SUMMARY OF THE INVENTION

At its most general, the present invention proposes snare structures arranged to radiate microwave frequency energy (e.g. electromagnetic energy with a frequency of at least three orders of magnitude higher than typical RF energy) within the area encircled by the snare's loop. By controlling the shape of the emitted microwave field, the risk of collateral thermal damage can be reduced. For example, typical peak voltages in embodiments of the invention are 10 V or less. Moreover, the emitted microwave field can be more effective than an RF field at coagulating blood.

According to a first aspect of the invention there is provided a surgical snare comprising: a retractable loop of conductive material for encircling an area containing biological tissue; a radiating structure arranged to radiate microwave frequency energy into the area encircled by the retractable loop; and a coaxial cable for conveying microwave frequency energy to the radiating structure, the coaxial cable comprising an inner conductor, an outer conductor surrounding and coaxial with the inner conductor, and a dielectric material separating the inner conductor and the outer conductor, wherein the radiating structure comprises: an elongate conductive member connected to the inner conductor of the coaxial cable and being electrically insulated from the outer conductor of the coaxial cable, and a snare base at a distal end of the coaxial cable, the snare base having a feed channel for conveying a length of the conductive material that forms the retractable loop, wherein the elongate conductive member comprises a distal portion that protrudes into the area encircled by the retractable loop to act as a radiating microwave monopole antenna, and a proximal portion that extends through the snare base alongside the feed channel. With this radiating structure, microwave power may be launched into the area encircled by the retractable loop both via the radiating microwave monopole antenna and also via a travelling wave set up on the conductive material by coupling energy from the proximal portion of the elongate conductive element into the length of conductive material in feed channel. Thus, the radiated microwave field may be directed into biological

have a second opening at a side facing away from the area enclosed by the loop.

Features of the first aspect expressed above may also be incorporated into the second aspect.

Similarly to the first aspect, the second aspect of the invention may also be expressed as an electrosurgical apparatus comprising a microwave signal generator for outputting microwave frequency energy, and a surgical snare as described above in relation to the second aspect connected to receive the microwave frequency energy and deliver it through the coaxial cable to be emitting as a microwave frequency field by the curved conductive portion.

According to a third aspect of the invention, there is provided a surgical snare comprising: a retractable loop for encircling an area containing biological tissue; a radiating structure arranged to radiate microwave frequency energy into the area encircled by the retractable loop; and a coaxial cable for conveying microwave frequency energy to the radiating structure, the coaxial cable comprising an inner conductor, an outer conductor surrounding and coaxial with the inner conductor, and a dielectric material separating the inner conductor and the outer conductor, wherein the radiating structure comprises a conductive portion formed in or on the retractable loop, the conductive portion being connected to receive microwave power from the coaxial cable and configured to radiate the received microwave frequency energy into the area encircled by the retractable loop, and wherein the retractable loop comprises a wire having a first end fixed at the distal end of the coaxial cable, and a second end whose position relative to the distal end of the coaxial cable is adjustable, and wherein the conductive portion extends around the retractable loop from the first end.

The third aspect differs from the first and second aspect in that the radiating structure is actually part of the retractable loop itself. For example, part of the loop may be metallised, i.e. coating in a conductive material, and electrically connected to the inner conductor of the coaxial cable but electrically insulated from the outer conductor of the coaxial cable. The coaxial cable may include an insulating cap at its distal end. The inner conductor may protrude through the cap, but the outer conductor may be insulated by the cap from everything on the distal side of the cap. The protruding part of the inner conductor may be electrically connected to the conductive portion by crimping or the like.

To radiate efficiently into biological tissue, the electrical length of the conductive portion around the retractable loop may be $\frac{(2n-1)\lambda_L}{4}$, where λ_L is the wavelength of the microwave frequency energy when propagating through the biological tissue, and n is a positive integer. The length of the conductive portion may be determined using the technique described above with reference to the first aspect of the invention.

The coaxial cable or sleeve may provide a torque-stable cable capable of transferring a rotational movement effected at the proximal end of the device to the retractable loop. Rotation of the loop enables the snare to be easily position over and around a polyp. In this aspect, the outer jacket of the co-axial cable may be semi-rigid or a tube (catheter) may be inserted over the outer jacket and form a tight fit.

