AMEN and ALARA – Remembering the dangers of the (new) technology of lesion formation

Mark Alexander[1] and Edward O'Leary[1]

[1]Boston Children's Hospital

April 28, 2022

Abstract

Catheter ablation in children has evolved to become a highly effective and safe therapy. Each iterative improvement in ablation technology provides another opportunity to investigate how much incremental benefit can be made without sacrificing safety. Contact force sensing catheters represent an example of such technology that has become commonplace in adult ablation. Its capability in predicting lesion size and collateral damage to critical structures has not been meticulously explored. Backhoff and colleagues describe an animal ablation model where they quantitate lesion characteristics at the atrium, atrioventricular groove, and ventricle using low and high contact force targets, with a specific focus on assessing for coronary arterial injury. In this controlled experiment, chronic lesion characteristics were widely variable (˜0-8 mm diameter) yet there was a statistically significant (albeit small) increase in lesion diameter for high (vs low) contact force lesions delivered to the atrioventricular groove. The risk of chronic sub-clinical coronary artery injury was 1-2%.

AMEN and ALARA – Remembering the dangers of the (new) technology of lesion formation.

Mark E Alexander, MD

Edward T O'leary, MD

Arrhythmia Service

Department of Cardiology

Boston Children's Hospital

Department of Pediatrics, Harvard Medical School

Boston, MA

1284 words

6 References

No external funding

Conflict of Interest:

Dr. O'leary receives research funding from Abbott Cardiovascular

Corresponding Author

Mark E Alexander, MD

Mark.alexander@cardio.chboston.org

617-355-6328

Fax: 617-730-0000

Catheter ablation has changed the natural history of children with supraventricular tachycardia. Those of us over 60 years of age remember the burden associated with recurrent arrhythmias, the emergency room visits (which before 1989 required some drug not named adenosine), the chronic drug therapy, digoxin toxicity, and maybe even having to give quinidine. For older children and adolescents with recurrent SVT, catheter ablation has become the therapy of choice.

Catheter ablation is both effective and safe, particularly for localized and easily characterized arrhythmia mechanisms. The high quality prospective observational PAPCA trial and the parallel European study demonstrated virtually no late myocardial dysfunction and very low incidence of atrioventricular (AV) block. Success rates are now routinely >95% for AV reciprocating mechanisms or AV nodal re-entrant tachycardia. Those success rates have probably incrementally improved over the last decade and build on a base of long-term success and safety. That safety profile has settled so that patients over ˜15 kg are reasonable candidates for elective ablation, with ablation in younger patients clearly feasible but reserved for those with substantial hemodynamic and/or drug morbidity.

Operators now have options for catheters with irrigated tips and contact force sensors for radiofrequency (RF) ablation, and larger tipped cryocatheters when that technology is preferred. The combination of contact force sensors and irrigated tip ablation has clearly contributed to increased ablation success in atrial flutter, atrial fibrillation, and ventricular tachycardia. Success rates with more localized mechanisms like accessory pathways have been sufficiently high for a sufficiently long period that demonstrating superiority of any approach is a challenge. This background is critical for viewing the present study by Backhoff and colleagues in this issue of the journal, where they investigate the use of a contact force ablation catheter in a careful animal experiment. They used 15-22 kg piglets which is a plausible model for younger children. The underlying hypothesis is quite reasonable: that elevated contact force results in a larger lesion size and thereby increases the frequency of coronary injury. Each animal had a sequence of lesions on the atrial and ventricular walls and the tricuspid and mitral annuli. They targeted either a low contact force of 10-20 g (which to explicitly state represents routine clinical care in humans) or a high contact force of 40-60 g and delivered 30 second lesions with a power ceiling of 30 W and temperature ceiling of 65 C. A total of 172 lesions were assessed with acute coronary angiography followed by subgroups with postmortem analysis at 48 hours and 6 months. Each targeted location had one RF application at the target contact force.

