

(2) FIGS. **2**A-**2**C depict views illustrating a distal portion of a removal device in the first embodiment: FIG. **2**A is a plan view; FIG. **2**B is a cross-sectional view; and FIG. **2**C is a cross-sectional view along the section line **2**A-**2**A in FIG. **2**A.

(3) FIGS. **3**A and **3**B depict cross-sectional views illustrating states in a blood vessel: FIG. **3**A illustrates a state where the removal system is inserted into the blood vessel; and FIG. **3**B illustrates a state where the removal device is caused to protrude from a sheath.

(4) FIGS. **4**A and **4**B depict cross-sectional views illustrating states in the blood vessel: FIG. **4**A illustrates a state where thrombi are caused to fall off from a body lumen by the removal device; and FIG. **4**B illustrates a state where the fallen-off thrombus are being led into the sheath.

(5) FIGS. **5**A-**5**E cross-sectional views illustrating modification examples of the removal device: FIG. **5**A illustrates a first modification example; FIG. **5**B illustrates a second modification example; FIG. **5**C illustrates a third modification example; FIG. **5**D illustrates a fourth modification example; and FIG. **5**E illustrates a fifth modification example.

(6) FIG. **6** is a plan view illustrating a removal device in a second embodiment.

(7) FIG. **7** is a cross-sectional view illustrating the removal device in the second embodiment.

(8) FIGS. **8**A and **8**B depict cross-sectional views illustrating states in a blood vessel: FIG. **8**A illustrates a state where the removal device is inserted into the blood vessel; and FIG. **8**B illustrates a state where an inflating part is indwelt in the blood vessel.

(9) FIG. **9** is a cross-sectional view illustrating a state where the thrombi cut by the removal device are being led into the sheath.

(10) FIGS. **10**A and **10**B depict cross-sectional views illustrating a sixth modification example of a removal device; FIG. **10**A illustrates a state where an inflating part of the removal device is disposed in a blood vessel; and FIG. **10**B illustrates a state where the inflating part is caused to deflate and is recovered into a sheath.

(11) FIGS. **11**A and **11**B depict plan views illustrating modification examples of the removal device: FIG. **11**A illustrates a seventh modification example; and FIG. **11**B illustrates an eighth modification example.

DETAILED DESCRIPTION

(12) Set forth below with reference to the accompanying drawings is a detailed description of embodiments of a removal device, a removal system and a manner of operation representing examples of the inventive removal device, removal system and operational method disclosed here. The dimensions or scales on the drawings may be exaggerated or different from actuality/reality for convenience of description and illustration.

First Embodiment

(13) A removal system **10** according to a first embodiment representing one example of the inventive removal device and removal system may be used to aspirate and remove an object such as a thrombus, plaque, or a calcified lesion in a blood vessel. In the description that follows, a side or end of the device to be inserted into a blood vessel is referred to as a “distal side” or “distal end”, and a hand-side (opposite side or end) where the device is operated is referred to as a “proximal

side" or "proximal end". Moreover, an object to be removed is not necessarily limited to a thrombus, plaque, or a calcified lesion, as the removal device and removal system disclosed here has useful application to remove all objects that can exist in a body lumen. In addition, in the description that follows, a source side of a flow in the blood vessel is referred to as an "upstream side", and a side toward which the flow of blood is headed is referred to as a "downstream side".

(14) The removal system **10** includes the combination of a removal device **20** that cuts an object in the blood vessel, and a sheath **30** configured to store therein the removal device **20**, as illustrated in FIGS. **1** and **2**. The removal device **20** includes an axially movable elongated shaft part **21**, and a main cutting body part **22** that is fixed to a distal portion of the shaft part **21** so that the main cutting body part **22** and the elongated shaft part **21** move together when the elongated shaft part **21** is axially moved.

(15) The shaft part **21** is an elongated wire that extends from a hand side (proximal end) to the main cutting body part **22**. The distal portion of the shaft part **21** is fixed to the main cutting body part **22**.

(16) A constituent material from which the shaft part **21** may be fabricated is not specially limited but preferably has a tensile strength to some extent. Examples of the material from which the shaft part **21** may be fabricated include stainless steel, a shape memory alloy, and the like. As for a shape memory alloy, Ni—Ti-based, Cu—Al—Ni-based, Cu—Zn—Al-based shape memory alloys, combinations thereof, and the like are preferably used. The shaft part **21** is not limited to a solid wire, but may be a hollow tubular body, for example.

(17) The main cutting body part **22** is an approximately cylindrical member having an outer diameter larger than that of the shaft part **21**. In the main cutting body part **22**, a concave portion or recessed (hollow) portion **23** that is closed at the distal side and is opened toward the proximal side is formed. The main cutting body **22** thus has a closed distal end and an open proximal end. An end portion on the proximal side of the main cutting body part **22** is sloped so that the main cutting body includes a slope (sloped proximal end surface) **24** that is inclined at an angle θ of less than 90 degrees (interior angle) relative to a center axis or central axis X of the shaft part **21**. In other words, a proximal portion of the main cutting body part **22** has a shape in which a cylinder having an inner diameter and an outer diameter that are constant in an axial direction is obliquely cut. The inclined angle θ exceeds 0 degrees and is less than 90 degrees, and is preferably between 20 degrees and 80 degrees, more preferably between 30 degrees and 60 degrees. The main cutting body part **22** and the shaft part **21** are arranged such that a part that is positioned at the most proximal side of the slope **24** is adjacent to the shaft part **21**. That is, as shown in FIGS. **2**A and **2**B, the sloped proximal end surface of the main cutting body part **22** slopes upwardly and in the distal direction away from the shaft part **21**. The concave portion **23** opens to the slope or sloping surface **24**. A ring-shaped or annular-shaped region that surrounds the concave portion **23** of the slope **24** forms a cutting part **25**. The cutting part **25** includes an outer edge **26** that is positioned at an outer peripheral surface side of the main cutting body part **22**, and an inner edge **27** that is positioned at an inner peripheral surface side of the main cutting body part **22**. The outer edge **26** and/or the inner edge **27** functions as a sharp cutting blade. Accordingly, the slope **24** is a surface on which the cutting blade is positioned. An end portion on the distal side or distal end of the main cutting body part **22** includes a distal surface or distal end surface **28**. An outer peripheral portion **28**A that is positioned radially outward of the distal surface **28** is subjected to curved surface processing so that the distal end portion possesses curved or rounded corners as shown in FIGS. **2**A and **2**B, and is smoothly connected to an outer peripheral surface of the main cutting body part **22**. The shape of the ring-shaped or annular-shaped sloped surface **24** may be an ellipse or a circle. A part of the surface (surface between the outer edge (outer periphery) and the inner edge (inner periphery)) of the ring may be partially thinned.