Alternatively, rotation of the retractable loop may be achieved using a mechanism located at the distal end of the cable that transforms a linear movement of the pull wire or the cable to a rotational movement of the loop to control the angle of the loop with respect to the stalk or stem of the polyp to enable the loop to be in the correct orientation to allow the loop to go around the polyp stalk. This linear to rotational translation may also be used to control the opening and closing (diameter) of the loop or the amount of loop that protrudes from the snare base.

In one embodiment, the conductive portion may be a "leaky feeder", i.e. a length of coaxial cable that is shorted at its distal end and along which portions of the outer conductor are periodically removed to permit radiation therefrom. The portions of removed outer conductor may be separated by a distance of $\frac{(2n-1)\lambda_L}{4}$, where λ_L is the wavelength of the microwave

CLAIMS

1. A surgical snare comprising:

a retractable loop of conductive material for encircling an area containing biological tissue;

a radiating structure arranged to radiate microwave frequency energy into the area encircled by the retractable loop; and

a coaxial cable for conveying microwave frequency energy to the radiating structure, the coaxial cable comprising an inner conductor, an outer conductor surrounding and coaxial with the inner conductor, and a dielectric material separating the inner conductor and the outer conductor,

wherein the radiating structure comprises:

an elongate conductive member connected to the inner conductor of the coaxial cable and being electrically insulated from the outer conductor of the coaxial cable, and

a snare base at a distal end of the coaxial cable, the snare base having a feed channel for conveying a length of the conductive material that forms the retractable loop,

wherein the elongate conductive member comprises a distal portion that protrudes into the area encircled by the retractable loop to act as a radiating microwave monopole antenna, and a proximal portion that extends through the snare base alongside the feed channel.

2. A surgical snare according to claim 1, wherein the electrical length of the elongate conductive member may be about $\frac{(2n-1)\lambda_L}{4}$, where λ_L is the wavelength of the microwave frequency energy along the proximal portion of the elongate conductive element, i.e. the wavelength in the snare base, and n is a positive integer.

3. A surgical snare according to claim 1 or 2, wherein the distal portion of the elongate conductive member is shaped to penetrate biological tissue.

4. A surgical snare according to any preceding claim, wherein the elongate conductive member is coated in a biocompatible material.

5. A surgical snare according to any preceding claim, wherein the snare base comprises an insulating disc.

6. A surgical snare according to any preceding claim, wherein the coaxial cable is encased in a sleeve suitable for insertion through the instrument channel of an endoscope.

7. A surgical snare according to claim 6, wherein the sleeve comprises a rotatable braided cable to permit adjustment of a orientation of the plane of the retractable loop.

8. A surgical snare according to any preceding claim, wherein the retractable loop comprises a wire that extends beyond the distal end of the coaxial cable, the wire being arranged to naturally adopt a looped shape between two ends located at the distal end of the coaxial cable.

9. A surgical snare according to claim 8, wherein the retractable loop is adjustable to vary the length of wire between the two ends.

10. A surgical snare according to any preceding claim, wherein the elongate conductive member is retractable independently of the retractable loop.

11. A surgical snare according to claim 10 including a cover mounted at the distal end of the coaxial cable, and slidable between a covering position in which it overlaps the elongate conductive member and a retracted position in which the elongate conductive member protrudes therefrom.

12. A surgical snare according to any preceding claim, wherein microwave frequency is in the range 1 GHz to 60 GHz.

13. Electrosurgical apparatus comprising:

a microwave signal generator for outputting microwave frequency energy having a frequency of 1 GHz or more, and

a surgical snare according to any preceding claim connected to receive the microwave frequency energy and

deliver it through the coaxial cable to be emitted as a microwave frequency field by the elongate conductive member.

