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Robotic surgical systems and drapes for covering components of robotic surgical systems

Abstract

A drape for covering a robotic surgical system includes a proximal section joined to and continuous with a distal section. The distal section is fabricated from a relatively strong material and is configured to cover the more dynamic portions of the robotic surgical system, and the proximal section is fabricated from a light-permeable material and is configured to cover the more static portions of the robotic surgical system.

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Background/Summary

(1) The present application is a U.S. National Stage Application filed under 35 U.S.C. § 371 (a) claiming the benefit of and priority to International Patent Application No. PCT/US2020/047779, filed Aug. 25, 2020, which claims the benefit of and priority to U.S. Provisional Patent Application No. 62/892,626, filed Aug. 28, 2019, the entire disclosures of each of which being incorporated by reference herein.

BACKGROUND

(1) Robotic surgical systems have been used in minimally invasive medical procedures. Some robotic surgical systems include a console supporting a surgical robotic arm and a surgical instrument, having at least one end effector (e.g., forceps or a grasping tool), mounted to the surgical robotic arm. The surgical robotic arm provides mechanical power to the surgical instrument for its operation and movement.

(2) In robotic assisted medical procedures, the various components of a robotic surgical system are generally draped to decrease the probability of inadvertent contamination of an external surgical sterile field. Accordingly, it would be beneficial to provide a means for more easily deploying a drape while decreasing the probability of inadvertent contamination of the external surgical sterile field.

SUMMARY

(3) In accordance with an aspect of the present disclosure, a drape for covering a robotic surgical system is provided. The drape includes a proximal section and a distal section each defining a cavity therein. The cavity of the proximal section is dimensioned for receipt of at least a base portion of a surgical robotic arm, and the cavity of the distal section is dimensioned for receipt a surgical assembly, which is coupled to the surgical robotic arm. The proximal section is fabricated from a first material, and the distal section is fabricated from a second material that is stronger than the first material. The proximal and distal sections are joined to one another, such that the cavity of the proximal section is contiguous with the cavity of the distal section.

(4) In aspects, the first material may be diaphanous and the second material may be opaque.

(5) In some aspects, the first material may be low density polyethylene and the second material may be polyurethane and/or ethylene methyl acrylate.

(6) In further aspects, the proximal and distal sections may be joined to one another via a medical grade adhesive.

(7) In other aspects, the proximal section may have an open and tubular distal end, and the distal section may have an open and tubular proximal end overlapping the distal end of the proximal section.

(8) In aspects, the proximal and distal sections may be joined to one another at their respective distal and proximal ends.
(9) In some aspects, the first material may be thinner than the second material.
(10) In further aspects, the second material may have a greater tensile strength, tear resistance, and puncture resistance relative to the first material.
(11) In other aspects, the first material may be more permeable to light than the second material.
(12) In aspects, the distal section may have a first region and a second region extending from the first region. The first region may be configured to cover a plurality of movable arms of the surgical robotic arm, and the second region may be configured to cover an instrument drive unit and a slide of the surgical assembly.
(13) In some aspects, the first region may have a greater diameter than the second region.
(14) In accordance with another aspect of the present disclosure, a robotic surgical system is provided and includes a surgical robotic arm, a surgical assembly, and a drape. The surgical robotic arm has a base portion and a plurality of movable members coupled to the base portion. The surgical assembly is coupled to a first movable member of the plurality of movable members of the surgical robotic arm. The drape includes a proximal section and a distal section joined to the proximal section and each defining a cavity therein. The cavity of the proximal section is dimensioned for receipt of the base portion of the surgical robotic arm, and the cavity of the distal section is dimensioned for receipt of the surgical assembly and the movable members of the surgical robotic arm. The proximal section is fabricated from a first material, and the distal section is fabricated from a second material, different than the first material.
(15) In aspects, the cavity of the proximal section may be contiguous with the cavity of the distal section.
(16) Further details and aspects of exemplary embodiments of the present disclosure are described in more detail below with reference to the appended figures.
(17) As used herein, the terms parallel and perpendicular are understood to include relative configurations that are substantially parallel and substantially perpendicular up to about plus or minus 10 degrees from true parallel and true perpendicular.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) Embodiments of the present disclosure are described herein with reference to the accompanying drawings, wherein:
(2) FIG. **1** is a schematic illustration of a robotic surgical system including a surgical robotic arm, a robotic surgical assembly coupled to the robotic arm, and a drape covering the surgical robotic arm and the robotic surgical assembly;
(3) FIG. **2** is a perspective view illustrating the robotic surgical assembly and the robotic arm of FIG. **1** attached to a robotic arm cart;
(4) FIG. **3** is a perspective view illustrating the robotic surgical assembly and the robotic arm of FIG. **2** covered in the drape of FIG. **1**;
(5) FIG. **4** is a perspective view illustrating the drape of FIG. **3**; and
(6) FIG. **5** is a side view illustrating the drape of FIG. **4**.
DETAILED DESCRIPTION
(7) Embodiments of the presently disclosed robotic surgical system including a surgical robotic arm, a surgical assembly (including an instrument drive unit (“IDU”) and a surgical instrument), and a drape for covering some or all of the aforementioned components, are described in detail with reference to the drawings, in which like reference numerals designate identical or corresponding elements in each of the several views. As used herein the term “distal” refers to that