There is, I think, no surprise that ventricular myocardial lesions were larger than AV groove lesions which were larger than atrial myocardial lesions. Similarly, there was some lesion contraction with lesion size being larger at 48 hours than at 6 months for those placed on the AV groove and in the ventricular myocardium (though not the atrial lesions). Backhoff and his colleagues in this research group in Gottingen, Germany have been careful about documenting potential risk of coronary injury with both acute clinical coronary angiography and an animal model using cryoablation. Extending the animal model to a contact force catheter demonstrated a frequency of coronary obstruction in 5% of all observed lesions on the day of the procedure, decreasing to 2.5% by 48 hours and 1.4% by 6 months. Fortunately, there was excellent coronary flow in the affected coronaries at each time point. They note a parallel but somewhat higher incidence of transmural extension of these lesions. These data provide the usual anxiety that we have about ablation on the AV groove, however the optimist can take comfort in the larger clinical experiences and their confidence that they are (hopefully) using a “low” contact force of 10-20 g.

When the relationship between contact force and lesion size is examined in detail, the limitations of their hypothesis become readily apparent. The only lesion set where high contact force was associated with larger lesions was that at the AV groove examined at 6 months. Here, both the lesion volume (˜6 mm diameter hemisphere) and percentage of transmural lesions were higher in high contact force than the low contact force lesions (˜5 mm diameter hemisphere). There were not significant differences in lesion volume or transmural extension for atrial lesions or ventricular lesions. In some of those lesion sets the low contact force set had insignificantly higher volumes. In figure 2 they present scatter plots of lesion volume and the force-time product, with the surprising conclusion that there is no relationship between those two values. Indeed, on

pathology only about 90% of the lesions could be identified, implying that 10% of the lesions they placed did not result in tissue damage. Lesion size ranged from 4.2 mm diameter to nearly 8 mm diameter hemispheres. There are obviously other metrics that could be correlated with lesion size with time-temperature integrals, impedance drops, and loss of electrogram size as obvious favorites; those are not presented.

There are several potential ways to digest these data. The initial hypothesis that higher contact force would reliably produce larger lesions is at best incompletely confirmed by the results. The statistical purest will focus on the weakness of that association with lesion volume and assert that that finding was the result of not correcting for multiple measures. They may say that this is underpowered and "more studies are needed " or even that the data do not support the authors' hypothesis. To me, the challenges of this analysis are actually the more important signal. Regardless of tip contact force, lesion size could range from ˜4-8.5mm in diameter with variable development of either transmural extension or lesion contraction. Even in a relatively controlled environment with careful lesion characterization, ˜10% of applications did not result in a pathologically visible lesion (so the size was really 0-8mm diameter!). Clinically, we look for an acute change in physiology to decide if a lesion is effective and then may place some additional "consolidation" or "insurance" lesions if that physiology remains favorable—or move to a different location if the pathway returns. Most of us, I believe, are unlikely to accept a single 30 second lesion on the AV groove. We do not have the luxury of seeing what these applications look like 2 days or 6 months later. What happens with the second 30 second application? What happens with further repeat applications? What is the catheter tip force when a catheter without that technology is used?

Each technology that assists in catheter ablation inserts not only increased precision, but also an increased "sense" of precision. The variables that we observe during these procedures are important and numerous, but each has a confidence interval. Some of the damage we create is silent and subclinical (at least for now). Analyses like these help refine what we know, which is that 6 months after a RF ablation in a 15 kg piglet, 1-2% of single lesions will produce subclinical coronary obstruction which would not have been identified without coronary angiography.

For fluoroscopy, a safety principle of As Low As Reasonably Achievable (ALARA) is the standard. Given both the uncertainty of lesion size and the clear potential of at least subclinical coronary injury that this group has demonstrated in both clinical and animal settings, combined with the low but real incidence of catastrophic coronary injury, maybe a similar principle is appropriate with ablation along the AV groove. At the same time ,the goal of each iteration of catheter technology is to assure that we give As Much as Effectively Needed (AMEN). Data like these, with low but real and potentially silent risks, remind us that those are goals we need to always to balance.