EDITORIAL

Near-Field Ultrasound Imaging of Ablation Lesion Formation

More Than Meets the Eye?

See Article by Haines et al

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Effective lesion formation with radiofrequency (RF) catheter ablation in current practice relies on the monitoring of variables which serve as surrogates to tissue destruction. Impedance drop, electrogram diminution, adequacy of contact force and power titration, and lack of pace capture after ablation all suggest effective RF delivery to targeted tissue, but none come close to a gold standard of pathological examination (Figure).[1–5] Intracardiac echocardiography can improve the safety and efficacy of catheter ablation because of its ability to offer direct visualization of the catheter-tissue interface, but in most cases provides insufficient resolution to adequately assess the depth of lesions created during RF delivery.[6,7] Near-field imaging to directly visualize lesion formation would offer a substantial improvement with potential to improve the safety and efficacy of catheter ablation; not only could near-field imaging confirm that targeted tissue was truly being affected by RF, but the power, contact force, and duration of RF delivery could be titrated in a manner to avoid delivery of excessive or unnecessary ablation which could otherwise put neighboring structures (phrenic nerve, periesophageal vagal nerve, or the esophagus itself) at risk.[8–10] The near-field ultrasound (NFUS) ablation catheter is designed to offer just that—NFUS imaging from the catheter tip to directly monitor lesion formation in hopes to ultimately improve the efficacy and safety of catheter ablation.

In the current issue of *Circulation: Arrhythmia and Electrophysiology*, Haines et al[11] investigate the application of the novel NFUS catheter in a series of ex vivo and in vivo canine studies. The NFUS system is configured with an 8F open irrigation catheter using a 5-mm platinum–iridium electrode tip platform. The NFUS ablation catheter has a series of 4 ultrasound transducers incorporated into the catheter tip, which are positioned in a fashion (1 at the catheter tip with axial imaging, and 3 mounted along the side of catheter tip at 120° intervals with radial imaging) such that at least 1 transducer will be in contact with tissue regardless of catheter orientation. Ultrasound imaging from the catheter tip was displayed in simultaneous M-mode, tissue Doppler, and strain rate formats with overlying bipolar electrograms using custom-built software for real-time display.

The authors first evaluated the NFUS catheter's ability to measure tissue thickness before delivery of RF energy, and the NFUS catheter proved capable in its ability to accurately measure tissue thicknesses in ex vivo phantom and tissue models throughout a wide range of contact and rotational angles. There was somewhat less accuracy, but still with reasonable correlation, in canine in vivo measurements of myocardial tissue thickness when compared with intracardiac echocardiography measurements as a gold standard, although left ventricular sites were excluded from analysis as the average left ventricle wall thickness exceeded the depth of view for NFUS. Overestimates of wall thickness were common when the catheter

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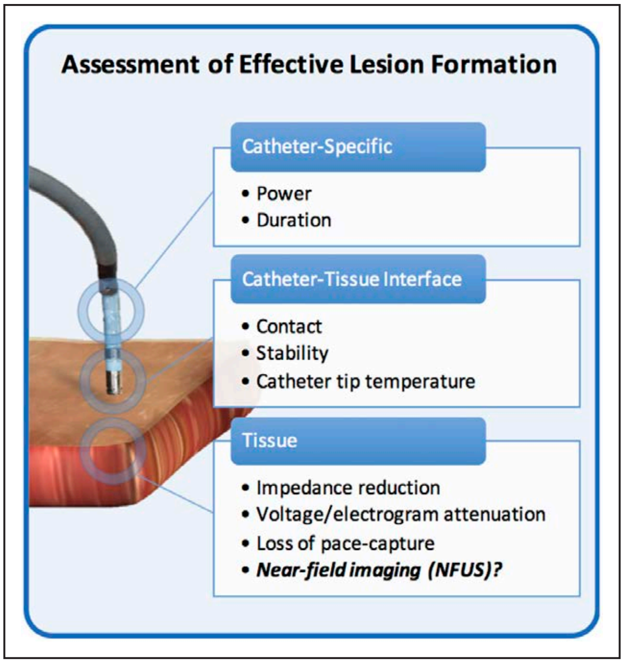

Figure. Parameters which can be used to assess or predict the effectiveness of radiofrequency delivery and ablation lesion formation.
NFUS indicates near-field ultrasound.

was oriented in a nonperpendicular angle to the tissue plane, and underestimates were possible if myocardial tissue was compressed with catheter contact. Nonetheless, because of the wide availability of intracardiac echocardiography (which is superior in its ability to evaluate larger scale cardiac structures, such as pulmonary veins, papillary muscles, and the like), the true value in a catheter with integrated ultrasound imaging is not in its ability to evaluate tissue thickness, but in an ability to provide real-time monitoring of tissue destruction with the application of RF.

