APD offers flexibility and quality of life enhancements to a person requiring dialysis. APD can free the patient from the fatigue and inconvenience that the day to day practice of CAPD represents to some individuals. APD can give back to the patient his or her waking and working hours free of the need to conduct dialysis exchanges.

Still, the complexity and size of past machines and associated disposables for various APD modalities have dampened widespread patient acceptance of APD as an alternative to manual peritoneal dialysis methods.

SUMMARY OF INVENTION

Aspects of the invention relate to various components, systems and methods for use in medical applications, including medical infusion operations such as peritoneal dialysis. In some cases, aspects of the invention are limited to applications in peritoneal dialysis, while others to more general dialysis applications (e.g., hemodialysis) or infusion applications, while others to more general methods or processes. Thus, aspects of the invention are not necessarily limited to APD systems and methods, although many of the illustrative embodiments described relate to APD.

In one aspect of the invention, there is provided a tubing state detector for detecting whether liquid is contained in a tubing segment, comprising:

a fill state light emitter having an optical axis that is arranged to pass through a space in which a tubing segment is to be positioned, the space being arranged to receive a tubing segment having a cylindrical outer surface and to hold the tubing segment without substantially deforming the tubing segment; and

an optical sensor positioned on a side of the space opposite the fill state light emitter and arranged to receive light emitted by the fill state light emitter to determine a presence or absence of liquid in the tubing segment, the optical sensor having a sensor optical axis that is arranged at an oblique angle to the optical axis of the fill state light emitter, wherein the optical sensor and fill state light emitter are arranged such that with a tubing segment in the space and the tubing segment containing no liquid, a light level detected by the optical sensor is over a threshold level, and such that with a tubing segment in the space and the tubing segment containing liquid, a light level detected by the optical sensor is less than the threshold level.

In another aspect of the invention, there is provided a tubing state detector for detecting whether liquid is contained in a tubing segment, comprising:

a fill state light emitter having an optical axis that is arranged to pass through a space in which a tubing segment is to be positioned, the space being arranged to receive a tubing segment having a cylindrical outer surface and to hold the tubing segment without substantially deforming the tubing segment; and

an optical sensor positioned on a side of the space opposite the fill state light emitter and arranged to receive light emitted by the fill state light emitter to determine a presence or absence of liquid in the tubing segment, the optical sensor having a sensor optical axis that is arranged at an oblique angle to the optical axis of the fill state light emitter, wherein the optical sensor and fill state light emitter are arranged such that with a tubing segment in the space and the tubing segment containing no liquid, a light level detected by the optical sensor is over about 150% of a calibration light level detected with no tubing segment in the space, and such that with a tubing segment in the space and the tubing segment containing liquid, a light level detected by the optical sensor is less than about 125% of the calibration light level.

In another aspect of the invention, there is provided a method for detecting a presence of liquid in a tubing segment, comprising:

emitting light along an optical axis toward a space without a tubing segment in the space;

sensing light along a sensor optical axis while light is emitted along the optical axis without a tubing segment in the space, the sensor optical axis extending into the space and arranged at an oblique angle relative to the optical axis;

determining a calibration level of light detected along the sensor optical axis without a tubing segment in the space;

emitting light along the optical axis toward the space in which a tubing segment is positioned, the tubing segment having a cylindrical outer surface;

sensing light along the sensor optical axis that extends into the space, wherein the sensor optical axis is arranged at an oblique angle relative to the optical axis; and

determining a presence or absence of liquid in the tubing segment in the space based on a sensed light level sensed along the sensor optical axis by comparing the sensed light level to the calibration level;

wherein a light level detected along the sensor optical axis with a tubing segment in the space containing no liquid is over about 150% of the calibration level, and a light level detected along the sensor optical axis is less than about 125% of the calibration level with a tubing segment in the space containing liquid.