14. A surgical snare comprising:

a retractable loop for encircling an area containing biological tissue;

a radiating structure arranged to radiate microwave frequency energy into the area encircled by the retractable loop; and

a coaxial cable for conveying microwave frequency energy to the radiating structure, the coaxial cable comprising an inner conductor, an outer conductor surrounding and coaxial with the inner conductor, and a dielectric material separating the inner conductor and the outer conductor,

wherein the radiating structure comprises a curved conductive portion partially bounding the area encircled by the retractable loop, the curved conductive portion being connected to the inner conductor of the coaxial cable and electrically insulated from the outer conductor of the coaxial cable to act as a radiating microwave monopole antenna.

15. A surgical snare according to claim 14, wherein the curved conductive portion extends between two ends, which are spaced at equal distances from a connection point at which the inner conductor of the coaxial cable is connected to the curved conductive portion.

16. A surgical snare according to claim 15, wherein the electrical length between the ends of the curved conductive portion is $\frac{(2n-1)\lambda_L}{4}$, where λ_L is the wavelength of the microwave frequency energy when propagating through the biological tissue, and n is a positive integer.

17. A surgical snare according to claim 15 or 16, wherein the electrical length of the curved conductive portion is 10 mm or more.

18. A surgical snare according to any one of claims 14 to 17, wherein the curved conductive portion comprises a pair

of flexible prongs extending from the distal end of the coaxial cable.

19. A surgical snare according to claim 18 having a tubular end cap mounted at the distal end of the coaxial cable, wherein the curved conductive portion and tubular end cap are movable relative to each other between:

a stored configuration in which the curved conductive portion is surrounded by the tubular end cap, and

a deployed configuration in which the curved conductive portion protrudes beyond a distal end of the tubular end cap.

20. A surgical snare according to claim 19, wherein the tubular end cap has an outer diameter less than 2.6 mm.

21. A surgical snare according to any one of claims 14 to 20, wherein the curved conductive portion comprises a guide for the retractable loop.

22. A surgical snare according to claim 21, wherein the guide comprises a hollow tubular section with an opening at one end thereof, wherein the retractable loop extends along the hollow tubular section and through the opening.

23. A surgical snare according to claim 22, wherein the opening of the hollow tubular section is at a first end of the curved conductive portion and wherein the retractable loop includes a wire that is fixed to a second end of the curved conductive portion.

24. Electrosurgical apparatus comprising:

a microwave signal generator for outputting microwave frequency energy having a frequency of 1 GHz or more, and

a surgical snare according to any one of claims 14 to 23 connected to receive the microwave frequency energy and deliver it through the coaxial cable to be emitted as a microwave frequency field by the curved conductive portion.

25. A surgical snare comprising:

a retractable loop for encircling an area containing biological tissue;

a radiating structure arranged to radiate microwave frequency energy into the area encircled by the retractable loop; and

a coaxial cable for conveying microwave frequency energy to the radiating structure, the coaxial cable comprising an inner conductor, an outer conductor surrounding and coaxial with the inner conductor, and a dielectric material separating the inner conductor and the outer conductor,

wherein the radiating structure comprises a conductive portion formed in or on the retractable loop, the conductive portion being connected to receive microwave power from the coaxial cable and configured to radiate the received microwave frequency energy into the area encircled by the retractable loop,

and wherein the retractable loop comprises a wire having a first end fixed at the distal end of the coaxial cable, and a second end whose position relative to the distal end of the coaxial cable is adjustable, and wherein the conductive portion extends around the retractable loop from the first end.

26. A surgical snare according to claim 25, wherein the electrical length of the conductive portion around the retractable loop is $\frac{(2n-1)\lambda_L}{4}$, where λ_L is the wavelength of the microwave frequency energy when propagating through the biological tissue, and n is a positive integer.

27. A surgical snare according to claim 25 or claim 26, wherein the conductive portion comprises a length of coaxial cable that is shorted at its distal end and along which portions of the outer conductor are periodically removed to permit radiation therefrom.

28. Electrosurgical apparatus comprising:

a microwave signal generator for outputting microwave frequency energy having a frequency of 1 GHz or more, and

a surgical snare according to any one of claims 25 to 27 connected to receive the microwave frequency energy and

deliver it through the coaxial cable to be emitting as a microwave frequency field by the conductive portion.

