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Editorial

Quantitative cardiology comes of age

In this quantitative cardiology symposium, the journal has assembled a remarkable series of papers that use quantitative methods to address clinical and research problems in cardiology. That most of the papers deal with cardiac electrophysiology is not surprising. Mathematical analysis has been critical to the evolution of cardiac electrophysiology, from the mathematical model developed by Hodgkin and Huxley to describe the ionic mechanisms underlying how the action potentials of squid axon are initiated and propagated [1] to the solution of the inverse problem, describing the electric potential distribution on the surface of the heart from measurements of potentials made on the torso of the body [2].

The standard 12 lead electrocardiogram remains a mainstay in the diagnosis of acute ST segment elevation myocardial infarction and the identification of conduction disturbances and arrhythmias. Long term ambulatory ECG recordings using surface electrodes or implantable recorders are used to identify intermittent arrhythmias or to quantitate the burden of atrial fibrillation. Increasingly, wearable devices that use photo-plethysmographic signals are used by patients to detect arrhythmias. Identification of ST segment elevation myocardial infarction in a timely matter is critical to allowing for interventions to re-establish blood flow in occluded vessels within 60 minutes of onset of ischemia, to reduce infarct size and mortality. Accurate identification of ST segment MI requires experienced appropriately trained personnel and suffers from both missing ST segment elevation and false positive identification. In this issue of the journal, we see the possibility of automated diagnostic systems being used to identify acute myocardial infarction with accuracy of $> 99.5\%$. Automated diagnostic systems using convolutional neural networks and long short term memory are being used to identify arrhythmias. Methodologic considerations were utilized in identifying atrial fibrillation in ambulatory ECG recordings and being able to calculate heart rate variability in wearable devices used for tracking heart rhythm.

Implantable cardioverter defibrillators (ICD) are the primary therapy for patients who have suffered cardiac arrest or have had sustained ventricular tachycardia in the setting of structural heart disease. Predictive computer models are useful for determining optimal lead placement for successful defibrillation by automatic ICDs and for utilization of routine 12 lead ECGs to identify patient eligibility for subcutaneous ICD implantation.

Ablation has evolved to be the most definitive and reliable treatment for most of the sustained arrhythmias encountered in clinical practice. Successful ablation requires accurate identification of targets that are critical to the maintenance of these arrhythmias. These targets may be the site of origin of automatic or triggered arrhythmias, location of bypass tracts, or slowly conducting pathways that form critical isthmuses that are requisite and vulnerable parts of reentrant circuits. Rapid rates resulting in hemodynamic instability, the existence of multiple circuits, and absence of high-density multi-electrode systems that allow for mapping of the circuit in several beats, limit identification of vulnerable ablation sites in re-entrant arrhythmias. Thus, ablation of reentrant tachycardias often involves ablation of myocardium that is based on voltage, location in relation to adjoining scar, and electrogram characteristics. This is commonly referred to as substrate ablation. A novel method for identifying focal wavefront origins utilizing limited recordings and conduction velocity calculations is described and was tested with the most commonly used commercial mapping system. Raiman and Tung use automated isochronal mapping that identifies areas of slow conduction to identify isthmus sites for ablation. Beheshti et al. show that decremental response to extrastimuli is related to the location and direction of the wavefront in relation to scar entry and the size of scar, and may prove to be useful as an adjunct to substrate mapping. In the study by Deng et al. cardiac MRI with delayed enhancement is used to identify reentry location, and one paper established that identifying gray zones with intensity thresholds of 20–30% resulted in the best match of simulated VT with actual reentrant circuits. Ablation is also limited by the ability to reach critical areas that are not on the endocardial or epicardial surfaces of the heart. Stereotactic body radiation therapy is a promising non-invasive therapy that has many advantages over radiofrequency ablation, including the ability to target areas not amenable to catheter ablation. John et al. discuss this new therapeutic modality and provide dose calculations for collateral structures that may limit the applicability of this therapy.

Fibrillation remains a difficult rhythm to analyze given the difficulty in identifying local areas of excitability when there are low amplitude, fractionated unpredictable signals present during fibrillation. Handa et al. review current methods to analyze fibrillation signals such as dominant frequency, organizational index, Shannon entropy and phase mapping, and present a novel new algorithm for identification of lines of conduction block in microreentrant circuits responsible for fibrillation. Sohn et al. discuss the structures of spiral waves and Jacquemet compares different interpolation techniques to define phase singularities, and found that phase interpolation was the most accurate.

Finally Ciaccio et al. use an automaton model to compare methods for cessation of attractable fibrillation. Their model shows multisite electrode stimulation to be superior to extensive ablation.

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