CLAIMS

1. A system comprising:

a catheter apparatus, the catheter apparatus having a single expandable membrane;

a pressure control system configured to regulate the expansion of the expandable membrane with a liquid such that the expandable membrane is expanded with the liquid with a pressure of less than 5 ATM (507 kPa); and,

a cooling element configured to establish a temperature of between +15°C (288K) and -35°C (238K) at an interface between the expandable membrane and a blood vessel when the catheter apparatus has been placed in the blood vessel.

2. A system according to claim 1, wherein the cooling element is selected from the group consisting of: a refrigerant; endothermic reaction components; a thermoelectric cooler; and combinations thereof.

3. A system according to claim 1 or 2, further comprising a temperature control system configured to monitor temperature and adjust the cooling element to maintain the interface temperature between +15°C (288K) and -35°C (238K).

4. A system according to any preceding claim, wherein the expandable membrane is configured to contain fluid, the system further comprising a fluid supply for supplying fluid to the expandable membrane and wherein the pressure control system is configured to regulate the pressure of the fluid supply such that the expandable membrane is expanded with a pressure of less than 5 ATM (507 kPa).

5. A system according to any preceding claim, further comprising a vacuum pump positioned in a return line between the expandable membrane and a fluid reservoir.

6. A system according to claim 4, further comprising a connection apparatus adapted to cool a refrigerant supply line by a separate refrigerant line from the fluid supply.

7. A method of supplying cryoenergy to a plaque within a blood vessel, comprising:

expanding an expandable membrane of a catheter apparatus with a pressure of less than 5 ATM (507 kPa), the catheter apparatus having been placed in thermal contact with the plaque within the blood vessel; and,

establishing a temperature of between +15°C (288K) and -35°C (238K) at an interface of the expandable membrane and the blood vessel.

8. A method of modifying the structure of a plaque within a blood vessel, comprising:

positioning a catheter apparatus in proximity to the plaque within the blood vessel;

expanding an expandable membrane of a catheter apparatus with a pressure of less than 5 ATM (507 kPa); and,

establishing a temperature of between +15°C (288K) and -35°C (238K) at an interface between the expandable membrane and the blood vessel.

9. A method according to claim 7, wherein the catheter apparatus has a single expandable membrane.

10. A method according to any of claims 7 to 9, wherein the expandable membrane is compliant with the blood vessel.

11. A method according to any of claims 7 to 9, wherein the expandable membrane is semi-compliant with the blood vessel.

12. A method according to any of claims 7 to 9, wherein the expandable membrane is non-compliant with the blood vessel.

13. A method according to any preceding claim, wherein the expandable membrane has a substantially smooth exterior surface.

14. A method according to any preceding claim, further comprising determining expandable membrane characteristics using a sensor provided with the catheter apparatus.

15. A method according to any preceding claim, further comprising imaging the catheter apparatus, wherein the expandable membrane comprises a radio opaque substance.

16. A method according to any preceding claim, wherein the expandable membrane is expanded with a pressure of less than 4 ATM (405 kPa).

17. A method according to claim 16, wherein the expandable membrane is expanded with a pressure of less than 3 ATM (304 kPa).

18. A method according to claim 17, wherein the expandable membrane is expanded with a pressure of less than 2 ATM (203 kPa).

19. A method according to claim 18, wherein the expandable membrane is expanded with a pressure of less than or approximately equal to 1 ATM (101 kPa).

20. A method according to any preceding claim, wherein the expandable membrane is configured to contain refrigerant and wherein the act of establishing a temperature comprises supplying refrigerant to the expandable membrane.

21. A method according to claim 20, wherein refrigerant inside the expandable membrane is maintained in a liquid state.

22. A method according to claim 21, wherein the refrigerant has a boiling point at atmospheric pressure above +37°C (310K), a freezing point at atmospheric pressure below -85°C (358K) and a dynamic viscosity at -85°C (188K) of below 10 cSt ($10x10^{-6}$ m^2/s).

23. A method according to any of claims 20 to 22, wherein refrigerant inside the expandable membrane is maintained at a temperature of between -25°C (248K) and -55°C (218K).

24. A method according to any of claims 20 to 23, wherein the refrigerant comprises a perfluorocarbon.

25. A method according to any of claims 20 to 24, further comprising determining refrigerant characteristics using a sensor provided with the catheter apparatus.

26. A method according to claim any of claims 20 to 25, further comprising imaging the refrigerant, wherein the refrigerant comprises a radio opaque substance.

27. A method according to claim 7 or 8, wherein the act of establishing a temperature comprises activating an endothermic reaction.

28. A method according to claim 27, wherein the endothermic reaction is activated by pressurising the expandable membrane.