SUMMARY OF THE INVENTION

At its most general, the present invention proposes snare structures arranged to radiate microwave frequency energy (e.g. electromagnetic energy with a frequency of at least three orders of magnitude higher than typical RF energy) within the area encircled by the snare's loop. By controlling the shape of the emitted microwave field, the risk of collateral thermal damage can be reduced. For example, typical peak voltages in embodiments of the invention are 10 V or less. Moreover, the emitted microwave field can be more effective than an RF field at coagulating blood.

According to a first aspect of the invention there is provided a surgical snare comprising: a retractable loop of conductive material for encircling an area containing biological tissue; a radiating structure arranged to radiate microwave frequency energy into the area encircled by the retractable loop; and a coaxial cable for conveying microwave frequency energy to the radiating structure, the coaxial cable comprising an inner conductor, an outer conductor surrounding and coaxial with the inner conductor, and a dielectric material separating the inner conductor and the outer conductor, wherein the radiating structure comprises: an elongate conductive member connected to the inner conductor of the coaxial cable and being electrically insulated from the outer conductor of the coaxial cable, and a snare base at a distal end for the coaxial cable, the snare base having a feed channel for conveying a length of the conductive material that forms the retractable loop, wherein the elongate conductive member comprises a distal portion that protrudes into the area encircled by the retractable loop to act as a radiating microwave monopole antenna, and a proximal portion that extends through the snare base alongside the feed channel. With this radiating structure, microwave power may be launched into the area encircled by the retractable loop both via the radiating microwave monopole antenna and also via a travelling wave set up on the conductive material by coupling energy from the proximal portion of the elongate conductive element into the length of conductive material in feed channel. Thus, the radiated microwave field may be directed into biological

have a second opening at a side facing away from the area enclosed by the loop.

Features of the first aspect expressed above may also be incorporated into the second aspect.

Similarly to the first aspect, the second aspect of the invention may also be expressed as an electrosurgical apparatus comprising a microwave signal generator for outputting microwave frequency energy, and a surgical snare as described above in relation to the second aspect connected to receive the microwave frequency energy and deliver it through the coaxial cable to be emitting as a microwave frequency field by the curved conductive portion.

According to a third aspect of the invention, there is provided a surgical snare comprising: a retractable loop for encircling an area containing biological tissue; a radiating structure arranged to radiate microwave frequency energy into the area encircled by the retractable loop; and a coaxial cable for conveying microwave frequency energy to the radiating structure, the coaxial cable comprising an inner conductor, an outer conductor surrounding and coaxial with the inner conductor, and a dielectric material separating the inner conductor and the outer conductor, wherein the radiating structure comprises a conductive portion formed in or on the retractable loop, the conductive portion being connected to receive microwave power from the coaxial cable and configured to radiate the received microwave frequency energy into the area encircled by the retractable loop.

The third aspect differs from the first and second aspect in that the radiating structure is actually part of the retractable loop itself. For example, part of the loop may be metallised, i.e. coating in a conductive material, and electrically connected to the inner conductor of the coaxial cable but electrically insulated from the outer conductor of the coaxial cable. The coaxial cable may include an insulating cap at its distal end. The inner conductor may protrude through the cap, but the outer conductor may be insulated by the cap from everything on the distal side of the cap. The protruding part of the inner conductor may be electrically connected to the conductive portion by crimping or the like.

To radiate efficiently into biological tissue, the electrical length of the conductive portion around the retractable loop may be $\frac{(2n-1)\lambda_L}{4}$, where λ_L is the wavelength of the microwave frequency energy when propagating through the biological tissue, and n is a positive integer. The length of the conductive portion may be determined using the technique described above with reference to the first aspect of the invention.

In this aspect, the retractable loop may have a fixed end e.g. at the distal end of the coaxial cable, and an adjustable end, e.g. connected to a pull wire that may extend to a proximal end of the coaxial cable, where it is operable using a slider or the like. Similarly to the first and second aspects above, the snare may include a slidable end cap, although this is optional in this case because only the retractable loop may extend beyond the distal end of the coaxial cable.

