CLAIMS

We Claim

1. A method of predicting infection of a patient, comprising:

illuminating a patient fluid in a fluid conduit from a plurality of illumination directions;

measuring an optical characteristic of the illuminated patient fluid using one or more sensors; and

predicting an infection state of the patient based at least in part on the measured optical characteristic.

2. The method of claim 1, wherein the plurality of illumination directions comprises a first illumination direction and a second illumination direction orthogonal to the first illumination direction.

3. The method of claim 2, wherein the predicted infection state of the patient is based at least in part on one or more 90-degree scatter angle light intensity measurements from the one or more sensors.

4. The method of claim 3, wherein the predicted infection state of the patient is further based at least in part on one or more 180-degree attenuation light intensity measurements from the one or more sensors.

5. The method of claim 1, wherein the plurality of illumination directions comprises a first illumination direction and a second illumination direction 180 degrees offset from the first illumination direction.

6. The method of claim 1, wherein illuminating the patient fluid comprises illuminating the patient fluid at a first wavelength from a first illumination direction and at the first wavelength from a second illumination direction, wherein the first and second illumination directions extend along a first plane.

7. The method of claim 6, wherein illuminating the patient fluid comprises illuminating the patient fluid along at least the first plane and along a second plane substantially parallel to the first plane.

8. The method of claim 1, wherein illuminating the patient fluid comprises illuminating the patient fluid at a first wavelength between about 800 nm and about 900 nm.

9. The method of claim 8, wherein illuminating the patient fluid comprises illuminating the patient fluid sequentially at a plurality of wavelengths including the first wavelength.

10. The method of claim 9, wherein the plurality of wavelengths comprises a second wavelength between about 400 nm and about 450 nm, and a third wavelength between about 500 nm and about 550 nm

11. The method of claim 10, wherein illuminating the patient fluid comprises sequentially illuminating the patient fluid at the third wavelength, the first wavelength, and then the second wavelength.

12. The method of claim 10, wherein the plurality of wavelengths comprises a fourth wavelength between about 230 nm and about 290 nm.

13. The method of claim 1, wherein the optical characteristic comprises one or more of optical scatter and attenuation detection angles.

14. The method of claim 1, wherein predicting the infection state comprises generating an infection score.

15. The method of claim 14, further comprising estimating turbidity of the patient fluid based at least in part on the measured optical characteristic, wherein the infection score is based at least in part on the estimated turbidity.

16. The method of claim 15, wherein predicting the infection state comprises predicting infection in response to the infection score exceeding a predetermined threshold during each of one or more successive measurement time periods.

17. The method of claim 15, wherein predicting the infection state comprises predicting infection in response to the infection score increasing from a patient baseline over time.

18. The method of claim 15, wherein predicting the infection state comprises predicting infection based on a rate of change of the infection score over time.

19. The method of claim 15, wherein predicting the infection state comprises predicting infection in response to any one or more of the following: the infection score exceeding a predetermined threshold during each of one or more successive measurement time periods, the infection score increasing from a patient baseline over time, and the infection score having an increasing rate of change over time.

20. The method of claim 1, wherein predicting the infection state comprises predicting a probability of infection.

21. The method of claim 1, wherein the fluid conduit is coupled to a peritoneal dialysis device fluid path.

22. The method of claim 1, wherein the fluid conduit is coupled to a peritoneal dialysis device tubing set.

23. The method of claim 1, wherein the fluid conduit is coupled to an inlet of the peritoneal dialysis device tubing set.

24. The method of claim 1, wherein the fluid conduit is coupled to an outlet of the peritoneal dialysis device tubing set.

25. The method of claim 1, wherein the fluid conduit is coupled to a drain line of a peritoneal dialysis cycler tubing set.

26. The method of claim 1, wherein the fluid conduit is coupled to a drain line extension configured to couple to a peritoneal dialysis cycler tubing set drain line.

27. The method of claim 1, wherein the fluid conduit is coupled to a patient line of a peritoneal dialysis cycler tubing set.

28. The method of claim 1, further comprising estimating a fluid flow rate in the fluid conduit based at least in part on the measured optical characteristic, wherein illuminating the patient fluid comprises activating illumination based on the estimated fluid flow rate.