portion of the surgical robotic arm, surgical assembly, or drape, that is closer to the patient, while the term “proximal” refers to that portion of the surgical robotic arm, surgical assembly, or drape, that is farther from the patient.

(8) As will be described in detail below, provided is a sterile, disposable or reusable drape for covering various components of a robotic surgical system. The drape maintains sterility of the surgical assembly and surgical robotic arm disposed therein. The drape may also protect the robotic surgical system from liquid and particle ingress that may otherwise harm the system. The drape is manufactured by joining two separate sheets of material via an adhesive or any other suitable type of connection. The two sheets of material each exhibit unique material properties making each suitable for covering particular sections of the robotic surgical system.

(9) Referring initially to FIGS. **1-3**, a surgical system, such as, for example, a robotic surgical system **1**, generally includes a robotic arm or robotic arms **2**, **3** coupled to a robotic cart **10**, a surgical assembly **100** coupled to the surgical robotic arm **2**, and a drape **200** for covering the robotic arm **2** and the surgical assembly **100**. In some embodiments, the drape **200** may be dimensioned to also cover the robotic arm cart **10**. The surgical assembly **100** includes an instrument drive unit (hereinafter “IDU”) **110** coupled to a slide rail **40** of surgical robotic arms **2**, **3**, and an electromechanical surgical instrument **130** operably coupled to IDU **110** by a sterile interface module **112** of surgical assembly **100**.

(10) The surgical system **1** further includes a control device **4** and an operating console **5** coupled with control device **4**. Operating console **5** includes a display device **6**, which is set up in particular to display three-dimensional images; and manual input devices **7**, **8**, by means of which a person (not shown), for example a surgeon, is able to telemanipulate robotic arms **2**, **3** in a first operating mode, as known in principle to a person skilled in the art. Each of the robotic arms **2**, **3** may be composed of a plurality of members **2***a*, **2***b*, **2***c*, which are connected through joints. The first member **2***a* couples to the surgical assembly **100** and the third member **2***c* couples to a base portion **42** of the surgical robotic arm **2**. The base portion **42** may include a plurality of pivotable arms **44** configured to detachably couple to the cart **10**, and a display screen **46** coupled to one of the pivotable arms **44**.

(11) Robotic arms **2**, **3** may be driven by electric drives (not shown) that are connected to control device **4**. Control device **4** (e.g., a computer) may be set up to activate the drives, in particular by means of a computer program, in such a way that robotic arms **2**, **3**, the attached robotic surgical assembly **100**, and thus electromechanical surgical instrument **130** (including an electromechanical end effector (not shown)) execute a desired movement according to a movement defined by means of manual input devices **7**, **8**. Control device **4** may also be set up in such a way that it regulates the movement of robotic arms **2**, **3**.