The coaxial cable or sleeve may provide a torque-stable cable capable of transferring a rotational movement effected at the proximal end of the device to the retractable loop. Rotation of the loop enables the snare to be easily position over and around a polyp. In this aspect, the outer jacket of the co-axial cable may be semi-rigid or a tube (catheter) may be inserted over the outer jacket and form a tight fit.

Alternatively, rotation of the retractable loop may be achieved using a mechanism located at the distal end of the cable that transforms a linear movement of the pull wire or the cable to a rotational movement of the loop to control the angle of the loop with respect to the stalk or stem of the polyp to enable the loop to be in the correct orientation to allow the loop to go around the polyp stalk. This linear to rotational translation may also be used to control the opening and closing (diameter) of the loop or the amount of loop that protrudes from the snare base.

In one embodiment, the conductive portion may be a "leaky feeder", i.e. a length of coaxial cable that is shorted at its distal end and along which portions of the outer conductor are periodically removed to permit radiation therefrom. The portions of removed outer conductor may be separated by a distance of $\frac{(2n-1)\lambda_L}{4}$, where λ_L is the wavelength of the microwave

CLAIMS

1. A surgical snare comprising:

a retractable loop of conductive material for encircling an area containing biological tissue;

a radiating structure arranged to radiate microwave frequency energy into the area encircled by the retractable loop; and

a coaxial cable for conveying microwave frequency energy to the radiating structure, the coaxial cable comprising an inner conductor, an outer conductor surrounding and coaxial with the inner conductor, and a dielectric material separating the inner conductor and the outer conductor,

wherein the radiating structure comprises:

an elongate conductive member connected to the inner conductor of the coaxial cable and being electrically insulated from the outer conductor of the coaxial cable, and

a snare base at a distal end for the coaxial cable, the snare base having a feed channel for conveying a length of the conductive material that forms the retractable loop,

wherein the elongate conductive member comprises a distal portion that protrudes into the area encircled by the retractable loop to act as a radiating microwave monopole antenna, and a proximal portion that extends through the snare base alongside the feed channel.

2. A surgical snare according to claim 1, wherein the electrical length of the elongate conductive member may be about $\frac{(2n-1)\lambda_L}{4}$, where λ_L is the wavelength of the microwave frequency energy along the proximal portion of the elongate conductive element, i.e. the wavelength in the snare base, and n is a positive integer.

3. A surgical snare according to claim 1 or 2, wherein the distal portion of the elongate conductive member is shaped to penetrate biological tissue.

4. A surgical snare according to any preceding claim, wherein the elongate conductive member is coated in a biocompatible material.

5. A surgical snare according to any preceding claim, wherein the snare base comprises an insulating disc.

6. A surgical snare according to any preceding claim, wherein the coaxial cable is encased in a sleeve suitable for insertion through the instrument channel of an endoscope.

7. A surgical snare according to claim 6, wherein the sleeve comprises a rotatable braided cable to permit adjustment of a orientation of the plane of the retractable loop.

8. A surgical snare according to any preceding claim, wherein the retractable loop comprises a wire that extends beyond the distal end of the coaxial cable, the wire being arranged to naturally adopt a looped shape between two ends located at the distal end of the coaxial cable.

9. A surgical snare according to claim 8, wherein the retractable loop is adjustable to vary the length of wire between the two ends.

10. A surgical snare according to any preceding claim, wherein the elongate conductive member is retractable independently of the retractable loop.

11. A surgical snare according to claim 10 including a cover mounted at the distal end of the coaxial cable, and slidable between a covering position in which it overlaps the elongate conductive member and a retracted position in which the elongate conductive member protrudes therefrom.

12. A surgical snare according to any preceding claim, wherein microwave frequency is in the range 1 GHz to 60 GHz.

13. Electrosurgical apparatus comprising:

a microwave signal generator for outputting microwave frequency energy having a frequency of 1 GHz or more, and

a surgical snare according to any preceding claim connected to receive the microwave frequency energy and

deliver it through the coaxial cable to be emitted as a microwave frequency field by the elongate conductive member.