29. The method of claim 28, further comprising determining a fluid flow state comprising detecting at least one of an ON state and an OFF state based on the estimated fluid flow rate, wherein illuminating the patient fluid comprises activating illumination in response to detecting the ON state and ceasing illumination in response to detecting the OFF state.

30. The method of claim 28, further comprising identifying a false positive fluid flow state based on the estimated fluid flow rate.

31. The method of claim 29, wherein identifying the false positive fluid flow state comprises detecting a predetermined number of pulses during less than each of two or more successive measurement time periods.

32. The method of claim 29, wherein detecting the ON state comprises detecting a predetermined number of pulses during each of two or more successive measurement time periods.

33. The method of claim 32, wherein the two or more successive measurement time periods are separated by a predetermined delay time period.

34. The method of claim 29, wherein estimating the fluid flow rate is based at least in part on applying one or more of a low pass filter and a high pass filter to the measured optical characteristic.

35. The method of claim 1, further comprising initiating illuminating the patient fluid and measuring the optical characteristic based on a user input.

36. The method of claim 1, further comprising detecting a bubble in the fluid conduit based at least in part on the optical measurement.

37. The method of claim 1, further comprising providing an indication of the predicted infection state to a user.

38. The method of claim 1, further comprising predicting a particle concentration of the patient fluid based at least in part on the measured optical characteristic.

39. The method of claim 1, further comprising predicting bleeding of the patient based at least in part on the measured optical characteristic.

40. The method of claim 1, further comprising predicting an immune response of the patient based at least in part on the measured optical characteristic.

41. The method of claim 1, further comprising predicting infection onset for ascites drainage patients based at least in part on the measured optical characteristic.

42. The method of claim 1, further comprising predicting a fibrin content of the patient fluid based at least in part on the measured optical characteristic.

43. A vessel for use in a fluid conduit, comprising:

an inlet portion;

an outlet portion; and

an optically transparent measurement portion between the inlet portion and the outlet portion, wherein the measurement portion comprises at least two substantially planar surfaces, a rotational alignment feature, and a depth alignment feature.

44. The vessel of claim 43, wherein the measurement portion comprises an internal volume configured to receive fluid, wherein the internal volume comprises radiused corners.

45. The vessel of claim 43, wherein the at least two substantially planar surfaces comprise a first planar surface generally orthogonal to a second planar surface.

46. The vessel of claim 43, wherein the at least two substantially planar surfaces comprise a first planar surface opposite to a second planar surface.

47. The vessel of claim 46, wherein the measurement portion comprises a generally square cross-section.

48. The vessel of claim 43, wherein at least a portion of the measurement portion is tapered.

49. The vessel of claim 43, wherein the measurement portion comprises one or more of copolyester, acrylonitrile butadiene styrene, polycarbonate, acrylic, cyclic olefin copolymer, cyclic olefin polymer, polyester, polystyrene, ultem, polyethylene glycol-coated silicone, zwitterionic coated polyurethane, polyethylene oxide-coated polyvinyl chloride, and polyamphiphilic silicone.

50. The vessel of claim 43, further comprising an opaque connector coupleable to the inlet portion or the outlet portion.

51. The vessel of claim 50, wherein at least one of the inlet portion and the outlet portion is coupleable to the fluid conduit.

52. The vessel of claim 51, further comprising one or more of a vent cap, clamp, and connector coupled to the fluid conduit.

53. The vessel of claim 51, wherein the vessel is coupled to a peritoneal dialysis drain set extension tubing.

54. The vessel of claim 51, wherein the vessel is coupled to a peritoneal dialysis cycler tubing cassette.

55. The vessel of claim 51, wherein the vessel is coupled to an inlet of a peritoneal dialysis cycler tubing cassette.

56. The vessel of claim 51, wherein the vessel is coupled to a peritoneal dialysis drain bag connector.

57. The vessel of claim 51, wherein the vessel is coupled to a proximal end of a peritoneal dialysis drain bag connector.

