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Transcatheter electrosurgery in bipolar or monopolar modes

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Radiofrequency energy, concentrated at the tip of a guidewire, has been used to recanalize vascular occlusions [1], cross cardiac chambers [2], and traverse between adjacent vessels [3]. All these applications have used monopolar radiofrequency energy, which is intrinsically suited to “cutting” tissue. Electrosurgical cutting works on the principle of thermal and electrostatic breakdown of water in cells caused by high current density at the electrode-tissue interface, leading to tissue vaporization. In monopolar mode, current density rapidly decreases with the square of the distance from the ionizing electrode. When applied precisely, only cells adjacent to the electrode are vaporized, while cells a few layers deep remain intact [4]. Bipolar applications, between two adjacent electrodes, have largely been reserved for tissue coagulation, commonly used surgically to stem bleeding in tissue held between forceps. This is because a much larger volume of high current density would be required for cutting between the two electrodes (Figure 1).

It is therefore interesting that Kanno et al. [5] used bipolar radiofrequency applied between two different insulated coronary guidewire tips on either side of chronically occluded coronary arteries. They reported the first-in-human use of these paired guidewires in five retrograde re-entry and two antegrade re-entry coronary chronic total occlusion cases. They achieved a channel with short bursts of ECG-gated radiofrequency pulses between wire tips ~2 mm apart. Readers should note that the difference between electrosurgical “cutting” and “coagulation” modes is the frequent lulls between bursts in “coagulation” mode to allow tissue to heat, as opposed to vaporization from continuous-duty-cycle “cutting.” The authors explain that the advantage of bipolar over monopolar systems is the ability to create channels without causing thermal damage and the ability to localize the ablated area. Their pre-clinical animal studies demonstrate localized radiofrequency heat damage around the channels created. However, localization and reduction of collateral thermal damage is theoretically better done using monopolar configurations where there is a more focal area of ionized gas, or “plasma,” formation.

The main advantage of using the bipolar system is that it provides charge directionality between wire tips without the need to align and advance guidewires. For a retrograde re-

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Editorial Comment: Regarding “Initial results of a first-in-human study on the PlasmaWire System, a new radiofrequency wire for recanalization of chronic total occlusions” by D Kanno et al (CCI-16-1959.R1).

CONFLICT OF INTEREST

Nothing to report.

entry approach, this is an attractive feature as it may increase the chances of true lumen re-entry and decrease the risk of vessel perforation. Worryingly, one of five retrograde re-entry attempts in this series resulted in a zigzag channel after bipolar ablation. The advantage of directionality is lost in an antegrade re-entry approach, however, with likely significant increased risk over monopolar radiofrequency delivery. The authors also report calcium disruption in one case after multiple radiofrequency applications. A possible mechanism is calcium disruption from shock-waves resulting from propagation of steam channels and is of interest as radiofrequency has historically performed poorly in heavily calcified lesions.

We are witnessing a broad range of new applications of transcatheter electrosurgery in interventional cardiology, from traversing transcaval access tracts, to transcatheter extra-anatomic bypass graft implantation, to transcatheter mitral and aortic leaflet slicing in the form of LAMPOON and BASILICA, to anchoring annular sutures in the form of PASTA, and now with reports like this to recanalization of chronic total arterial occlusion of coronary and also of peripheral arteries.

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Key Points

- Transcatheter electrosurgery has emerging value in a range of other new procedures that require traversing tissue (transcaval access, transcatheter Glenn Shunt) or slicing tissue (LAMPOON slicing of the mitral valve and BASILICA slicing of the aortic valve).
- This is the first report of bipolar radiofrequency wires used to cross lesions in humans, reported here in seven re-entry CTO cases.
- The bipolar configuration may provide directionality to charge without need for wire alignment and advancement, but is theoretically disadvantageous for tissue “cutting” because of problems with charge concentration.

FIGURE 1.

Nine electric field lines shown in monopolar (A) and bipolar (B) mode. Cutting occurs at regions of high current density, which is localized near the electrode surface in monopolar mode and distributed between the two electrodes in bipolar mode