with conductive fluid (e.g., using a relatively low pressure of 2-4 atm) so that the balloon expands to contact the lesion but not to a degree that substantively displaces the lesion. Voltage pulses can then be applied across the electrodes of electrode pairs to produce acoustic shock waves that propagate through the walls of the angioplasty balloon and into the lesions. Once the lesions have been cracked by the acoustic shock waves, the balloon can be expanded further to increase the cross-sectional area of the lumen and improve blood flow through the lumen. Alternative devices to deliver IVL therapy can include electrodes disposed within a closed volume other than an angioplasty balloon, such as a cap, balloons of variable compliancy, or other type of enclosure.

**[0009]** In particular, a slimmer profile at the distal end of the catheter may be desired for improved deliverability and navigability. However, greatly reducing the distal end profile may negatively affect performance, such as sonic output uniformity along a length of an IVL catheter's treatment region, which is generally preferred for shock wave devices.

## SUMMARY

**[0010]** According to aspects of the disclosure, a catheter for treating a lesion in a body lumen includes: an elongate member extending from a proximal region of the catheter to a distal region of the catheter; a distal shock wave emitter having a distal outer diameter and located at the distal region of the catheter, wherein the distal shock wave emitter is the distal most shock wave emitter; a proximal shock wave emitter having a proximal outer diameter greater than the distal outer diameter and located proximally of the distal shock wave emitter, wherein the proximal shock wave emitter is the proximal most shock wave emitter; and an enclosure. The enclosure may include: a central region surrounding the distal shock wave emitter and the proximal shock wave emitter; a proximal region proximal of the central region and having a proximal leg portion and a proximal tapering portion connecting the proximal region and the central region; and a distal region distal of the central region and having a distal leg portion and a distal tapering portion connecting the distal region and the central region. The enclosure, in some embodiments, is an angioplasty balloon.

**[0011]** The difference between the distal outer diameter and the proximal outer diameter may be at least 0.001 inch (0.0254 mm).

**[0012]** The difference between the distal outer diameter and proximal outer diameter may be least 0.0015 inch (0.0381 mm).

**[0013]** The distal outer diameter may be at most 98% of the proximal outer diameter.

**[0024]** When the enclosure is filled with a fluid to a pressure between 0.5 atm and 5 atm, the central region may taper in diameter. The fluid may include a saline solution, a fluoroscopic contrast solution, or a mixture of saline and contrast solution.

**[0025]** According to aspects of the disclosure, a shock wave catheter for treating a lesion in a body lumen with shock waves includes: an elongate member extending from a proximal region of the catheter to a distal region of the catheter; a plurality of shock wave emitters located at the distal region of the catheter; and an enclosure. The enclosure may include: a distal portion; a proximal portion; and a central portion located between the distal portion and the proximal portion and surrounding the plurality of shock wave emitters. In a first configuration, the enclosure is substantially collapsed, and a proximal outer diameter of the catheter at a proximal side of the central portion may be greater than a distal outer diameter of the catheter at a distal side of the central portion. In a second configuration, the enclosure is inflated with a fluid, and the proximal outer diameter of the catheter may be no less than the distal outer diameter.

**[0026]** In the first configuration, the difference between the distal outer diameter and the proximal outer diameter may be at least 0.2 mm.

**[0027]** In the first configuration, the difference between the distal outer diameter and proximal outer diameter may be at least 0.4 mm.

**[0028]** In the first configuration, the distal outer diameter may be no greater than 98% of the proximal outer diameter.

**[0029]** In the first configuration, the distal outer diameter may be no greater than 97.5% of the proximal outer diameter.

**[0030]** The plurality of shock wave emitters may further include a proximal shock wave emitter and a distal shock wave emitter, wherein a longitudinal distance from a center of the distal shock wave emitter to a center of the proximal shock wave emitter is no less than 6 mm.

**[0031]** The longitudinal distance from the center of the distal shock wave emitter to the center of the proximal shock wave emitter may be at least than 7 mm.

**[0032]** The distal shock wave emitter may include a distal electrode pair and the proximal shock wave emitter may include a proximal electrode pair.