(18) The outer peripheral surface of the main cutting body part **22** is fixed to the shaft part **21** by a fixing part **29**. The fixing part **29** is formed, for example, by welding, soldering, brazing, an

adhesive, or the like. The shaft part **21** is fixed to the main cutting body part **22** at a position that is spaced in the radial direction from a center axis or central axis Y of the main cutting body part **22** and the cutting part **25** (i.e., the center axis X of the elongated shaft part **21** and the center axis Y of the main cutting body part **22**/cutting part **25** are not coaxial). The shaft part **21** does not need to be fixed to the outer peripheral surface of the main cutting body part **22**. For example, the shaft part **21** may be fixed to an inner peripheral surface of the main cutting body part **22**. Alternatively, the shaft part **21** may be fitted into a fitting hole that is formed in the sloped surface **24** of the main body cutting part **22** toward the distal side. In this case, the shaft part **21** is positioned between the inner peripheral surface and the outer peripheral surface of the main cutting body part **22**. When the fixing part **29** abuts on a distal surface of the sheath **30**, the cutting part **25** is positioned outward in a radial direction of the sheath **30** (e.g., the central axis Y of the cutting part **25** is positioned radially outwardly of the central axis of the sheath **30**). At this time, the contact of the fixing part **29** with the distal surface of the sheath **30** can be further reduced (e.g., by virtue of the curved configuration of the fixing part **29**). Accordingly, the cutting part **25** can be smoothly led into a lumen (a lumen **34**, which is described later) of the sheath **30**.

(19) A constituent material from which the main cutting body part **22** may be fabricated is preferably hard to the extent that makes it difficult to damage biological tissue (e.g., a blood vessel wall) and the sheath **30**, while also allowing an object such as thrombus to be cut. Examples of materials from which the main cutting body part **22** may be fabricated include engineering plastics such as polyether ether ketone (PEEK), polyamide (PA), polycarbonate (PC), polysulfone (PSU), and polyamideimide (PAI).

(20) The sheath **30** includes a sheath main body **31**, a hub **32**, and an anti-kink protector **33**, as illustrated in FIG. **1**. The sheath main body **31** is provided with the lumen **34** configured to accommodate the removal device **20**. The sheath main body **31** includes a sheath opening portion (sheath opening) **36** in an end portion on the distal side. The hub **32** is fixed to the proximal end portion of the sheath main body **31**. The hub **32** is provided with a hub opening portion (hub opening) **35** that communicates with the lumen **34**. The hub opening portion **35** can be connected with an aspirating device that generates an aspiration force via a Y connector or the like. The aspirating device may be, for example, a syringe, a pump, or the like. The hub opening portion **35** is connected with the Y connector to allow the aspirating device, in a state of an elongated device (for example, the shaft part **21**) being inserted or positioned in the hub **32** and the sheath main body **31**, to be connected thereto. Moreover, the hub opening portion **35** can also be connected with a syringe, the Y connector, or the like with which a thrombolytic agent and the like are supplied. The anti-kink protector **33** is a flexible member that covers an interlock part of the sheath main body **31** and the hub **32**. The anti-kink protector **33** suppresses a kink of the sheath main body **31**.

(21) A constituent material from which the sheath main body **31** may be fabricated is not specifically limited. Examples of the constituent material from which the sheath main body **31** may be fabricated include polyolefin such as polyethylene, polypropylene, ethylene-propylene copolymer, or ethylene-vinyl acetate copolymer, polyvinyl chloride, polystyrene, polyamide, polyimide, or a combination thereof. The sheath main body **31** may be fabricated from a plurality of materials, or a reinforcing member such as a wire rod may be embedded therein.

(22) Next, a method of using a removal device **10** according to the present embodiment will be described, considering as an example a situation in which a thrombus (object) in a blood vessel (body lumen) is aspirated and removed.

(23) Firstly, an operator percutaneously inserts an introducer sheath into a blood vessel (lumen in a living body), at the upstream side (proximal side) from a thrombus in the blood vessel. Next, the operator inserts a guide wire into the blood vessel through this introducer sheath. Subsequently, the operator inserts a proximal side end portion of the guide wire (the proximal end portion of the guide wire located outside the living body) into the sheath opening portion or open distal end **36** of the sheath **30**. Subsequently, the operator advances the sheath along the guide wire to cause the

