Tissue Coverage Matters

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April 23, 2021

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Total Word Count:

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Although radiofrequency (RF) catheter ablation for ventricular tachycardia has been shown to provide superior outcomes to escalating anti-arrhythmic therapies, multi-center trials continue to report arrhythmia recurrence rates in 20-50% of patients. Failure of catheter ablation is often due to deep intra-mural portions of reentry circuits and anatomic barriers to ablation. Means of increasing lesion size are of interest.

During ablation current passing through high resistance cell membranes produces resistive heating. Heat produced by resistive heating is transferred to the surrounding tissue by conduction and convection.[1] Tissue heating also heats the electrode lying on the tissue. Energy delivery is limited by the denaturation of blood proteins and formation of char on the electrode when temperatures exceed 70 degrees C. Furthermore, if temperatures in the tissue reach 100 degrees C, steam formation can occur and explode through the tissue with the potential for embolization and rupture.[2] Thus to achieve deep, durable RF lesions the goal is to deliver maximal current into the tissue while maintaining tissue electrode temperatures below that which generates coagulum and tissue temperatures below that which creates steam pops. Irrigating the RF electrode reduces its temperature and allows more tissue heating to occur before electrode temperature reaches the level at which char formation occurs. Resulting lesion size is due to a complex interplay of multiple factors, as was evident early on when in experimental in-vivo studies RF lesions created with the same RF ablation settings were variable in size and often absent at some ablation sites, and optimizing RF parameters is still a topic of great interest.

The greater the RF current, the greater the resistive heating in the tissue. Current can be increased by increasing power, or lowering resistance for a given power, as by moving the cutaneous disperisive electrode closer to the heart or using two dispersive electrodes.[3] The RF electrode is in the blood pool and only a fraction of the current passes through the myocardium, with the remainder passing through the blood pool. Replacing the normal saline irrigant with half normal (0.45%) reduces shunting of current through the blood pool, increasing the proportion of current passing through the tissue[4 5].

The amount of current transferred into the tissue is also influenced by electrode-tissue contact and the area of the electrode that is in contact with the underlying tissue.[6, 7] Electrode contact force is an important determinant of lesion size with increased force also resulting in a higher incidence of steam pops and thrombus formation for a given energy setting[8]. However, even when all these parameters are measured, our ability to predict lesion size and pops for a given set of parameters is inconsistent. In this issue of the journal Bourier et al evaluate the relation between surface area of the RF ablation electrode in contact, or covered by myocardium with lesion size and steam pops while maintaining power, duration and impedance the same. Porcine ventricular endocardium was ablated in a tissue bath where the impedance was maintained at 120 Ohms by alterations to the tonicity of the bath and RF lesions were with RF at 30W for 30 seconds. Three different ablation electrode tip configurations were studied: only the tip in contact (I), tip electrode pushed into the tissue such that half of the length of the electrode was covered (II), and the entire electrode wedged into a trabeculum such that it was entirely covered (III). Contact force was similar for each preparation. Despite similar RF parameters greater electrode coverage increased lesion size and steam pops, which occurred in 0%, 10% and 100% of coverage I, II and III ablations respectively.

These observations are consistent with the effect of greater electrode surface area contact to increase current flow into tissue rather than the circulating fluid pool and increase lesion size, as has been observed when comparing electrode that are oriented perpendicular versus parallel to tissue. There are some caveats that should be considered in interpretating their data. Consistent with greater heating, the impedance of system decreased during ablation to a greater extent with greater electrode coverage. With RF set to a fixed power, a decrease in impedance results in an increase in current delivery to maintain the same power, hence, this could play a role in increasing lesion size. Secondly the impedance of the system would be expected to be greater when the electrode is more covered by tissue, as opposed to when it is in the blood pool.[9, 10] They adjusted impedance to 120 Ohms in all situations by adjusting the tonicity of the tissue bath, which could influence lesion size. Increasing tonicity to reduce impedance could have the effect of decreasing current delivery into the tissue; despite this covered lesions were larger.

The findings have important implications for ablation in the ventricles and pectinated regions of the atrium where trabeculae can increase coverage of the ablating electrode and provide an explanation of unanticipated steam pops. They also suggest that electrode coverage can not reliably predicted from contact force as recorded from ablation catheters. Whether careful assessment of baseline impedance in the blood pool versus at the target site, or analysis of the impedance curve versus current during ablation might provide some insight in this regard is not certain.

Despite extensive studies aimed at optimizing RF delivery, occasional overheating and steam pops occur. Variations in electrode tissue coverage in trabeculated regions of atrium and ventricles likely play a role and are not easily appreciated during the procedure. Reducing power in response to rapid falls in impedance and use of intra-cardiac echocardiography for excessive bubble formation that likely indicates overheating of the endocardial surface[11] remain useful means of avoiding steam pops.

Disclosures:

William G Stevenson has received speaking honoria from Medtronic, Biotronik, Abbott, Johnson and Johnson and Boston Scientific, and holds a patent for irrigated needle ablation that is consigned to Brigham Hospital.

Arvindh Kanagasundram has received speaking honoraria from Janssen and Johnson and Johnson

Travis D Richardson has no disclosures

Funding: None

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