14. A surgical snare comprising:

a retractable loop for encircling an area containing biological tissue;

a radiating structure arranged to radiate microwave frequency energy into the area encircled by the retractable loop; and

a coaxial cable for conveying microwave frequency energy to the radiating structure, the coaxial cable comprising an inner conductor, an outer conductor surrounding and coaxial with the inner conductor, and a dielectric material separating the inner conductor and the outer conductor,

wherein the radiating structure comprises a curved conductive portion partially bounding the area encircled by the retractable loop, the curved conductive portion being connected to the inner conductor of the coaxial cable and electrical insulated from the outer conductor of the coaxial cable to act as a radiating microwave monopole antenna.

15. A surgical snare according to claim 14, wherein the curved conductive portion extends between two ends, which are spaced at equal distances from a connection point at which the inner conductor of the coaxial cable is connected to the curved conductive portion.

16. A surgical snare according to claim 15, wherein the electrical length between the ends of the curved conductive portion is $\frac{(2n-1)\lambda_L}{4}$, where λ_L is the wavelength of the microwave frequency energy when propagating through the biological tissue, and n is a positive integer.

17. A surgical snare according to claim 15 or 16, wherein the electrical length of the curved conductive portion is 10 mm or more.

18. A surgical snare according to any one of claims 14 to 17, wherein the curved conductive portion comprises a pair

of flexible prongs extending from the distal end of the coaxial cable.

19. A surgical snare according to claim 18 having a tubular end cap mounted at the distal end of the coaxial cable, wherein the curved conductive portion and tubular end cap are movable relative to each other between:

a stored configuration in which the curved conductive portion is surrounded by the tubular end cap, and

a deployed configuration in which the curved conductive portion protrudes beyond a distal end of the tubular end cap.

20. A surgical snare according to claim 19, wherein the tubular end cap has an outer diameter less than 2.6 mm.

21. A surgical snare according to any one of claims 14 to 20, wherein the curved conductive portion comprises a guide for the retractable loop.

22. A surgical snare according to claim 21, wherein the guide comprises a hollow tubular section with an opening at one end thereof, wherein the retractable loop extends along the hollow tubular section and through the opening.

23. A surgical snare according to claim 22, wherein the opening of the hollow tubular section is at a first end of the curved conductive portion and wherein the retractable loop includes a wire that is fixed to a second end of the curved conductive portion.

24. Electrosurgical apparatus comprising:

a microwave signal generator for outputting microwave frequency energy having a frequency of 1 GHz or more, and

a surgical snare according to any one of claims 14 to 23 connected to receive the microwave frequency energy and deliver it through the coaxial cable to be emitted as a microwave frequency field by the curved conductive portion.

25. A surgical snare comprising:

a retractable loop for encircling an area containing biological tissue;

a radiating structure arranged to radiate microwave frequency energy into the area encircled by the retractable loop; and

a coaxial cable for conveying microwave frequency energy to the radiating structure, the coaxial cable comprising an inner conductor, an outer conductor surrounding and coaxial with the inner conductor, and a dielectric material separating the inner conductor and the outer conductor,

wherein the radiating structure comprises a conductive portion formed in or on the retractable loop, the conductive portion being connected to receive microwave power from the coaxial cable and configured to radiate the received microwave frequency energy into the area encircled by the retractable loop.

26. A surgical snare according to claim 25, wherein the electrical length of the conductive portion around the retractable loop is $\frac{(2n-1)\lambda_L}{4}$, where λ_L is the wavelength of the microwave frequency energy when propagating through the biological tissue, and n is a positive integer.

27. A surgical snare according to claim 25 or 26, wherein the retractable loop comprises a wire having a first end fixed at the distal end of the coaxial cable, and a second end whose position relative to the distal end of the coaxial cable is adjustable, and wherein the conductive portion extends around the retractable loop from the first end.

28. A surgical snare according to any one of claims 25 to 27, wherein the conductive portion comprises a length of coaxial cable that is shorted at its distal end and along which portions of the outer conductor are periodically removed to permit radiation therefrom.

29. Electrosurgical apparatus comprising:

a microwave signal generator for outputting microwave frequency energy having a frequency of 1 GHz or more, and

a surgical snare according to any one of claims 25 to 28 connected to receive the microwave frequency energy and

deliver it through the coaxial cable to be emitting as a microwave frequency field by the conductive portion.