(12) Robotic surgical system **1** is configured for use on a patient “P” lying on a surgical table “ST” to be treated in a minimally invasive manner by means of a surgical instrument, e.g., electromechanical surgical instrument **130**. In embodiments, robotic arms **2**, **3** may be coupled to robotic arm cart **10** (FIG. **2**) rather than surgical table “ST.” Robotic surgical system **1** may also include more than two robotic arms **2**, **3**, the additional robotic arms likewise being connected to control device **4** and being telemanipulatable by means of operating console **5**. A surgical instrument, for example, electromechanical surgical instrument **130** (including the electromechanical end effector), may also be attached to the additional robotic arm.

(13) Control device **4** may control a plurality of motors, e.g., motors (Motor **1** . . . n), with each motor configured to drive movement of robotic arms **2**, **3** in a plurality of directions. Further, control device **4** may control a motor assembly (not explicitly shown) of IDU **110** of robotic surgical assembly **100** that drives various operations of surgical instrument **130**. In embodiments, each motor of the IDU **110** can be configured to actuate a drive rod/cable or a lever arm to effect operation and/or movement of electromechanical surgical instrument **130**.

(14) For a detailed discussion of the construction and operation of a robotic surgical system,

reference may be made to U.S. Pat. No. 8,828,023, entitled “Medical Workstation,” the entire contents of which are incorporated by reference herein.

(15) With reference to FIGS. **3-5**, the drape **200** of the robotic surgical system **1** has a generally elongated configuration, such as, for example, a tubular shape, and generally includes a proximal section **202** configured to cover the static portions of the surgical robotic system **1** and a distal section **204** configured to cover the more dynamic portions of the surgical robotic system **1**. The proximal section **202** of the drape **200** has a tubular shape and defines an elongated cavity **206** therein dimensioned for receipt of the base portion **42** of the surgical robotic arm **2** (including the arms **44** and the display **46**). The proximal section **202** is fabricated from a first material that is diaphanous to provide a clear view of the components (e.g., display **46**) of the surgical robotic system **1** covered by the proximal section **202**. An exemplary material for the proximal section **202** may be low density polyethylene, which is light-permeable and fluid-resistant. In other aspects, the first material of the proximal section **202** may be high-density polyethylene (HDPE), polypropylene, and/or polyethylene materials or other similar non-toxic, biocompatible compounds.

(16) The proximal section **202** may have a pair of handles **212***a*, **212***b* for guiding the drape **200** over the surgical robotic system **1**. The handles **212***a*, **212***b* may be affixed to any suitable location of the drape **200**. The proximal section **202** of the drape **200** has an open proximal end **202***a* and an open distal end **202***b* joined to or otherwise coupled with an open proximal end **204***a* of the distal section **204**.

(17) The distal section **204** of the drape **200** has a tubular shape and defines an elongated cavity **208** therein dimensioned for receipt of the members **2***a*, **2***b*, **2***c* of the surgical robotic arm **2** and the surgical assembly **100** (including the instrument drive unit **110** and the slide **40**). The distal section **204** is fabricated from a second material, different than the first material of the proximal section **202**. Since the distal section **204** is configured to cover the more dynamic portions of the robotic surgical system **1** (e.g., the movable arms **2***a*, **2***b*, **2***c* and the IDU **110**), a stronger material is selected for the distal section **204** compared to the proximal section **202**. Exemplary materials for the distal section **204** are polyurethane and/or ethylene methyl acrylate; however, other suitable materials are also contemplated. The material from which the distal section **204** is fabricated is more resistant to tearing and puncture and exhibits greater tensile strength than the material from which the proximal section **202** is fabricated. Depending on the material used to form the distal section **204**, it may be opaque and therefore less translucent compared to the proximal section **202**.