In another aspect of the invention, there is provided a method for detecting a presence of liquid in a tubing segment, comprising:

emitting light along an optical axis toward a space in which a tubing segment is positioned, the tubing segment having a cylindrical outer surface;

sensing light along a sensor optical axis that extends into the space, wherein the sensor optical axis is arranged at an oblique angle relative to the optical axis; and

determining a presence or absence of liquid in the tubing segment in the space based on a sensed light level sensed along the sensor optical axis,

wherein the step of determining a presence or absence of liquid in the tubing segment comprises:

determining that liquid is not present in the tubing segment if a light level detected along the sensor optical axis is over a threshold level, and determining that liquid is present in the tubing segment if a light level detected along the sensor optical axis is below a threshold level.

In another aspect of the invention, there is provided a tubing state detector for detecting whether liquid is contained in a tubing segment, comprising:

a fill state light emitter having an optical axis that is arranged to pass through a space in which a tubing segment is to be positioned, the space being arranged to receive a tubing segment having a cylindrical outer surface and to hold the tubing segment without substantially deforming the tubing segment;

an optical sensor positioned on a side of the space opposite the fill state light emitter and arranged to receive light emitted by the fill state light emitter to determine a presence or absence of liquid in the tubing segment, the optical sensor having a sensor optical axis that is arranged at an oblique angle to the optical axis of the fill state light emitter;

a first light emitter having a first optical axis directed toward the space in which a tubing segment is to be positioned; and

a second light emitter having a second optical axis directed toward the space, the second light emitter being adjacent the first light emitter, wherein the optical sensor is positioned on a side of the space opposite the first and second light emitters and arranged to receive light emitted

by the first and second light emitters to determine a presence or absence of a tubing segment in the space, and wherein with a tubing segment in the space, a detected light level for both the first and second light emitters is within about 15-20% of a calibration light level for the first and second light emitters that is detected when a tubing segment is known to be absent from the space.

In another~~one~~ aspect of the invention, a tubing state detector may be included with a dialysis system for detecting the presence or absence of a tubing segment, such as a portion of a patient line to be connected to a patient access for delivering dialysate to the peritoneal cavity. The tubing state detector may include a first light emitter having a first optical axis directed toward a space in which a tubing segment is to be positioned, and a second light emitter, adjacent to the first light emitter and having a second optical axis directed toward the space. An optical sensor may be positioned on a side of the space opposite the first and second light emitters and arranged to receive light emitted by the first and second light emitters to determine a presence or absence of a tubing segment in the space.

In one embodiment, the first optical axis may be approximately collinear with a sensor optical axis of the optical sensor, and may pass approximately through a center of a tubing segment when the tubing segment is positioned in the space. In contrast, the second optical axis may be approximately parallel to the first optical axis, and thus, the second optical axis may be offset from the center of the tubing segment and sensor optical axis.

The optical sensor may be arranged to detect a range of light levels when a tubing segment is in the space, e.g., a light level that is higher and/or lower that a light level detected when the tubing segment is absent from the space. However, the optical sensor may detect a lower light level from the second light emitter when a tubing segment is in the space that is detected when the tubing segment it absent from the space. For example, with a tubing

CLAIMS

1.- A tubing state detector for detecting whether liquid is contained in a tubing segment, comprising:

a fill state light emitter having an optical axis that is arranged to pass through a space in which a tubing segment is to be positioned, the space being arranged to receive a tubing segment having a cylindrical outer surface and to hold the tubing segment without substantially deforming the tubing segment; and

an optical sensor positioned on a side of the space opposite the fill state light emitter and arranged to receive light emitted by the fill state light emitter to determine a presence or absence of liquid in the tubing segment, the optical sensor having a sensor optical axis that is arranged at an oblique angle to the optical axis of the fill state light emitter,

wherein the optical sensor and fill state light emitter are arranged such that with a tubing segment in the space and the tubing segment containing no liquid, a light level detected by the optical sensor is over a threshold level, and such that with a tubing segment in the space and the tubing segment containing liquid, a light level detected by the optical sensor is less than the threshold level.

2.- The detector of claim 1, wherein the oblique angle is about 110-120 degrees.