sheath **30** to reach the vicinity of the thrombus.
(24) Subsequently, the operator extracts the guide wire from the sheath **30**. The operator then connects the Y connector to the hub opening portion **35**, and inserts the removal device **20** into the lumen **34** of the sheath **30** by way of the hub opening portion **35**. Subsequently, the operator operates the shaft part **21** that is positioned outside of the body to move the main cutting body part **22** to the distal side (in the distal direction), as illustrated in FIG. **3**A.
(25) Subsequently, the operator operates the shaft part **21** that is positioned outside the body to axially move the shaft part **21** in the forward or distal direction so that the main cutting body part **22** protrudes distally beyond the distal open end of the sheath **30**. To cause the removal device **20** to reach a distal side of a thrombus **200** in the lumen of the living body, a separately prepared support catheter can also be used.
(26) Subsequently, the operator operates the shaft part **21** to alternately move the main cutting body part **22** to the distal side (in the distal direction) and to the proximal side (in the proximal direction) along the blood vessel. More specifically, the operator operates the shaft part **21** to move the main cutting body part **22** from a position proximal of the thrombus **200** to a position distal of the thrombus, and from a position distal of the thrombus **200** to a position proximal of the thrombus. When the main cutting body part **22** moves to the distal side or in the distal direction, as illustrated in FIG. **3**B, the smooth outer peripheral portion **28**A of the main cutting body part **22** comes into contact with the thrombus **200**. Therefore, the main cutting body part **22** can excellently move through a clearance of the thrombus **200** to the distal side of the thrombus **200**. When the main cutting body part **22**, positioned on the distal side of the thrombus **200**, moves to the proximal side or in the proximal direction, as illustrated in FIG. **4**A, the cutting part **25** comes into contact with the thrombus **200**. The cutting part **25** having a ring shape with the three-dimensional shape in the inside thereof receives a part of the thrombus **200**, and is thus configured in a way facilitating catching the thrombus **200**. A ring-shaped cutting part is better able to catch the thrombus compared to a solid cutting part **25** because the ring-shaped cutting part **25** has a space to catch the thrombus inside. Therefore, the outer edge **26** and/or the inner edge **27** that each function as a cutting blade or cutting edge of the cutting part **25** is not likely to slip with respect to the thrombus **200**, and can effectively cut the thrombus **200**. In particular, the inner edge **27** that constitutes the cutting blade in the cutting part **25** that is provided at a position distant from the shaft part **21** (a position at an opposite side in the peripheral direction) is effectively caught on the thrombus **200**, and can effectively cut the thrombus **200**. Cut thrombi (cut object(s)) **201** float in the blood vessel. Subsequently, the aspirating device that is connected to the hub opening portion **35** via the Y connector causes a negative pressure to act on the lumen **34** of the sheath main body **31**, thus drawing the cut thrombus toward the proximal end of the sheath **30**. Accordingly, the sheath **30** aspirates the floating thrombi **201** from the sheath opening portion **36**. The aspirated thrombi **201** are discharged to outside the living body through the lumen **34** and the hub opening portion **35**.
(27) When the thrombus **201** floating in the blood vessel is larger than the sheath opening portion **36**, the thrombus **201** is not able to enter the lumen **34** but is caught by the sheath opening portion **36**. Accordingly, the sheath opening portion **36** is blocked by the large thrombus **200**. For solving this blockage, the operator can repeatedly operate the shaft part **21** to move the cutting part **25** toward the sheath opening portion **36** and away from the sheath opening portion **36**. When the cutting part **25** moves in the proximal direction and is led into the sheath opening portion **36**, the large thrombus **201** that blocks the sheath opening portion **36** is sandwiched between the sheath opening portion **36** and the cutting part **25**. The inside of the ring-shaped cutting part **25** receives a part of the thrombus **201** having a three-dimensional shape and is thus easy to be caught by the thrombus **201**. Therefore, as illustrated in FIG. **4**B, the outer edge **26** and/or the inner edge **27** that each function as the cutting blade of the cutting part **25** can effectively sandwich the thrombus **201** that blocks the sheath opening portion **36** between the outer edge **26** and/or the inner edge **27** and the sheath opening portion **36**, and can cut the thrombus **201**. The sandwiched thrombus **201**

receives a shear force from the sheath opening portion **36** and the cutting part **25**, and is effectively cut. A site at which the shear force of the cutting part **25** is caused to act can be both of or either one of the outer edge **26** and the inner edge **27** that function as the cutting blade. The thrombi **201** having been cut and led into the lumen **34** are aspirated by the aspirating device, and are discharged to outside the body.

(28) Meanwhile, the cutting part **25** is inclined relative to the center axis X of the shaft part **21**. Therefore, the cutting part **25** does not come into strong contact with the sheath opening portion **36** but can smoothly enter the sheath opening portion **36**. Therefore, the cutting part **25** is not so likely to damage the sheath opening portion **36**.

(29) When the cutting part **25** moves to the distal side and is exposed from the sheath opening portion **36**, the circulation in the lumen **34**, having been partially blocked by the thrombi **201** and the main cutting body part **22**, is increased. This recovers the aspiration force at the sheath opening portion **36** at the distal end of the sheath **30**. Accordingly, the sheath **30** can excellently aspirate the floating thrombus **200** from the sheath opening portion **36**. The aspirated thrombi **201** are discharged to outside the living body through the lumen **34** and the hub opening portion **35**. Subsequently, when thrombus **201** larger than the sheath opening portion **36** is aspirated, the thrombus **201** does not enter the lumen **34** but is caught by the sheath opening portion **36**. When the cutting part **25** is again led into the sheath opening portion **36**, the large thrombus **201** that blocks the sheath opening portion **36** is cut by being sandwiched between the sheath opening portion **36** and the cutting part **25**, and is removed.

(30) Subsequently, the operator alternately moves the main cutting body part **22** to the distal side and to the proximal side along the blood vessel. That is, the operator moves the main cutting body part **22** in the distal direction from a position proximal of the thrombus **200** to a position distal of the thrombus, and moves the main cutting body part **22** in the proximal direction from a position distal of the thrombus **200** to a position proximal of the thrombus. This enables the operator to cut, aspirate, and remove the thrombus **201** that is caught at the sheath opening portion **36** while causing the thrombus **201** adhered on the blood vessel to fall off or separate from the blood vessel by the cutting part **25**.

(31) After the aspiration and the removal of the thrombi **201** has been completed, the operator stops the aspiration by the aspirating device. Thereafter, the operator extracts the removal device **20** through the sheath **30** to outside the body, and extracts the sheath **30**. Accordingly, the procedure of removing the thrombi **200** and **201** is completed.