**[0033]** The distal electrode pair may include a distal outer electrode and a distal inner electrode and the proximal electrode pair may include a proximal outer electrode and a proximal inner electrode. An outer diameter of the distal outer electrode may be less than an outer diameter of the proximal outer electrode.

**[0034]** The distal shock wave emitter and the proximal shock wave emitter may be independently wired to a voltage pulse generator.

**[0035]** The plurality of shock wave emitters may include four distal shock wave emitters and four proximal shock wave emitters.

**[0036]** According to aspects of the disclosure, a shock wave catheter includes: an elongate member extending form a proximal region of the catheter to a distal region of the catheter; a distal shock wave emitter including a distal inner band and a distal outer band having a distal outer diameter, wherein the distal shock wave emitter is the distal most shock wave emitter; and a proximal shock wave emitter including a proximal inner band and a proximal outer band having a proximal outer diameter greater than the distal outer diameter, wherein the proximal shock wave emitter is the proximal most shock wave emitter.

**[0037]** The distal inner band may be thinner than the proximal inner band.

**[0038]** The distal inner band may have the same thickness as the proximal inner band.

**[0039]** The distal shock wave emitter may include a distal insulative layer, the proximal shock wave emitter may include a proximal insulative layer, and the distal insulative layer may be thinner than the proximal insulative layer.

**[0040]** The distal shock wave emitter may include a distal insulative layer, the proximal shock wave emitter may include a proximal insulative layer, and the distal insulative layer may be the same thickness as the proximal insulative layer.

## DESCRIPTION OF THE FIGURES

**[0041]** Illustrative aspects of the present disclosure are described in detail below with reference to the following figures. It is intended that the embodiments and figures disclosed herein are to be considered illustrative and exemplary rather than restrictive.

## CLAIMS

1. A catheter for treating a lesion in a body lumen, the catheter comprising:

an elongate member extending from a proximal region of the catheter to a distal region of the catheter;

a distal shock wave emitter having a distal outer diameter and located at the distal region of the catheter, wherein the distal shock wave emitter is the distal most shock wave emitter;

a proximal shock wave emitter having a proximal outer diameter greater than the distal outer diameter and located proximally of the distal shock wave emitter, wherein the proximal shock wave emitter is the proximal most shock wave emitter; and

an enclosure having:

a central region surrounding the distal shock wave emitter and the proximal shock wave emitter;

a proximal region proximal of the central region and having a proximal leg portion and a proximal tapering portion connecting the proximal region and the central region; and

a distal region distal of the central region and having a distal leg portion and a distal tapering portion connecting the distal region and the central region.

2. The catheter of claim 1, wherein the difference between the distal outer diameter and the proximal outer diameter is at least 0.0254 mm.

3. The catheter of claim 1 or 2, wherein the difference between the distal outer diameter and proximal outer diameter is at least 0.0381 mm.

4. The catheter of any one of claims 1-3, wherein the distal outer diameter is at most 98% of the proximal outer diameter.

5. The catheter of any one of claims 1-4, wherein the distal outer diameter is at most 97.5% of the proximal outer diameter.

6. The catheter of any one of claims 1-5, wherein a longitudinal distance from a center of the distal shock wave emitter to a center of the proximal shock wave emitter is no less than 6 mm.

7. The catheter of claim 6, wherein the longitudinal distance from the center of the distal shock wave emitter to the center of the proximal shock wave emitter is at least 7 mm.

8. The catheter of any one of claims 1-7, wherein the distal shock wave emitter comprises a distal electrode pair and the proximal shock wave emitter comprises a proximal electrode pair.

9. The catheter of claim 8, wherein:

the distal electrode pair comprises a distal outer electrode and a distal inner electrode and the proximal electrode pair comprises a proximal outer electrode and a proximal inner electrode, and

an outer diameter of the distal outer electrode is less than an outer diameter of the proximal outer electrode.

10. The catheter of any one of claims 1-9, wherein the distal shock wave emitter and the proximal shock wave emitter are independently wired to a voltage pulse generator.

11. The catheter of any one of claims 1-10, further comprising a distal conductor that extends from a voltage pulse generator to the distal shock wave emitter and a proximal conductor that extends from the voltage pulse generator to the proximal shock wave emitter and not the distal shock wave emitter.