~~3. A tubing state detector for detecting whether liquid is contained in a tubing segment, comprising:~~

~~a fill state light emitter having an optical axis that is arranged to pass through a space in which a tubing segment is to be positioned, the space being arranged to receive a tubing segment having a cylindrical outer surface and to hold the tubing segment without substantially deforming the tubing segment; and~~

~~an optical sensor positioned on a side of the space opposite the fill state light emitter and arranged to receive light emitted by the fill state light emitter to determine a presence or absence~~

~~of liquid in the tubing segment, the optical sensor having a sensor optical axis that is arranged at an oblique angle to the optical axis of the fill state light emitter,~~

~~wherein the optical sensor and fill state light emitter are arranged such that with a tubing segment in the space and the tubing segment containing no liquid, a light level detected by the optical sensor is over about 150% of a calibration light level detected with no tubing segment in the space, and such that with a tubing segment in the space and the tubing segment containing liquid, a light level detected by the optical sensor is less than about 125% of the calibration light level.~~

~~4.~~ 3. The detector of claim 1, wherein the threshold level is about 125~~-~~-150% of a light level detected by the optical sensor with no tubing segment in the space.

~~5.~~ 4. The detector of claim 1, wherein the fill state light emitter is a light emitting diode.

~~6.~~ 5. The detector of claim 1, further comprising:

a first light emitter having a first optical axis directed toward the space in which a tubing segment is to be positioned; and

a second light emitter having a second optical axis directed toward the space, the second light emitter being adjacent the first light emitter,

wherein the optical sensor is positioned on a side of the space opposite the first and second light emitters and arranged to receive light emitted by the first and second light emitters to determine a presence or absence of a tubing segment in the space.

~~7.~~ 6. The detector of claim ~~6~~5, wherein the second optical axis is approximately parallel to the first optical axis.

~~8.~~ 7. The detector of claim ~~6~~5, wherein the optical sensor detects a higher or lower light level from the first light emitter when a tubing segment is in the space.

~~9.~~ 8. The detector of claim ~~6~~7 wherein the optical sensor detects a lower light level from the second light emitter when a tubing segment is in the space.

~~10.~~ 9. The detector of claim ~~6~~5, wherein with a tubing segment in the space, a detected light level for both the first and second light emitters is within about 15-20% of a calibration light level for the first and second light emitters that is detected when a tubing segment is known to be absent from the space.

1~~1~~0.- The detector of claim ~~8~~9, wherein with a tubing segment not in the space, a detected light level for the second light emitter is less than about 15-20% of the calibration light level for the second light emitter.

1~~2~~1.- The detector of claim ~~6~~5, wherein the optical sensor has an optical axis that is approximately collinear with the first optical axis.

1~~3~~2.- The detector of claim ~~6~~5, wherein the first optical axis passes approximately through a center of a tubing segment with the tubing segment positioned in the space.

1~~4~~3.- The detector of claim ~~13~~12, wherein the second optical axis is offset from a center of a tubing segment with the tubing segment positioned in the space.

1~~5~~4.- The detector of claim 1, wherein the fill state light emitter and the optical sensor are arranged such that the optical sensor receives light from the fill state light emitter both when a

tubing segment in the space is filled with liquid and when a tubing segment in the space is empty of liquid.

~~16. The method of claim 20, wherein the space is arranged to receive and hold a tubing segment having a cylindrical outer surface without substantially deforming the tubing segment.~~

~~17.~~ 15. The detector of claim 1, wherein the tubing segment is a portion of a patient line of a dialysis system.

1~~8~~6. The detector of claim ~~17~~15, wherein the tubing segment is at a distal end of the patient line.

1~~9~~7. The detector of claim ~~18~~16, wherein the tubing segment is a portion of a connector used to connect the patient line to a patient access connection.

