JACC: CLINICAL ELECTROPHYSIOLOGY VOL. ■, NO. ■, 2018

PUBLISHED BY ELSEVIER

Longer Duration Versus Increasing Power During Radiofrequency Ablation Yields Different Ablation Lesion Characteristics

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ABSTRACT

OBJECTIVES The goal of this study was to characterize differences in ablation lesions with varying radiofrequency ablation (RFA) power and time.

BACKGROUND Increasing power delivery or prolonging duration can improve the efficacy of RFA. However, the extent to which ablation lesion characteristics change, based on varying degrees of power and duration, is unknown.

METHODS An ex vivo model consisting of viable bovine myocardium in a circulating warmed saline bath was used. An open irrigated RFA catheter was positioned with 10 g of force in the perpendicular position, and RFA was delivered at powers of 20, 30, 40, and 50 W and for various time intervals, up to a total of 90 s, at each power. An in vivo porcine thigh preparation model was used to perform RFA at 50 W for 5 s and 20 W for 30 s. Lesion volumes were analyzed.

RESULTS Greater power delivery and longer radiofrequency time increased ablation lesion size. However, compared with a proportional change in radiofrequency duration, the same proportional increase in power produced a significantly larger lesion volume ($p < 0.01$). For in vivo models, 50 W/5 s ablation lesions yielded similar volumes but significantly less depth than 20 W/30 s ablation lesions. Peak temperatures were not significantly different at 2 and 4 mm with 50 W/5 s versus 20 W/30 s.

CONCLUSIONS Varying power and duration will confer different ablation lesion characteristics that can be tailored according to the substrate/anatomy that is being ablated. This phenomenon has important implications during catheter ablation. (J Am Coll Cardiol EP 2018;■:■–■) © 2018 by the American College of Cardiology Foundation.

Radiofrequency ablation (RFA) has become increasingly used and is considered first-line therapy for certain cardiac arrhythmias. Newer catheter development and design, including open irrigated, force-sensing catheters, have been shown to improve safety and outcomes (1–3). However, challenges remain in the delivery of durable ablation lesions, and complications arise related to collateral damage from ablation. The decision to deliver a larger, deeper lesion (i.e., mid-myocardial or epicardial substrates seen commonly with ventricular arrhythmias) or a superficial lesion (i.e., the posterior left atrial wall where risk of esophageal injury is present) needs to be considered with ablation to minimize collateral damage and to improve safety and efficacy.

Multiple strategies have been developed to improve the efficacy of RFA: changing the

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All authors attest that they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the *JACC: Clinical Electrophysiology* author instructions page.

Manuscript received February 7, 2018; revised manuscript received March 12, 2018, accepted March 26, 2018.

ISSN 2405-500X/$36.00 https://doi.org/10.1016/j.jacep.2018.03.020

ABBREVIATIONS AND ACRONYMS

AF = atrial fibrillation

PVI = pulmonary vein isolation

RFA = radiofrequency ablation

surrounding environment with the use of different irrigation solution (i.e., half normal saline), bipolar and multipolar ablation, and high-power/short-duration ablation strategies. However, the simplest change is by varying ablation power and/or duration. Although increasing power delivery and prolonging the duration of RFA are readily available strategies that can improve radiofrequency (RF) efficacy, the extent to which ablation lesion characteristics (e.g., size, shape, depth) change based on varying degrees of power and duration is unknown. The goal of the present study was to characterize differences in ablation lesions with varying RFA power and time.

METHODS

The experimental protocols conformed to the Guide for the Care and Use of Laboratory Animals, and they have been approved by the Institutional Animal Care and Use Committees of the University of Colorado.

EX VIVO MODEL. An ex vivo model consisting of viable bovine myocardium, a submersible load cell, circulating bath, and an open irrigated ablation catheter was assembled. A load cell, used to standardize application of energy, was submersed in the bath and contained a section of bovine ventricular myocardium. An open irrigated catheter was positioned with 10 g of force perpendicular to the myocardium by using a deflectable sheath. This ex vivo model has been validated and well described (4-7). RFA was delivered at powers of 20, 30, 40, and 50 W and at various time intervals (15, 30, 60, and 90 s) for each power. Ablation lesion characteristics and volumes were analyzed. In addition, for ex vivo tissue temperature analyses, RFA was delivered at 50 W for 5 s and 20 W for 30 s with 10 g of force while tissue temperatures at various depths and lesion volumes were measured.

TISSUE TEMPERATURE ANALYSIS. T-type thermocouple wires were inserted horizontally into the myocardium at 2 mm and 4 mm depths and perpendicular to the ablation surface. Thermocouple analog inputs were converted to digital signals by using LabVIEW software version 7.0 (National Instruments, Austin, Texas). Temperature and temperature increases over time were recorded in a continuous fashion throughout the RF application at a rate of 5 Hz. Peak tissue temperature was defined as the maximum temperature reading during RF application. The area under the temperature curve was calculated as a temperature time integral for all lesions. RF applications that generated steam pops were excluded from the temperature curve analysis.

IN VIVO MODEL. An in vivo model was constructed. Yorkshire pigs were anesthetized, and porcine thighs were prepared bilaterally. Briefly, the skin and connective tissues were dissected to expose the underlying muscle. The skin was raised to form a cradle, and heparinized, warmed porcine blood was circulated at 350 ml/min. An ablation catheter was placed perpendicular to the muscle surface. Ablations were delivered at 50 W for 5 s and 20 W for 30 s with the same amount of force, as measured by a force-sensing, open irrigated tip RF catheter; ablation lesions were tagged by using the electroanatomic mapping system and averaged between 10 and 20 g of force. After the animals were euthanized, thigh preparations were resected, and the ablation lesion sizes were measured.

The power and duration parameters used in the in vivo models were determined after a limited pilot study to choose the optimal setting that would yield useful lesion volume measurements but not have excessive steam pops. Although 20 W is not frequently used for ventricular arrhythmias, it is often used during left atrial posterior wall ablation to mitigate risk of esophageal injury.

ABLATION LESION ANALYSIS. Single lesion volumes were acquired by visually analyzing tissue sections with a digital micrometer and were calculated by using the equation for an oblate ellipsoid based on the core lesion. For each lesion, maximum depth (A), maximum diameter (B), depth at maximum diameter (C), and lesion surface diameter (D) were measures.

$$LesionVolume = \left[0.75\pi\left(\frac{B}{2}\right)^2(A-C)\right] - \left[0.25\pi\left(\frac{D}{2}\right)^2(A-2C)\right]$$

A Nikon D7000 (Nikon Inc., Melville, New York) was used to obtain visual representations of the ablation lesions, and Adobe Photoshop Elements 12 (Adobe Systems Incorporated, San Jose, California) was used to process the images.

STATISTICAL ANALYSIS. Statistical analyses were performed by using IBM SPSS version 24.0 (IBM SPSS Statistics, IBM Corporation, Armonk, New York). The chi-square test was used for dichotomous comparisons in lesion characteristics from various configurations, and the analysis of variance test was used to