CLAIMS

1. A system for detecting dislodgment of a catheter or needle in a vascular access comprising a first and second catheter or needle in a blood vessel, fistula or graft, the system comprising:

a first line fluidly connecting the first catheter or needle to an inlet of a pump;

a second line fluidly connecting the second catheter or needle to an outlet of the pump;

a first connector connecting the first line to the first catheter or needle, and a second connector connecting the second line to the second catheter or needle, each connector having an electrode in fluid communication with a fluid-carrying lumen of said connector;

an electronic circuit electrically connected to the electrodes of the first and second connectors, and configured to measure electrical impedance of fluid between the first connector and the second connecter via a conductive path through the blood vessel, fistula or graft;

a controller configured to receive a series of sampled electrical impedance values from the electronic circuit, and to process the electrical impedance values as a signal; wherein the controller is configured to:

sample and filter or smooth the signal using a first time constant, yielding a first filtered signal;

sample and filter or smooth the signal using a second longer time constant, yielding a second filtered signal;

provisionally set a disconnection flag and initiate a counter if at a point in time the difference between the first filtered signal and the second filtered signal is greater than a first threshold value;

clear the disconnection flag if the difference between the first filtered signal and the second filtered signal decreases to less than a second lower threshold value before the counter has reached a pre-determined count; and

declare a vascular disconnection if the disconnection flag is not cleared before the counter has reached the pre-determined count;

said declaration causing the controller to activate one or more mechanical line occluders to stop a flow of fluid in the first and second lines, stop the pump, or notify a user of the occurrence of a possible vascular disconnection.

2. The system of claim 1, wherein the counter counts units of time, and the pre-determined count is a pre-determined time interval.

3. The system of claim 1, wherein the counter counts units of blood volume pumped to the vascular access and the pre-determined count is a pre-determined volume of blood.

4. The system of claim 1, wherein the counter counts strokes of the pump and the pre-determined count is a pre-determined number of strokes.

5. The system of claim 1, wherein the signal is a time derivative of the electrical impedance values.

6. The system of claim 1, wherein the controller stops processing the electrical impedance values if the pump stops pumping fluid through the first and second lines.

7. The system of claim 1, wherein notification of the user comprises requesting that the user verify the position of the first and second catheters or needles at the vascular access.

8. The system of claim 7, wherein the controller is configured to receive from the user a command to resume operation of the pump or to discontinue further operation of the pump.

9. The system of claim 8, wherein operation of the pump comprises extracorporeal circulation of a portion of the user’s blood.

10. The system of claim 8, wherein the controller is configured to raise the first threshold value if a plurality of declarations of a vascular disconnection are each followed by a user command to resume operation of the pump.

11. The system of claim 1, wherein the controller continues to process the electrical impedance values if a declaration of a vascular disconnection is made and the mechanical line occluders are activated, and wherein the controller is configured to confirm a vascular disconnection if the difference between the first filtered signal and the second filtered signal exceeds a third threshold value that is greater than the first threshold value.

12. A system for detecting dislodgment of a catheter or needle in a vascular access comprising a first and second catheter or needle in a blood vessel, fistula or graft, the system comprising:

a first line fluidly connecting the first catheter or needle to an inlet of a pump;

a second line fluidly connecting the second catheter or needle to an outlet of the pump;

a first connector connecting the first line to the first catheter or needle, and a second connector connecting the second line to the second catheter or needle, each connector having an electrode in fluid communication with a fluid-carrying lumen of said connector;

an electronic circuit electrically connected to the electrodes of the first and second connectors, and configured to measure electrical impedance of fluid between the first connector and the second connecter via a conductive path through the blood vessel, fistula or graft;

a controller configured to receive a series of sampled electrical impedance values from the electronic circuit, and to process the electrical impedance values as a signal; wherein the controller is configured to:

provisionally set a disconnection flag and initiate a counter if at a point in time the signal is greater than a first threshold value;

clear the disconnection flag if the signal decreases to less than a second lower threshold value before the counter has reached a pre-determined count; and

declare a vascular disconnection if the disconnection flag is not cleared before the counter has reached the pre-determined count,

wherein the signal is a difference between a first filtered value of the impedance values using a first time constant and a second filtered value of the impedance values using a second longer time constant.

13. The system of claim 12, wherein the counter counts units of time, and the pre-determined count is a pre-determined time interval.

14. The system of claim 12, wherein the counter counts units of blood volume pumped to the vascular access and the pre-determined count is a pre-determined volume of blood.

15. The system of claim 12, wherein the counter counts strokes of the pump and the pre-determined count is a pre-determined number of strokes.

16. The system of claim 12, wherein the controller stops processing the electrical impedance values if the pump stops pumping fluid through the first and second lines.

17. The system of claim 12, wherein said declaration causes the controller to activate one or more mechanical line occluders to stop a flow of fluid in the first and second lines, stop the pump, or notify a user of the occurrence of a vascular disconnection.