58. The vessel of claim 51, wherein the vessel is coupled to a urinary catheter or Foley catheter drain bag.

59. The vessel of claim 51, wherein the vessel is coupled to a central venous drain line.

60. The vessel of claim 51, wherein the vessel is coupled to a hemodialysis blood circulation tube set.

61. The vessel of claim 51, wherein the vessel is coupled to an in-dwelling catheter.

62. The vessel of claim 51, wherein the vessel is coupled to a proximal end of the in-dwelling catheter

63. A patient monitoring device, comprising:

a housing comprising:

a holder configured to releasably receive a portion of a fluid conduit;

at least one illumination source configured to illuminate the received portion of the fluid conduit; and

at least one optical sensor configured to generate a signal,

wherein the holder comprise one or more engagement features configured to orient the received portion of the fluid conduit in a predetermined rotational and vertical orientation relative to the at least one illumination source and the at least one optical sensor.

64. The device of claim 63, wherein the housing comprises a light seal.

65. The device of claim 63, wherein the one or more engagement features is configured to orient the received portion of the fluid conduit by mating with an alignment feature of the received portion of the fluid conduit.

66. The device of claim 63, wherein the one or more engagement features comprises an open slot.

67. The device of claim 63, wherein the at least one illumination source comprises a plurality of illumination sources.

68. The device of claim 67, wherein the illumination sources are configured to illuminate in a first illumination direction and a second illumination direction orthogonal to the first illumination direction.

69. The device of claim 67, wherein at least two of the illumination sources are configured to illuminate along a first plane at a first wavelength.

70. The device of claim 67, wherein at least another two of the illumination sources are configured to illuminate along a second plane substantially parallel to the first plane.

71. The device of claim 67, wherein the illumination sources are configured to illuminate in a first illumination direction and a second illumination direction opposite the first direction.

72. The device of claim 63, wherein the illumination sources are configured to illuminate in a first illumination direction and a second illumination direction 180 degrees offset from the first direction.

73. The device of claim 63, wherein the illumination sources comprise a first illumination source configured to emit light at a first wavelength between about 800 nm and about 900 nm.

74. The device of claim 63, wherein the illumination sources comprise a second illumination source configured to emit light at a second wavelength between about 400 nm and about 450 nm.

75. The device of claim 63, wherein the illumination sources comprise a third illumination source configured to emit light at a third wavelength between about 500 nm and about 550 nm.

76. The device of claim 63, wherein the illumination sources comprise a fourth illumination source configured to emit light at a third wavelength between about 230 nm and about 290 nm.

77. The device of claim 63, wherein the at least one optical sensor comprises a plurality of optical sensors.

78. The device of claim 63, wherein one or more of the at least one illumination source and the at least one optical sensor comprises an anti-reflective coating.

79. The device of claim 63, wherein the holder defines a longitudinal axis, and wherein the at least one optical sensor comprises a plurality of optical sensors spaced apart parallel to the longitudinal axis.

80. The device of claim 63, further comprising a controller configured to generate patient data based at least in part on the signal.

81. The device of claim 63, wherein the patient data comprises an infection state.

82. The device of claim 63, further comprising a display.

83. The device of claim 63, further comprising a base, wherein the housing is offset and spaced apart from the base.

84. The device of claim 63, wherein the housing comprises a peritoneal dialysis cycler.

85. The device of claim 63, wherein the housing comprises a hemodialysis device.

86. The device of claim 63, wherein the housing is configured to couple to one or more of a patient platform and medical cart.

87. The device of claim 63, wherein the housing comprises a peritoneal dialysis device fluid path.

88. The device of claim 63, wherein the fluid conduit is coupled to a peritoneal dialysis tubing set.

89. The device of claim 63, wherein the fluid conduit is coupled to a peritoneal dialysis cycler tubing set.

90. The device of claim 63, wherein the fluid conduit is coupled to a peritoneal dialysis drain bag connector.

91. The device of claim 63, wherein the fluid conduit comprises:

an inlet portion;

an outlet portion; and

an optically transparent measurement portion between the inlet portion and the outlet portion, wherein the measurement portion comprises at least two substantially planar surfaces, a rotational alignment feature, and a depth alignment feature.

92. The device of claim 91, wherein at least one of the rotational alignment feature and the depth alignment feature is configured to mate with the one or more engagement features of the holder.

93. The device of claim 63, further comprising a controller configured to generate patient data based at least in part on the signal.