(18) Due to the proximal and distal sections **202**, **204** being fabricated from two different materials with each possibly having a different melting temperature, joining the proximal and distal sections **202**, **204** using heat sealing may be challenging. Accordingly, the open and tubular distal end **202***b* of the proximal section **202** and the open and tubular proximal end **204***a* of the distal section **204** may be bonded, joined, or otherwise coupled to one another using a medical grade adhesive, such as, for example, acrylic, cyanoacrylate, and/or epoxy. The proximal end **204***a* of the distal section **204** may be disposed around the distal end **202***b* of the proximal section **202** or the distal end **202***b* of the proximal section **202** may be disposed around the proximal end **204***a* of the distal section **204** and then joined to one another. In some aspects, the proximal and distal sections **202**, **204** may be joined using any suitable fastening mechanism, such as, for example, glue, thermally bonds, ultrasonically welds, stitches, hook and loop fasteners, or seam bonds.

(19) The distal section **204** includes a first region **214** coupled to the proximal section **202** and a second region **216** coupled to (e.g., via heat sealing) and extending distally from the first region **214**. The first region **214** has a first diameter configured to surround the movable members **2***a*, **2***b*, **2***c* of the surgical robotic arm **2** and a length sufficient to accommodate the members **2***a*, **2***b*, **2***c* in a fully extended position. The second region **216** has a second diameter, less than the first diameter of the first region **214**, and is configured to surround the instrument drive unit **110** and the slide **40**. The second region **216** may terminate at a closed distal-most end.

(20) The second region **216** may have a reinforcement patch **220** (FIG. **5**) disposed at a location where the instrument drive unit **110** is intended to be when the drape **200** is covering the robotic surgical system **1**. The second region **216** defines an inlet or channel **218** in fluid communication with the cavity **206** of the proximal section **202**. The inlet **218** has a generally annular shape dimensioned to form a fluid-tight seal with the sterile interface module **112** (FIG. **3**) of the surgical assembly **100**. In some aspects, the inlet **218** may be dimensioned to form a fluid tight seal with a distal end portion of the instrument drive unit **110** when the sterile interface module **112** is not used. Reinforcement patch **220** may be located distal of inlet **218** and/or substantially midway along a length of second region **216**.
(21) It is contemplated that the first material of first region **214** of drape **200** may be relatively thinner than the second material of second region **216** of drape **200**. It is further contemplated that the second material of second region **216** of drape **200** may have a relatively greater tensile strength, tear resistance and/or puncture resistance as compared to the first material of first region **214** of drape **200**.
(22) During assembly, the drape **200** is placed over the rail **40** and the instrument drive unit **110** using the handles **212***a*, **212***b* to guide the drape **200** over the robotic surgical system **1**. The proximal section **202** of the drape **200** is guided over the base portion **42** of the surgical robotic arm **2** and the seal **203** between the proximal and distal sections **202**, **204** is disposed distally (e.g., in front of) the display **46**. The first region **214** of the distal section **204** is positioned over the movable members **2***a*, **2***b*, **2***c* of the robotic arm **2** and the second region **216** of the distal section **204** is positioned over the slide **40** and the instrument drive unit **110**. The sterile interface module **112** is positioned to extend through the inlet **218** of the distal section **204** of the drape **200** with the surgical instrument **130** protruding from the drape **200**. A latch **219**, flexible strips **221**, ties **223**, clips, straps, or any other suitable fasteners may be used to attach selected sections of the drape **200** to the robotic surgical system **1** to ensure the drape **200** is maintained in position.
(23) It will be understood that various modifications may be made to the embodiments disclosed herein. Therefore, the above description should not be construed as limiting, but merely as exemplifications of various embodiments. Those skilled in the art will envision other modifications within the scope and spirit of the claims appended thereto.