18. A tubing state detector for detecting whether liquid is contained in a tubing segment, comprising:

a fill state light emitter having an optical axis that is arranged to pass through a space in which a tubing segment is to be positioned, the space being arranged to receive a tubing segment having a cylindrical outer surface and to hold the tubing segment without substantially deforming the tubing segment; and

an optical sensor positioned on a side of the space opposite the fill state light emitter and arranged to receive light emitted by the fill state light emitter to determine a presence or absence of liquid in the tubing segment, the optical sensor having a sensor optical axis that is arranged at an oblique angle to the optical axis of the fill state light emitter, wherein the optical sensor and fill state light emitter are arranged such that with a tubing segment in the space and the tubing segment containing no liquid, a light level detected by the optical sensor is over about 150% of a calibration light level detected with no tubing segment in the space, and such that with a tubing

segment in the space and the tubing segment containing liquid, a light level detected by the optical sensor is less than about 125% of the calibration light level.

~~20~~19. A method for detecting a presence of liquid in a tubing segment, comprising:

emitting light along an optical axis toward a space without a tubing segment in the space;

sensing light along a sensor optical axis while light is emitted along the optical axis without a tubing segment in the space, the sensor optical axis extending into the space and arranged at an oblique angle relative to the optical axis;

determining a calibration level of light detected along the sensor optical axis without a tubing segment in the space;

emitting light along the optical axis toward the space in which a tubing segment is positioned, the tubing segment having a cylindrical outer surface;

sensing light along the sensor optical axis that extends into the space, wherein the sensor optical axis is arranged at an oblique angle relative to the optical axis; and

determining a presence or absence of liquid in the tubing segment in the space based on a sensed light level sensed along the sensor optical axis by comparing the sensed light level to the calibration level;

wherein a light level detected along the sensor optical axis with a tubing segment in the space containing no liquid is over about 150% of the calibration level, and a light level detected along the sensor optical axis is less than about 125% of the calibration level with a tubing segment in the space containing liquid.

20. The method of claim 19, wherein the space is arranged to receive and hold a tubing segment having a cylindrical outer surface without substantially deforming the tubing segment.

21.~~-~~ The method of claim 19~~20~~, wherein the oblique angle is about 110-120 degrees.

22.- A method for detecting a presence of liquid in a tubing segment, comprising:

emitting light along an optical axis toward a space in which a tubing segment is positioned, the tubing segment having a cylindrical outer surface;

sensing light along a sensor optical axis that extends into the space, wherein the sensor optical axis is arranged at an oblique angle relative to the optical axis; and

determining a presence or absence of liquid in the tubing segment in the space based on a sensed light level sensed along the sensor optical axis,

wherein the step of determining a presence or absence of liquid in the tubing segment comprises:

determining that liquid is not present in the tubing segment if a light level detected along the sensor optical axis is over a threshold level, and determining that liquid is present in the tubing segment if a light level detected along the sensor optical axis is below a threshold level.

23.- The method of claim 22, wherein the threshold level is about 125-150% of a calibration level detected along the sensor optical axis with no tubing segment in the space.

24.- A tubing state detector for detecting whether liquid is contained in a tubing segment, comprising:

a fill state light emitter having an optical axis that is arranged to pass through a space in which a tubing segment is to be positioned, the space being arranged to receive a tubing segment having a cylindrical outer surface and to hold the tubing segment without substantially deforming the tubing segment;

an optical sensor positioned on a side of the space opposite the fill state light emitter and arranged to receive light emitted by the fill state light emitter to determine a presence or absence of liquid in the tubing segment, the optical sensor having a sensor optical axis that is arranged at an oblique angle to the optical axis of the fill state light emitter;

a first light emitter having a first optical axis directed toward the space in which a tubing segment is to be positioned; and

a second light emitter having a second optical axis directed toward the space, the second light emitter being adjacent the first light emitter,

wherein the optical sensor is positioned on a side of the space opposite the first and second light emitters and arranged to receive light emitted by the first and second light emitters to determine a presence or absence of a tubing segment in the space, and

wherein with a tubing segment in the space, a detected light level for both the first and second light emitters is within about 15-20% of a calibration light level for the first and second light emitters that is detected when a tubing segment is known to be absent from the space.

25.- The detector of claim 24, wherein with a tubing segment not in the space, a detected light level for the second light emitter is less than about 15-20% of the calibration light level for the second light emitter.