94. The device of claim 63, wherein the controller is located remote from the housing, and wherein the device further comprises a communication device configured to transmit data representative of the signal to the controller.

95. The device of claim 94, wherein the controller is configured to predict an infection score of a patient based at least in part on the signal.

96. The device of claim 94, wherein the controller is configured to predict an infection state of a patient in response to any one or more of the following: the infection score exceeding a predetermined threshold during each of one or more successive measurement time periods, the infection score increasing from a patient baseline over time, and the infection score having an increasing rate of change over time.

97. The device of claim 96, wherein the infection state comprises a probability of infection.

98. The device of claim 94, wherein the fluid conduit is configured to receive a patient fluid and the controller is configured to estimate turbidity of the patient fluid based at least in part on the signal, wherein the infection score is based at least in part on the estimated turbidity.

99. The device of claim 94, wherein the controller is configured to monitor a trend in infection score predicting infection resolution of the patient.

100. The device of claim 94, wherein the controller is configured to monitor a trend in infection score predicting infection resolution of the patient by predicting infection resolution in response to any one or more of the following: the infection score falling below a predetermined threshold during each of one or more successive measurement time periods, the infection score decreasing from a patient baseline over time, and the infection score having a decreasing rate of change over time.

101. A method for remote monitoring of a patient, comprising:

at one or more processors:

receiving an optical characteristic measurement of a patient fluid associated with the patient over a remote communication link;

determining an infection score predicting infection of the patient, wherein the infection score is based at least in part on the received optical characteristic measurement; and

associating the patient as one of a plurality of patient infection states based at least in part on the determined infection score.

102. The method of claim 101, further comprising notifying a user of the associated patient infection state.

103. The method of claim 101, further comprising prompting a user to perform one or more predetermined patient treatment actions based on the associated patient infection state.

104. The method of claim 103, wherein the one or more predetermined patient treatment actions comprises administering a broad spectrum antimicrobial to the patient.

105. The method of claim 103, wherein the one or more predetermined patient treatment actions comprises administering a pathogen-specific antimicrobial to the patient.

106. The method of claim 103, wherein the one or more predetermined patient treatment actions comprises remotely monitoring a trend in infection score predicting infection resolution of the patient.

107. The method of claim 103, wherein remotely monitoring the trend in infection score predicting infection resolution comprises predicting infection resolution in response to the infection score decreasing from a patient baseline over time.

108. The method of claim 107, wherein remotely monitoring the trend in infection score predicting infection resolution comprises predicting infection resolution based on a rate of change of the infection score over time.

109. The method of claim 107, wherein remotely monitoring the trend in infection score predicting infection resolution comprises predicting infection resolution in response to any one or more of the following: the infection score falling below a predetermined threshold during each of one or more successive measurement time periods, the infection score decreasing from a patient baseline over time, and the infection score having a decreasing rate of change over time.

110. The method of claim 101, wherein the plurality of patient infection states comprises a first patient infection state corresponding to a healthy patient.

111. The method of claim 101, wherein the plurality of patient infection states comprises a second patient infection state corresponding to a patient brought to a medical care provider.

112. The method of claim 101, wherein the plurality of patient infection states comprises a third patient infection state corresponding to a patient who has received a broad spectrum antibiotic treatment.

113. The method of claim 101, wherein the plurality of patient infection states comprises a third patient infection state corresponding to a patient who has received a pathogen-specific antimicrobial treatment.

114. The method of claim 101, wherein the plurality of patient infection states comprises a fourth patient infection state corresponding to a patient who has been hospitalized.

115. The method of claim 101, wherein the plurality of patient infection states comprises a fifth patient infection state corresponding to a patient who has been transitioned to hemodialysis.

116. The method of claim 101, wherein the predicted infection is peritonitis.

CLAIMS

We claim:

1. A patient monitoring device, comprising:

a housing comprising:

a holder configured to releasably receive a portion of a fluid conduit;

at least one illumination source configured to illuminate the received portion of the fluid conduit; and

at least one optical sensor configured to generate a signal,

wherein the holder comprises one or more engagement features configured to orient the received portion of the fluid conduit in a predetermined rotational and vertical orientation relative to the at least one illumination source and the at least one optical sensor.