Claims

1. A drape for covering a robotic surgical system, the drape comprising: a proximal section defining a cavity therein dimensioned for receipt of at least a base portion of a surgical robotic arm, the proximal section being fabricated from a first material, the proximal section being tubular and defining a first diameter; and a distal section defining a cavity therein dimensioned for receipt of a surgical assembly that is coupled to the surgical robotic arm, the distal section being fabricated from a second material, stronger than the first material, wherein the proximal and distal sections are joined to one another, such that the cavity of the proximal section is contiguous with the cavity of the distal section, the distal section being tubular and including: a first region having a diameter equal to the first diameter of the proximal section; a second region integral with and extending distally from the first region, the second region defining a second diameter which is smaller than the first diameter; and an inlet formed in a side wall of the second region of the distal section and being in fluid communication with the cavity of the distal section, wherein the surgical assembly is connected to the surgical robotic arm through the inlet such that the surgical assembly is located externally of the second region of the distal section and the surgical robotic arm is located internally of the second region of the distal section.
2. The drape according to claim 1, wherein the first material is diaphanous and the second material is opaque.
3. The drape according to claim 1, wherein the first material is low density polyethylene and the

second material is at least one of polyurethane or ethylene methyl acrylate.
4. The drape according to claim 1, wherein the proximal and distal sections are joined to one another via a medical grade adhesive.
5. The drape according to claim 1, wherein the proximal section has an open and tubular distal end, and the distal section has an open and tubular proximal end overlapping the distal end of the proximal section.
6. The drape according to claim 5, wherein the proximal and distal sections are joined to one another at their respective distal and proximal ends.
7. The drape according to claim 1, wherein the first material is thinner than the second material.
8. The drape according to claim 1, wherein the second material has a greater tensile strength, tear resistance, and puncture resistance relative to the first material.
9. The drape according to claim 1, wherein the first material is more permeable to light than the second material.
10. The drape according to claim 1, wherein the first region of the distal section is configured to cover a plurality of movable arms of the surgical robotic arm, and the second region of the distal section is configured to cover an instrument drive unit and a slide of the surgical assembly.
11. The drape according to claim 1, wherein the distal section includes a latch supported thereon and extending outwardly therefrom.
12. The drape according to claim 11, wherein the latch is supported on the first region of the distal section.
13. The drape according to claim 11, wherein the latch includes a pair of fingers.
14. The drape according to claim 1, wherein the proximal section defines a first central longitudinal axis, and wherein the second region of the distal section defines a second central longitudinal axis, wherein the second central longitudinal axis extends parallel to the first central longitudinal axis and is spaced a radial distance from the first central longitudinal axis.
15. A drape for covering a robotic surgical system, the drape comprising: a proximal section defining a cavity therein dimensioned for receipt of at least a base portion of a surgical robotic arm, the proximal section being fabricated from a first material, the proximal section being tubular and defining a first diameter and a first central longitudinal axis; and a distal section defining a cavity therein dimensioned for receipt of a surgical assembly that is coupled to the surgical robotic arm, the distal section being fabricated from a second material, stronger than the first material, wherein the proximal and distal sections are joined to one another, such that the cavity of the proximal section is contiguous with the cavity of the distal section, the distal section being tubular and including: a first region having a diameter equal to the first diameter of the proximal section; a second region integral with and extending distally from the first region, the second region defining a second diameter and a second central longitudinal axis, wherein the second central longitudinal axis extends parallel to the first central longitudinal axis and is spaced a radial distance from the first central longitudinal axis; and an inlet formed in a side wall of the second region of the distal section and being in fluid communication with the cavity of the distal section, wherein the surgical assembly is connected to the surgical robotic arm through the inlet such that the surgical assembly is located externally of the second region of the distal section and the surgical robotic arm is located internally of the second region of the distal section.
16. The drape according to claim 15, wherein the proximal section has an open and tubular distal end, and the distal section has an open and tubular proximal end overlapping the distal end of the proximal section.
17. The drape according to claim 15, wherein the distal section includes a latch supported thereon and extending outwardly therefrom.
18. The drape according to claim 17, wherein the latch is supported on the first region of the distal section.
19. The drape according to claim 17, wherein the latch includes a pair of fingers.

20. The drape according to claim 15, wherein the second region of the distal section defines a second diameter which is smaller than the first diameter of the proximal section.