(32) The removal device **20** in the first embodiment includes: the elongated shaft part **21**; and the cutting part **25** that is fixed to the distal portion of the shaft part **21**, and the proximal portion of the cutting part **25** includes a ring-ring-shaped cutting blade, and a surface on which the cutting blade is positioned is inclined relative to the center axis X of the shaft part **21** at an angle of less than 90 degrees.

(33) The removal device **20** configured as the above is inserted into a body lumen and then pulled to allow the cutting blade to cut an object such as the thrombus **200**. The inside of the cutting blade having a ring shape receives a part of an object having a three-dimensional shape and is thus easy to be caught by the object. Therefore, the removal device **20** can effectively cut and remove the object by the cutting blade, and the cutting blade is difficult to slip with respect to the object. Moreover, the surface on which the cutting blade is positioned is inclined relative to the center axis X of the shaft part **21** at an angle of less than 90 degrees. The cutting blade is thus not likely to damage the sheath **30** when moving to the proximal side. Accordingly, the removal device **20** can suppress damage to another device such as the sheath **30**. The cutting blade can be either one or both of the outer edge **26** and the inner edge **27**. Accordingly, for example, each of the outer edge and the inner edge of the cutting blade does not need to have a ring shape, but a combination of the outer edge and the inner edge may configure the ring shape. Moreover, the surface on which the cutting blade is positioned is inclined relative to the center axis X of the shaft part **21** at an angle of

less than 90 degrees, so that in a case where the cutting blade abuts on the distal surface of the sheath **30**, the cutting part **25** is positioned radially outward of the sheath **30**. At this time, the contact with the distal surface of the sheath **30** can be further reduced by the surface on which the cutting blade is positioned. Accordingly, the cutting part **25** can be smoothly led into the lumen (the lumen **34**, which is described later) of the sheath **30**.

(34) Moreover, in the cutting part **25**, the concave portion **23** is formed from the proximal end toward the distal side. Therefore, the cutting part **25** having a ring shape, receives a part of the object having a three-dimensional shape in the concave portion **23**, and is easy to be caught by the object.

(35) Moreover, the shaft part **21** is fixed to the cutting part **25** at a position spaced in the radial direction from the center axis Y of the cutting part **25**. Accordingly, a maximum distance from the center axis X of the shaft part **21** to the cutting part **25** becomes larger than that in a case where the shaft part **21** is positioned at the center axis Y of the main cutting body part **22**. Accordingly, the cutting part **25** having a high cut effect can be effectively disposed in the main cutting body part **22** the size of which is limited in order to be inserted into the body lumen. The position spaced from the center axis Y of the cutting part **25** may be, for example, on the outer peripheral surface of the cutting part **25**, but may be on the inner peripheral surface of the cutting part **25** or between the outer peripheral surface and the inner peripheral surface.

(36) Moreover, the shaft part **21** is fixed to the proximal end of the cutting blade (the outer edge **26** and the inner edge **27**). Accordingly, when the cutting part **25** that penetrates through the sheath **30** and protrudes to the distal side from the sheath **30** moves to the proximal side or in the proximal direction by being pulled by the shaft part **21**, the cutting part **25** can smoothly enter the sheath opening portion **36** because the cutting blade is inclined. Accordingly, the cutting part **25** is not caught by the distal end of the sheath **30**, thereby improving the operability of the removal device **20**.

(37) Moreover, the removal system **10** according to the first embodiment includes: the sheath **30** in which a lumen to cause or convey an aspiration force to act is formed; and the removal device **20** capable of being inserted into the sheath **30**, and in the removal system **10**, the removal device **20** includes the elongated shaft part **21**, and the cutting part **25** that is fixed to the distal portion of the shaft part **21**; the proximal portion of the cutting part **25** includes the ring-shaped cutting blade; and a surface on which the cutting blade is positioned is inclined relative to the center axis of the shaft part **21** at an angle of less than 90 degrees.

(38) The removal system **10** configured as above, by positioning the cutting part **25** so that the cutting part **25** is distal of the distal end of the sheath **30** so that the cutting part **25** protrudes distally from the sheath **30** and then pulling the shaft part **21** to the proximal side, can effectively cut an object such as the thrombus **201** that is sandwiched between the sheath opening portion **36** and the cutting blade. The inside of the cutting blade having a ring shape receives a part of an object having a three-dimensional shape, and is thus readily able to catch the object. Therefore, the removal system **10** can effectively cut the object by the cutting blade that is difficult to slip with respect to the object. Accordingly, the removal system **10** can continuously aspirate and remove the object without clogging the sheath **30** with the object. Moreover, the sloped or inclined surface **24** on which the cutting blade is positioned is inclined relative to the center axis X of the shaft part **21** at an angle of less than 90 degrees, so that the cutting blade is difficult to damage the sheath **30** when moving to the proximal side. Accordingly, the removal system **10** can suppress damage to another device such as the sheath **30**. The cutting blade can be either one or both of the outer edge **26** and the inner edge **27**.

(39) The form of a main cutting body part is not limited to the abovementioned example. For example, FIG. **5**A illustrates a removal device **40** serving as a first modification example. In this example of the removal device, the main cutting body part **41** may be surrounded by the cutting part **25**, and a through-hole **42** that penetrates from the distal end to the proximal end may be

formed. In other words, the concave portion that is formed in the embodiment of the cutting part **25** described above is formed so that it penetrates completely through the cutting part. This allows the object cut by the cutting part **25** to come out from both sides of the through-hole **42**, so that the object is not so likely to remain in the through-hole **42**. Therefore, the removal device **40** can maintain the cut effect long. Moreover, even in a case where the through-hole **42** is clogged with the object, when the main cutting body part **41** enters an inside of the sheath **30**, the aspiration force acts on the through-hole **42**. Therefore, the object having clogged up the through-hole **42** is moved to the proximal side, and removed. Therefore, the removal device **40** can maintain the cut effect long. In the description above and below, features that are the same or similar to those described previously are identified by the same reference numerals and a detailed description of such features is not repeated.