The study's investigators evaluated the accuracy of NFUS measurements of lesion depth compared with pathological examination on necropsy with RF ablation delivery at 318 sites in 19 canines in all cardiac chambers. For atrial ablations, investigators terminated catheter ablation for each lesion when it seemed that transmurality had been achieved by NFUS. Overall, there was correlation between lesion depth by NFUS compared with pathology, and NFUS outperformed other parameters (power, duration, local electrogram amplitude change, impedance change, and post ablation pacing threshold) in the prediction of lesion depth in the right and left ventricles. For atrial ablation, lesion transmurality was achieved in 87% of ablation lesions.

Although the concept of real-time imaging during lesion formation is compelling, the NFUS catheter did seem to have some limitations with respect to accuracy of lesion depth measurements. Although there was correlation between the depth measured by NFUS and lesion depth measured at pathology (R=0.78), NFUS measurements on a lesion-by-lesion basis were imperfect. For instance, for a lesion depth of 4 mm measured by NFUS catheter imaging, actual measurements of lesion depths by pathology ranged from <2 mm to >8 mm, with a fairly even distribution of lesion measurements across this range. For lesions, NFUS measured at 6 mm, pathological measurements ranged from 2 mm to >12 mm, again with a fairly even distribution across this range. This might have been expected, as the authors report that because of limitations of the NFUS imaging, error might be expected as lesions approach the 8 mm maximum near-field depth of view of the transducers; however, there appeared to be a fair amount of error even at shallower depths. NFUS seems to uniformly underestimate actual lesion depth when NFUS-measured depths are ≤ 1 mm. In this setting, 100% of lesions measured by pathology were >1 mm, with a range of measured lesion depths of 1 mm to 6 mm. This error may limit the actual safety value of the catheter in the setting of ablation to the posterior left atrium, with the possibility of false reassurance that lesion depths were being limited to 1 to 2 mm of atrial tissue when in reality excessive RF could be delivered (to the esophagus).

Although the authors limited the assessment of transmurality to atrial ablation, a great deal of recent clinical effort and innovation has been focused on creating deeper lesions for the successful ablation of ventricular arrhythmias.[12–14] It is unclear how this catheter would compare to currently available catheters in its ability to deliver deep lesions, though the notion of bipolar ablation using a currently available contact force sensing catheter as the active catheter paired with an imaging-capable catheter such as NFUS as the ground catheter to monitor lesion formation is compelling.

The study had some other notable limitations. Because the catheter lacked the ability to provide contact force information (aside from visual assessment of contact with NFUS imaging), comparisons could not be made between NFUS assessment of transmurality and other calculated measures such as the force-time integral, which not only has been shown to be a good determinant of lesion effectiveness but also is easier to learn and incorporate into the ablation process.[15–17] Comparison of electrogram characteristics between a standard 3.5-mm tip catheter and the NFUS 5-mm tip catheter were not made, though one could presume that the NFUS catheter with a larger distance between electrodes would have a more limited resolution for small electrograms and fractionated signals.

The authors admit that use of the NFUS catheter in standard practice would require significant training. Imaging with M-mode, tissue Doppler, and strain rate provide ample additional data during ablation, but accurate real-time interpretation may prove to be difficult when considering that this data must also be synthesized with monitoring of electrograms, catheter position, impedance changes, and other procedural variables. Not only was lesion depth analysis performed offline in this study, but interpretation was by consensus without evaluation of interobserver variability. Ease, standardization, and reliability of data interpretation would ultimately be critical for widespread adoption of this technology.

Many limitations currently exist in the effective ablation of arrhythmias. Poor lesion durability with electric reconnection of pulmonary veins and an inability to deliver effective RF to depths sufficient to reach critical elements of arrhythmia circuits in the ventricle are among the most commonly cited obstacles to success. The application of real-time monitoring of ablation lesions during RF delivery could ultimately become a welcomed addition to currently available catheter ablation technologies and improve safety and efficacy. The authors should be commended on this well-designed study as a good first step in characterizing a new technology and its application; however, it must ultimately demonstrate ease of use, consistent fidelity, and ability to be used in any cardiac chamber for it to have widespread clinical adoption.

AFFILIATION

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DISCLOSURES

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FOOTNOTES

Circ Arrhythm Electrophysiol is available at http://circep.ahajournals.org.

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