2. The device of claim 1, wherein the housing comprises a light seal.

3. The device of claim 1, wherein the one or more engagement features is configured to orient the received portion of the fluid conduit by mating with an alignment feature of the received portion of the fluid conduit.

4. The device of claim 1, wherein the one or more engagement features comprises an open slot.

5. The device of claim 1, wherein the at least one illumination source comprises a plurality of illumination sources.

6. The device of claim 5, wherein the illumination sources are configured to illuminate in a first illumination direction and a second illumination direction orthogonal to the first illumination direction.

7. The device of claim 5, wherein the illumination sources are configured to illuminate in a first illumination direction and a second illumination direction opposite the first direction.

8. The device of claim 5, wherein at least two of the illumination sources are configured to illuminate along a first plane at a first wavelength band.

9. The device of claim 5, wherein at least another two of the illumination sources are configured to illuminate along a second plane substantially parallel to the first plane.

10. The device of claim 5, wherein the illumination sources comprise a first illumination source configured to emit light at a first centered wavelength band between about 800 nm and about 900 nm.

11. The device of claim 5, wherein the illumination sources comprise a second illumination source configured to emit light at a second centered wavelength band between about 400 nm and about 450 nm.

12. The device of claim 5, wherein the illumination sources comprise a third illumination source configured to emit light at a third centered wavelength band between about 500 nm and about 550 nm.

13. The device of claim 5, wherein the illumination sources comprise a fourth illumination source configured to emit light at a fourth centered wavelength band between about 230 nm and about 290 nm.

14. The device of claim 1, wherein the at least one optical sensor comprises a plurality of optical sensors.

15. The device of claim 1, wherein the housing comprises one or more collimators comprising an anti-reflective coating.

16. The device of claim 1, wherein the housing comprises a peritoneal dialysis cycler.

17. The device of claim 1, wherein the housing comprises a hemodialysis device.

18. The device of claim 1, wherein the housing comprises a peritoneal dialysis device fluid path.

19. The device of claim 1, wherein the fluid conduit is coupled to a peritoneal dialysis tubing set.

20. The device of claim 1, wherein the fluid conduit is coupled to a peritoneal dialysis cycler tubing set.

21. The device of claim 1, wherein the fluid conduit is coupled to a peritoneal dialysis drain bag connector.

22. The device of claim 1, wherein the fluid conduit comprises:

an inlet portion;

an outlet portion; and

an optically transparent measurement portion between the inlet portion and the outlet portion, wherein the measurement portion comprises at least two substantially planar surfaces, a rotational alignment feature, and a depth alignment feature.

23. The device of claim 22, wherein at least one of the rotational alignment feature and the depth alignment feature is configured to mate with the one or more engagement features of the holder.

24. The device of claim 1, further comprising a controller configured to generate patient data based at least in part on the signal.

25. The device of claim 24, wherein the controller is located remote from the housing, and wherein the device further comprises a communication device configured to transmit data representative of the signal to the controller.

26. The device of claim 25, wherein the controller is configured to predict an infection score of a patient based at least in part on the signal.

27. The device of claim 25, wherein the controller is configured to predict an infection state of a patient in response to any one or more of the following: the infection score exceeding a predetermined threshold during each of one or more successive measurement time periods, the infection score increasing from a patient baseline over time, and the infection score having an increasing rate of change over time.

28. The device of claim 27, wherein the infection state comprises a probability of infection.

29. The device of claim 25, wherein the fluid conduit is configured to receive a patient fluid and the controller is configured to estimate turbidity of the patient fluid based at least in part on the signal, wherein the infection score is based at least in part on the estimated turbidity.

30. The device of claim 25, wherein the controller is configured to monitor a trend in infection score predicting infection resolution of the patient.

31. The device of claim 25, wherein the controller is configured to monitor a trend in infection score predicting infection resolution of the patient by predicting infection resolution in response to any one or more of the following: the infection score falling below a predetermined threshold during each of one or more successive measurement time periods, the infection score decreasing from a patient baseline over time, and the infection score having a decreasing rate of change over time.

32. The device of claim 30, wherein the controller is configured to estimate fluid flow rate in the fluid conduit based at least in part on the measured optical characteristic, wherein illuminating the fluid conduit comprises activating illumination in response to the estimated fluid flow rate.