(40) In a removal device **50** serving as a second modification example illustrated in FIG. **5**B, a main cutting body part **51** may include a tubular body having an approximately central portion in the axial direction that possesses an outer diameter that is relatively large. In the illustrated embodiment, the approximately axially central portion of the tubular main cutting body part **51** possesses an outer diameter larger than a remainder of the tubular main cutting body part **51**. The shaft part **21** may be fixed to an inner peripheral surface of the main cutting body part **51**, instead of the outer peripheral surface of the main cutting body part **51**. An outer diameter of a distal portion of the main cutting body part **51** decreases toward the distal side (i.e., in the distal direction toward the left in FIG. **5**B, and substantially coincides with an inner diameter of the main cutting body part **51** at the distal end. In other words, the thickness of the distal portion of the main cutting body part **51** becomes thinner toward the distal end. Therefore, the main cutting body part **51** can smoothly proceed to the distal side while widening a clearance of a stenosed site of the body lumen.

(41) Moreover, in a removal device **60** serving as a third modification example illustrated in FIG. **5**(C), two or more main cutting body parts **41** each having a structure similar to that in the abovementioned first modification example shown in FIG. **5**A may be provided. The plurality of the main cutting body parts **41** are arranged so as to surround the shaft part **21**. The removal device **60** can improve the ability to cut the thrombi **200** and **201** because the removal device **60** is provided with the plurality of the main cutting body parts **41**.

(42) Moreover, in a removal device **70** serving as a fourth modification example illustrated in FIG. **5**(D), a main cutting body part **71** may include a sharp cutting blade **72** that protrudes to the proximal side. Accordingly, the cutting blade **72** can be formed sharper than a case where the cutting blade **72** is formed by obliquely cutting the cylinder. In the fourth modification example, the cutting blade **72** is formed on the outer edge **26** that is positioned at an outer peripheral surface side of the main cutting body part **71**. Accordingly, an inner diameter of the cutting part **25** spreads or expands in a tapered shape toward the proximal side (i.e., to the right in FIG. **5**(D)). This expands a cross-sectional area of the through-hole that is surrounded by the cutting part **25**, so that an object serving as a cut target can easily enter the through-hole. Accordingly, the cutting part **25** can excellently cut the object. Moreover, a slope **73** on which the ring-shaped cutting blade **72** is positioned does not need to be a plane, but may be a curved surface, for example. An inclined angle θ of the slope **73** relative to the center axis X of the shaft part **21** may become larger (i.e., may increase) apart farther distances from the shaft part **21** in a direction orthogonal to the center axis X of the shaft part **21**. Accordingly, the cutting part **25** is able to rather easily catch an object, and can excellently cut the object.

(43) Moreover, in a removal device **80** serving as a fifth modification example illustrated in FIG. **5**(E), a cutting blade **82** of a main cutting body part **81** may be formed on the inner edge **27** that is positioned at an inner peripheral surface side of the main cutting body part **81**. Accordingly, the outer diameter of the cutting part **25** decreases in a tapered shape toward the proximal side (i.e., toward the right in FIG. **5**E). This makes the cutting blade **82** difficult to come into contact with the

sheath opening portion **36**, so that it is possible to suppress damage to the sheath **30**. The cutting blade may be disposed at a position (for example, between the inner peripheral surface and the outer peripheral surface) different from the inner peripheral surface and the outer peripheral surface of the main cutting body part.

Second Embodiment

(44) A removal system **100** according to a second embodiment differs from the first embodiment in that, as illustrated in FIGS. **6** and **7**, an expandable part **120** capable of expanding (automatically expanding) in a radial direction (a direction orthogonal to the center axis X of the shaft part **21**) is provided at the distal side from a cutting part **143**. In the description below, features that are the same or similar to those described above are identified by the same reference numerals and a detailed description of such features is not repeated.

(45) The removal system **100** according to the second embodiment is provided with a removal device **110** and the sheath **30** (see FIG. **1**). The removal device **110** is provided with the expandable part **120** and the shaft part **21**.

(46) The expandable part **120** is a filter that collects an object such as the thrombi **201** flowing with the blood. The expandable part **120** is provided with a plurality of linear bodies **121** that are braided in a net shape so as to form a tubular body and are flexibly deformable, a distal side interlock portion **130**, and a proximal side interlock portion **140** (main cutting body part) that is interlocked or fixed to the shaft part **21**. The plurality of the linear bodies **121** include gaps **127** among or between the linear bodies **121** by virtue of being braided.

(47) The distal side interlock portion **130** pinches and fixes distal ends of the plurality of the linear bodies **121** between two coaxial and axially overlapping tubular bodies or tubes. The distal side interlock portion **130** includes a distal side through-hole **131** that penetrates from the distal end to the proximal end. The distal side through-hole **131** may allow the guide wire to be inserted thereinto. The distal side through-hole **131** does not need to be formed.

(48) The proximal side interlock portion **140** pinches and fixes proximal ends of the plurality of the linear bodies **121** and the distal end of the shaft part **21** between two coaxial and axially overlapping tubular bodies or tubes. In the proximal side interlock portion **140**, a proximal side through-hole **141** that penetrates from the distal end to the proximal end is formed. The proximal side through-hole **141** may allow the guide wire to be inserted thereinto. A proximal end portion of the proximal side interlock portion **140** includes a slope (sloping surface) **142** that is inclined at an angle θ of more than zero degrees and of less than 90 degrees relative to the center axis X of the shaft part **21**. A ring-shaped region that surrounds the proximal side through-hole **141** of the slope **142** forms the cutting part **143**. Accordingly, the slope **142** is a surface on which or at which the cutting blade is positioned.