29. A method according to claim 27, wherein the endothermic reaction is activated by expanding the expandable membrane.

30. A method according to claim 27, wherein the endothermic reaction is a reaction between one or more of the following pairs of compounds: water and ammonium nitrate; water and ammonium chloride; barium hydroxide octahydrate crystals and dry ammonium chloride; water and ammonium chloride; thionyl

chloride and cobalt(II) sulphate heptahydrate; water and potassium chloride; water and ammonium thiocyanate; ethanoic acid and sodium carbonate; and combinations thereof.

31. A method according to claim 7 or 8, wherein the temperature within the expandable membrane is maintained by a cooling element positioned proximate to the expandable membrane.

32. A method according to claim 31, wherein the cooling element comprises a thermoelectric cooling element.

33. A method according to claim 32, wherein the cooling element comprises a Peltier component.

34. A method according to any preceding claim, further comprising determining a state of occlusion of the blood vessel using a temperature sensor provided with the catheter apparatus.

35. A catheter apparatus for treating vulnerable plaque as described in reference to the figures.

36. A system for treating vulnerable plaque as described in reference to the figures.

37. A method of treating vulnerable plaque as described in reference to the figures.

38. A method of supplying cryoenergy to a plaque within a blood vessel to a pressure of less than 5 ATM (507 kPa) and the inside surface vessel to a temperature of between +15°C (288K) and -35°C (238K) such that it increases the level of collagen and the plaque is stabilized.

39. A cryomedical refrigerant system using a liquid refrigerant where the liquid is infused with gaseous bubbles in suspension and where the bubbles expand and burst within the heat transfer section to create a Joule Thomson effect cooling within the liquid refrigerant.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A system comprising:

a catheter apparatus, the catheter apparatus having a single expandable membrane;

a pressure control system configured to regulate the expansion of the expandable membrane using a liquid such that the expandable membrane is expanded with a pressure of less than 5 ATM (507 kPa);

a cooling element configured to establish a temperature of between +15°C (288K) and -35°C (238K) at an interface between the expandable membrane and a blood vessel when the catheter apparatus has been placed in the blood vessel;

and a temperature control system configured to monitor temperature at the interface and adjust the cooling element to maintain the interface temperature between +15°C (288K) and -35°C (238K).

2. A system according to claim 1, wherein the cooling element is selected from the group consisting of: a refrigerant; endothermic reaction components; a thermoelectric cooler; and combinations thereof.

3. A system according to any preceding claim, further comprising a vacuum pump positioned in a return line between the expandable membrane and a fluid reservoir.

4. A system according to any preceding claim, wherein the expandable membrane is compliant with the blood vessel.

5. A system according to any preceding claim, wherein the expandable membrane is semi-compliant with the blood vessel.

6. A system according to any preceding claim, wherein the expandable membrane is non-compliant with the blood vessel.

7. A system according to any preceding claim, further comprising a temperature sensor provided for the catheter apparatus.

8. A method of operating a system for supplying cryoenergy, comprising:

expanding a single expandable membrane of a catheter apparatus using a liquid to a pressure of less than 5 ATM (507 kPa), the catheter apparatus having been placed in thermal contact with the plaque within the blood vessel; and,

establishing a temperature of between +15°C (288K) and -35°C (238K) at the expandable membrane.

9. A method according to claim 8, wherein the expandable membrane has a smooth exterior surface.

10. A method according to claim 8 or 9, further comprising determining expandable membrane characteristics using a sensor provided for the catheter apparatus.

11. A method according to any one of claims 8 to 10, wherein the expandable membrane is expanded with a pressure of less than 4 ATM (405 kPa).

12. A method according to claim 11, wherein the expandable membrane is expanded with a pressure of less than 3 ATM (304 kPa).

13. A method according to claim 11, wherein the expandable membrane is expanded with a pressure of less than 2 ATM (203 kPa).

14. A method according to claim 11, wherein the expandable membrane is expanded with a pressure of less than or equal to 1 ATM (101 kPa).

15. A method according to any one of claims 8 to 14, wherein the expandable membrane is configured to contain refrigerant and wherein the act of establishing a temperature comprises supplying refrigerant to the expandable membrane.

16. A method according to claim 15, wherein refrigerant inside the expandable membrane is maintained in a liquid state.

17. A method according to claim 16, wherein the refrigerant has a boiling point at atmospheric pressure above +370°C (310K), a freezing point at atmospheric pressure below -85°C (358K) and a dynamic viscosity at -85°C (188K) of below 10 cSt ($10x10^{-6}$ m^2/s).

18. A method according to one any of claims 15 to 17, wherein refrigerant inside the expandable membrane is maintained at a temperature of between -25°C (248K) and -55°C (218K).

19. A method according to any one of claims 15 to 18, wherein the refrigerant comprises a perfluorocarbon.