18. The system of claim 17, wherein notification of the user comprises requesting that the user verify the position of the first and second catheters or needles at the vascular access.

19. The system of claim 18, wherein the controller is configured to receive from the user a command to resume operation of the pump or to discontinue further operation of the pump.

20. The system of claim 19, wherein operation of the pump comprises extracorporeal circulation of a portion of the user’s blood.

21. The system of claim 19, wherein the controller is configured to raise the first threshold value if a plurality of declarations of a vascular disconnection are each followed by a user command to resume operation of the pump.

22. The system of claim 12, wherein the controller continues to process the electrical impedance values if a declaration of a vascular disconnection is made and the mechanical line occluders are activated, and wherein the controller is configured to confirm a vascular disconnection if the signal exceeds a third threshold value that is greater than the first threshold value.

23. The system of claim 12, wherein the first threshold value and the second threshold value are based on a filtered value of the electrical impedance values.

24. A system for detecting dislodgment of a catheter or needle in a vascular access comprising a first and second catheter or needle in a blood vessel, fistula or graft, the system comprising:

a first line fluidly connecting the first catheter or needle to an inlet of a pump;

a second line fluidly connecting the second catheter or needle to an outlet of the pump;

a first connector connecting the first line to the first catheter or needle, and a second connector connecting the second line to the second catheter or needle, each connector having an electrode in fluid communication with a fluid-carrying lumen of said connector;

an electronic circuit electrically connected to the electrodes of the first and second connectors, and configured to measure electrical impedance of fluid between the first connector and the second connecter via a conductive path through the blood vessel, fistula or graft;

a controller configured to receive a series of sampled electrical impedance values from the electronic circuit, and to process the electrical impedance values as a signal; wherein the controller is configured to:

sample and filter or smooth the signal using a first time constant, yielding a first filtered signal;

sample and filter or smooth the signal using a second longer time constant, yielding a second filtered signal;

set a disconnection flag if at a point in time the difference between the first filtered signal and the second filtered signal is greater than a first threshold value; and

declare a vascular disconnection causing the controller to activate one or more mechanical line occluders to stop a flow of fluid in the first and second lines, stop the pump, or notify a user of the occurrence of a possible vascular disconnection.

25. The system of claim 24, wherein the signal is a time derivative of the electrical impedance values.

26. The system of claim 24, wherein the controller stops processing the electrical impedance values if the pump stops pumping fluid through the first and second lines.

27. The system of claim 24, wherein notification of the user comprises requesting that the user verify the position of the first and second catheters or needles at the vascular access.

28. The system of claim 27, wherein the controller is configured to receive from the user a command to resume operation of the pump or to discontinue further operation of the pump.

29. The system of claim 28, wherein operation of the pump comprises extracorporeal circulation of a portion of the user's blood.

30. The system of claim 28, wherein the controller is configured to raise the first threshold value if a plurality of declarations of a vascular disconnection are each followed by a user command to resume operation of the pump.

31. The system of claim 24, wherein the controller continues to process the electrical impedance values if a declaration of a vascular disconnection is made and the mechanical line occluders are activated, and wherein the controller is configured to confirm a vascular disconnection if the difference between the first filtered signal and the second filtered signal exceeds a third threshold value that is greater than the first threshold value.

32. A system for detecting dislodgment of a catheter or needle in a vascular access comprising a first and second catheter or needle in a blood vessel, fistula or graft, the system comprising:

a first line fluidly connecting the first catheter or needle to an inlet of a reciprocating positive displacement pump;

a second line fluidly connecting the second catheter or needle to an outlet of the pump;

a first connector connecting the first line to the first catheter or needle, and a second connector connecting the second line to the second catheter or needle, each connector having an electrode in fluid communication with a fluid-carrying lumen of said connector;

an electronic circuit electrically connected to the electrodes of the first and second connectors, and configured to measure electrical impedance of fluid between the first connector and the second connecter via a conductive path through the blood vessel, fistula or graft;

a controller configured to receive a series of sampled electrical impedance values from the electronic circuit, and to process the electrical impedance values as a signal; wherein the controller is configured to:

sample and filter or smooth the signal using a first time constant, yielding a first filtered signal;

sample and filter or smooth the signal using a second longer time constant, yielding a second filtered signal;

initiate a counter and set a provisional disconnection flag if a difference between the first filtered signal and the second filtered signal exceeds a first threshold value;

temporarily clear the provisional disconnection flag if the difference between the first filtered signal and the second filtered signal drops below a second lower threshold value before the counter reaches a preset count;

command an actuator of the pump to apply a force to a pumping chamber of the pump to complete a fluid delivery stroke to the first or second catheter or needle;

command the actuator to apply a reduced force to the pumping chamber; and

declare an access disconnection if the difference between the first filtered signal and the second filtered signal exceeds a third threshold value that is equal to or greater than the first threshold value.