(49) In a natural state where no external force acts, the expandable part **120** is in a turned back state where a part of the expandable part **120** is turned back on itself in the axial direction by the self-elastic force (restoring force) of the linear bodies **121**. When the expandable part **120** is in the turned back state, the proximal side interlock portion **140** and the distal side interlock portion **130** approach each other. In turned back state, the expandable part **120** is provided with a first section **122** that is interlocked to the distal side interlock portion **130**, and a second section **123** that is interlocked to the proximal side interlock portion **140**. The second section **123** has entered or is positioned in an interior of the first section **122**. In an interior of the expandable part **120**, an internal space **125** is formed. The second section **123** has a concave shape that is open to the proximal side to form a collecting space **124** in which the thrombus **200** or the like is collected. The first section **122** includes a large-diameter portion **126** having an approximately constant outer diameter within a prescribed range in the axial direction, in the vicinity of the second section **123**. The large-diameter portion **126** is a section having an approximately maximum outer diameter of the expandable part **120**. A gap **127**B in the first section **122** is larger than a gap **127**A in the second section **123**.

(50) The number of the linear bodies **121** is not specifically limited, and may be 4 to 72, for example. Moreover, the condition of the braiding of the linear bodies **121** is not specifically limited. The outer diameter of the linear body **121** is selectable as appropriate in accordance with the material of the linear body **121** and the usage purpose of the expandable part **120**, and may be 20 to 300 μm, for example.
(51) A constituent material from which the linear bodies **121** may be fabricated is preferably a material having flexibility. Examples of the material from which the linear bodies **121** may be fabricated include a shape memory alloy to which the shape memory effect and the super elasticity are applied by thermal treatment, stainless steel, tantalum (Ta), titanium (Ti), white silver (Pt), gold (Au), tungsten (W), polyolefin such as polyethylene or polypropylene, polyamide, polyester such as polyethylene terephthalate, fluorinated polymer such as tetrafluoroethylene-ethylene copolymer (ETFE), polyether ether ketone (PEEK), polyimide.
(52) Constituent materials from which the distal side interlock portion **130** and the proximal side interlock portion **140** may be fabricated are not specifically limited. For example, stainless steel, polyether ether ketone (PEEK), and the like can be suitably used.
(53) The expandable part **120** is elastically deformed or collapsed by being accommodated in the sheath **30** as illustrated in FIG. **8**A to become in a collapsed state in which the outer diameter is small. When the expandable part **120** is in the collapsed state, the proximal side interlock portion **140** and the distal side interlock portion **130** are axially spaced apart from each other.
(54) When the expandable part **120** is released from the sheath **30**, the expandable part **120** expands and is indwelt in the blood vessel in a shape close to the natural state as illustrated in FIG. **8**B. At this time, the large-diameter portion **126** comes into contact with the blood vessel wall. The inflating part **120** is actually indwelt in the blood vessel wall in a state of being collapsed to a greater extent in the radial direction than the natural state of the inflating part **120** so as to generate an outward pressing force with respect to the blood vessel wall by a self-expanding force. The large-diameter portion **126** comes into contact with the blood vessel wall over a wide area because the large-diameter portion **126** has a length to some extent in the axial direction. Therefore, the large-diameter portion **126** is firmly fixed to the blood vessel wall.
(55) The expandable part **120** does not need to be in a turned back state immediately after being released from the sheath main body **31** in the blood vessel. In this case, after the expandable part **120** has been indwelt in the blood vessel, the sheath main body **31** may push the expandable part **120** to the distal side or in the distal direction. Moreover, a dilator or another sheath is used to push the expandable part **120** to the distal side or in the distal direction. Accordingly, the second section **123** of the expandable part **120** enters an inner side of the first section **122**, and the expandable is in a turned back state.
(56) The expandable part **120** acts as a filter and collects, as illustrated in FIG. **9**, the thrombi **201** having been destroyed or cut-up by a device that is separately provided in the blood vessel. The thrombi **201** are collected in the collecting space **124** and the internal space **125**. Subsequently, the aspirating device that is connected to the sheath **30** causes a negative pressure to act on the lumen **34** of the sheath main body **31**. Accordingly, the sheath **30** aspirates the thrombi **201** collected in the collecting space **124** from the sheath opening portion **36**. The aspirated thrombi **201** are discharged to the outside of the living body through the lumen **34**.
(57) In addition, the operator operates the shaft part **21** to alternately move the proximal side interlock portion **140** to the proximal side (in the proximal direction) and the distal side (in the distal direction) along the blood vessel. Accordingly, the second section **123** of the inflating part **120** moves to the distal side and to the proximal side with respect to the first section **122**. Therefore, the thrombi **201** having been adhered to the inflating part **120** by the blood flow are separated from the inflating part **120**. Accordingly, the sheath **30** can effectively aspirate the thrombi **201**.
(58) Moreover, the expandable part **120** is in a turned back state, so that the second section **123** that

is positioned at the inner side is easy to move to the proximal side and the distal side with respect to the first section **122** fixed to the blood vessel. This makes it easy to move the proximal side interlock portion **140** to the proximal side and the distal side. Moreover, when the range where the first section **122** and the second section **123** overlap with each other is long in the axial direction, the proximal side interlock portion **140** is capable of moving long to the proximal side and the distal side. When the proximal side interlock portion **140** moves to the proximal side, the cutting part **143** cuts the large thrombus **201** that blocks the sheath opening portion **36**, and leads the cut thrombi **201** into the sheath **30**. Accordingly, the sheath **30** can excellently continue the aspirating of the thrombi **201**.

(59) Moreover, the operator may operate not only the shaft part **21** but may also alternately move the sheath **30** to the proximal side and the distal side along the blood vessel. The sheath **30** moves to the distal side to allow the cutting part **143** of the proximal side interlock portion **140** to enter the sheath opening portion **36** while cutting the thrombus **201**.