12. The catheter of any one of claims 1-11, further comprising an intermediate shock wave emitter having an intermediate outer diameter greater than the distal outer diameter and less than the proximal outer diameter and located proximally of the distal shock wave emitter.

13. The catheter of any one of claims 1-12, wherein the catheter comprises four distal shock wave emitters and four proximal shock wave emitters.

14. The catheter of any one of claims 1-13, wherein the catheter comprises two proximal shock wave emitters and a single distal shock wave emitter.

15. The catheter of any one of claims 1-14, wherein, when the enclosure is filled with a fluid to a pressure between 0.5 atm and 5 atm, the central region tapers in diameter.

16. A shock wave catheter for treating a lesion in a body lumen with shock waves, the catheter comprising:

an elongate member extending from a proximal region of the catheter to a distal region of the catheter;

a plurality of shock wave emitters located at the distal region of the catheter; and

an enclosure having:

a distal portion;

a proximal portion; and

a central portion located between the distal portion and the proximal portion and surrounding the plurality of shock wave emitters,

wherein:

in a first configuration, the enclosure is substantially collapsed and a proximal outer diameter of the catheter at a proximal side of the central portion is greater than a distal outer diameter of the catheter at a distal side of the central portion, and,

in a second configuration, the enclosure is inflated with a fluid and the proximal outer diameter of the catheter is no less than the distal outer diameter.

17. The catheter of claim 16, wherein, in the first configuration, the difference between the distal outer diameter and the proximal outer diameter is at least 0.2 mm.

18. The catheter of claim 16 or 17, wherein, in the first configuration, the difference between the distal outer diameter and proximal outer diameter is at least 0.4 mm.

19. The catheter of any one of claims 16-18, wherein, in the first configuration, the distal outer diameter is no greater than 98% of the proximal outer diameter.

20. The catheter of any one of claims 16-19, wherein, in the first configuration, the distal outer diameter is no greater than 97.5% of the proximal outer diameter.

21. The catheter of any one of claims 16-20, wherein the plurality of shock wave emitters comprises a proximal shock wave emitter and a distal shock wave emitter, wherein a longitudinal distance from a center of the distal shock wave emitter to a center of the proximal shock wave emitter is at least 6 mm.

22. The catheter of claim 21, wherein the longitudinal distance from the center of the distal shock wave emitter to the center of the proximal shock wave emitter is at least 7 mm.

23. The catheter of claim 22, wherein the distal shock wave emitter comprises a distal electrode pair and the proximal shock wave emitter comprises a proximal electrode pair.

24. The catheter of claim 23, wherein:

the distal electrode pair comprises a distal outer electrode and a distal inner electrode and the proximal electrode pair comprises a proximal outer electrode and a proximal inner electrode, and

an outer diameter of the distal outer electrode is less than an outer diameter of the proximal outer electrode.

25. The catheter of any one of claims 22-24, wherein the distal shock wave emitter and the proximal shock wave emitter are independently wired to a power supply.

26. The catheter of claim 22, wherein the plurality of shock wave emitters comprises four distal shock wave emitters and four proximal shock wave emitters.

27. A shock wave catheter for treating a lesion a body lumen with shock waves, the catheter comprising:

an elongate member extending form a proximal region of the catheter to a distal region of the catheter;

a distal shock wave emitter comprising a distal inner band and a distal outer band having a distal outer diameter, wherein the distal shock wave emitter is the distal most shock wave emitter; and

a proximal shock wave emitter comprising a proximal inner band and a proximal outer band having a proximal outer diameter greater than the distal outer diameter, wherein the proximal shock wave emitter is the proximal most shock wave emitter.

28. The shock wave catheter of claim 27, wherein the distal inner band is thinner than the proximal inner band.

29. The shock wave catheter of claim 27 or 28, wherein the distal inner band has the same thickness as the proximal inner band.

30. The shock wave catheter of any one of claims 27-29, wherein the distal shock wave emitter includes a distal insulative layer, the proximal shock wave emitter includes a proximal insulative layer, and the distal insulative layer is thinner than the proximal insulative layer.

31. The shock wave catheter of any one of claims 27-30, wherein the distal shock wave emitter includes a distal insulative layer, the proximal shock wave emitter includes a proximal insulative layer, and the distal insulative layer is the same thickness as the proximal insulative layer.