(60) After the aspirating of the thrombus **200** by the sheath **30** has been completed, the operator pushes the sheath **30** to the distal side or in the distal direction while holding the position of the shaft part **21**. Accordingly, the proximal side interlock portion **140** is separated from the distal side interlock portion **130** while entering an interior of the sheath **30**. Further, the expandable part **120** is moved to a collapsed state illustrated in FIG. **8**A. Thereafter, the operator extracts the removal device **110** together with the sheath **30** from the blood vessel, and completes the procedure.

(61) The second embodiment of the removal device **110** includes the expandable part **120** capable of expanding, and the expandable part **120** is positioned at the distal side from the cutting part **143**. Accordingly, the removal device **110** can aspirate and remove the thrombus **200** while suppressing the object flowing in the body lumen from flowing downstream by the expanding expandable part **120**. The expandable part **120** may be directly interlocked to the shaft part **21**, or may be interlocked to the shaft part **21** via the cutting part **143**.

(62) Moreover, the expandable part **120** includes gaps **127**A at the proximal side, and gaps **127**B at the distal side larger than the gaps **127**A at the proximal side. This allows the small thrombus **201** having passed through the gap **127**A at the proximal side to be released downstream from the gap **127**B at the distal side. Accordingly, the inflating part **120** can suppress the thrombi **201** from remaining in the internal space **125**, and is easy to be collapsed and recovered into the sheath **30**.

(63) Moreover, the expandable part **120** can be turned back, and the first section **122** that is not turned back includes the gaps **127**B larger than the gaps **127**A of the turned-back second section **123**. This allows the small thrombus **201** having passed through the gap **127**A of the turned-back second section **123** to be released downstream from the gap **127**B of the first section **122** that is not turned back. Accordingly, the expandable part **120** can suppress the thrombi **201** from remaining in the internal space **125**, and is easy to be collapsed and recovered into the sheath **30**.

(64) The form or configuration of the expandable part is not limited to the abovementioned example. For example, in a removal device **150** serving as a sixth modification example illustrated in FIG. **10**A, an expandable part **151** including the plurality of the linear bodies **121** may be provided with at least one release opening portion **152** having a gap in the mesh larger than the gaps **127**A and the gaps **127**B, at the distal side. Therefore, the thrombi **201** having passed through the gaps **127**A and entered the internal space **125** of the inflating part **151** can be released from the release opening portion **152**, as illustrated in FIG. **10**B. The thrombi **201** having entered the internal space **125** are the small thrombi **201** having passed through the gaps **127**A, so that such thrombi **201** flowing downstream hardly affect the living body. The expandable part **151** releases the thrombi **201** in the internal space **125**, and is easy to be collapsed and recovered into the sheath **30**.

(65) In a removal device **160** serving as a seventh modification example illustrated in FIG. **11**A, an expandable part **161** does not need to have a turned back shape in the natural state in which no external force is acted.

(66) In a removal device **170** serving as an eighth modification example illustrated in FIG. **11**B, an

expandable part **171** may be a balloon capable of inflating by a fluid being supplied from a balloon hub **172**. The fluid having flowed from the balloon hub **172** flows into the expandable part **171** through a lumen of a hollow shaft part **173**. The expandable part **171** closes the blood vessel, and suppresses the thrombi **201** from flowing downstream. Accordingly, after the expandable part **171** is indwelt in the blood vessel wall, by using the deformation of the expandable part **171**, the main cutting body part **41** including the cutting part **25** can be moved in the axial direction.

(67) This invention is not limited to the above-described embodiments. Various changes by those skilled in the art can be made within the technical scope of this invention. For example, in the abovementioned embodiments, a structure in which the removal system is accessed to a target lesion from the upstream side of the target lesion is employed, however, a structure in which the removal system is accessed to a target lesion from the downstream side thereof may be employed. Moreover, the body lumen into which the removal device is inserted is not limited to the blood vessel, but may be the vessel, the ureter, the bilary duct, the oviduct, or the hepatic duct, for example.

(68) Moreover, in the ring-shaped cutting part, no blade may be formed on a part in the peripheral direction (for example, a section to which the shaft part is fixed). Moreover, the ring-like cutting part does not need to be a perfect ring over 360 degrees, but a slit that extends in the axial direction may be formed, for example. Moreover, the blade of the cutting part may include saw-like asperities, for example.

(69) The detailed description above describes embodiments of an object removal device, object removal system and operational method representing examples of the inventive object removal device, object removal system and operational method disclosed here. The invention is not limited, however, to the precise embodiments and variations described. Various changes, modifications and equivalents can be effected by one skilled in the art without departing from the spirit and scope of the invention as defined in the accompanying claims. It is expressly intended that all such changes, modifications and equivalents which fall within the scope of the claims are embraced by the claims.

Claims

1. A removal system for removing objects from a living body during an object removal operation, the removal system comprising: an elongated sheath that includes a lumen possessing a distal end that is open and a proximal end that is open, the lumen in the elongated sheath being connectable to an aspirating device that produces an aspiration force in the lumen to draw the objects into the lumen in the elongated sheath and toward the proximal end of the elongated sheath; an elongated shaft part possessing a proximal portion and a distal portion at opposite axial ends of the elongated shaft part, the elongated shaft part possessing a center axis; a cutting part fixed to the distal portion of the elongated shaft part so that the cutting part and the elongated shaft part move together when the elongated shaft part is axially moved, the elongated shaft part and the cutting part being positionable in the lumen of the elongated shaft part and being axially movable relative to the elongated shaft part; the cutting part including a distal portion and a proximal portion, the proximal portion of the cutting part including an inclined cutting surface to cut the objects, the inclined cutting surface being inclined relative to the center axis of the elongated shaft part at an angle of more than 0 degrees and less than 90 degrees; and an expandable net fixed to the cutting part or the elongated shaft part so that axial movement of the elongated shaft part results in axial movement of the expandable net, the expandable net including a plurality of gaps that pass through the expandable net; and the expandable net also including a release opening that passes through the expandable net, the release opening being larger than the gaps so that one of the objects that has entered an interior of the expandable net by way of the gaps during the object removal operation is able to be released out of the interior of the expandable net by way of the release opening.

2. The removal system according to claim 1, wherein the release opening in the expandable net is

located distal of the cutting part during the object removal operation.
3. The removal system according to claim 1, wherein the expandable net is comprised of a plurality of linear bodies that are braided together so that the gaps exist between adjacent ones of the linear bodies.
4. The removal system according to claim 3, wherein the each of the linear bodies includes a distal end and a proximal end, the expandable net including a distal side interlock portion that fixes together the distal ends of the plurality of the linear bodies, the expandable net including a proximal side interlock portion that fixes together the proximal ends of the plurality of the linear bodies.
5. The removal system according to claim 4, wherein the release opening is positioned closer to the distal side interlock portion than the proximal side interlock portion during the object removal operation.
6. The removal system according to claim 4, wherein the expandable net includes a first section interlocked to the distal side interlock portion and a second section interlocked to the proximal side interlock portion, at least some of the gaps in the first section of the expandable net being larger than at least some of the gaps in the second section of the expandable net.
7. The removal system according to claim 6, wherein the release opening is larger than the at least some of the gaps in the first section of the expandable net.
8. The removal system according to claim 6, wherein the release opening is larger than the at least some of the gaps in the first section of the expandable net.
9. The removal system according to claim 1, wherein the cutting part includes a hollow portion that extends in a proximal direction from the inclined cutting surface.
10. The removal system according to claim 1, wherein the cutting part includes a center axis, the elongated shaft part being fixed to the cutting part at a position such that the center axis of the elongated shaft part and the center axis of the cutting part are not coaxial.
11. A removal device that is positionable in a living body, comprising: an elongated shaft part possessing a proximal portion and a distal portion at opposite axial ends of the elongated shaft part, the elongated shaft part possessing a center axis and being axially movable in a distal direction and a proximal direction; a cutting part fixed to the distal portion of the shaft part so that the cutting part and the elongated shaft part move together when the elongated shaft part is axially moved in the distal direction and the proximal direction, the cutting part including a distal portion and a proximal portion; the cutting part including a cutting blade surface to be brought into contact with objects in the living body during axial movement of the cutting part in the proximal direction to cut the objects, the cutting blade surface facing towards the proximal portion of the elongated shaft part and being inclined relative to the center axis of the elongated shaft part at an angle of more than 0 degrees and less than 90 degrees; an expandable part fixed to the shaft part or the cutting part, the expandable part including a plurality of gaps that pass through the expandable part; and the expandable part including a release opening that passes through the expandable part and that is larger than the plurality of gaps to allow one of the objects that has entered an interior of the expandable part by way of the gaps is able to be released out of the interior of the expandable net by way of the release opening.
12. The removal device according to claim 11, wherein the release opening in the expandable net is located distal of the cutting part during the axial movement of the cutting part in the proximal direction.
13. The removal system according to claim 11, wherein the expandable part is comprised of a plurality of linear bodies that are braided together so that the gaps exist between adjacent ones of the linear bodies.
14. The removal system according to claim 13, wherein the each of the linear bodies includes a distal end and a proximal end, the expandable part including a distal side interlock portion that fixes together the distal ends of the plurality of the linear bodies, the expandable net including a

proximal side interlock portion that fixes together the proximal ends of the plurality of the linear bodies.

15. The removal system according to claim 14, wherein the release opening is positioned closer to the distal side interlock portion than the proximal side interlock portion during the axial movement of the cutting part in the proximal direction.

16. The removal system according to claim 14, wherein the expandable part includes a first section interlocked to the distal side interlock portion and a second section interlocked to the proximal side interlock portion, at least some of the gaps in the first section of the expandable part being larger than at least some of the gaps in the second section of the expandable part.

17. The removal system according to claim 11, wherein the cutting part includes a hollow portion that extends in a proximal direction from the inclined cutting blade surface.

18. The removal system according to claim 11, wherein the cutting part includes a center axis, the elongated shaft part being fixed to the cutting part at a position such that the center axis of the elongated shaft part and the center axis of the cutting part are not coaxial.

19. A removal device that is positionable in a living body to remove objects from the living body, comprising: an elongated shaft part possessing a proximal portion and a distal portion at opposite axial ends of the elongated shaft part; an expandable net fixed to the elongated shaft part, the expandable net including gaps that pass through the expandable net to allow at least some of the objects to pass through the gaps and enter an interior of the expandable net; and the expandable net also including a release opening that passes through the expandable net, the release opening being completely surrounded by a plurality of the gaps, the release opening being larger than all of the gaps that pass through the expandable net so that one or more of the objects that have entered the interior of the expandable net by way of the gaps is able to be released out of the interior of the expandable net by way of the release opening.

20. The removal system according to claim 19, wherein the expandable net includes a distal portion and a proximal portion, the distal portion of the expandable net being positioned distal of the distal portion of the elongated shaft part, the release opening being located in the distal portion of the expandable net that is positioned distal of the distal portion of the elongated shaft part, the release opening being located distal of at least some of the gaps in the expandable net.

21. The removal system according to claim 19, wherein the release opening is larger than all of the gaps that pass through the expandable net.

22. The removal system according to claim 19, wherein the gaps that pass through the expandable net include plural first gaps that pass through the expandable net and plural second gaps that pass through the expandable net, all of the plural second gaps being larger than all of the first gaps, the release opening being larger than all of the second gaps.

23. The removal system according to claim 19, wherein the expandable net is fixed to the distal portion of the elongated shaft part so that the elongated shaft part extends away from the expandable net in a proximal direction, the gaps that pass through the expandable net including plural first gaps that pass through the expandable net and plural second gaps that pass through the expandable net, the first gaps being located on a proximal side of the second gaps, all of the plural second gaps being larger than all of the first gaps, the gaps that completely surround the release opening being the second gaps.