Surface Electrocardiography: Can Arrhythmia Circuits Be Localized?*

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The last 20 years have been marked by an explosion of diagnostic and treatment modalities in the field of cardiovascular medicine. In the wake of this expansion, skills and techniques that were once the cornerstones of diagnosis have often been abandoned or relegated to a less important role. The original observations of MacKenzie and subsequent analysis by Wenckbach (1) on heart block deduced from the analysis of jugular venous and radial artery pressure tracings are not likely to be repeated in this era, yet analysis of the surface electrocardiogram (ECG), in contrast to other “less sophisticated” techniques, has not fallen prey to advanced technology. Indeed, the value of the surface ECG and its interpretation has grown hand in hand with the advances made in clinical electrophysiology, a field that, since the report (2) of the first recording of a His bundle potential in humans, has evolved into an important subspecialty of cardiology. The study of complex arrhythmias with use of invasive electrophysiologic techniques has provided new insight into the interpretation of the surface ECG. As a result, there now exists a level of expertise whereby the mechanisms responsible for an arrhythmia can be diagnosed with a high degree of certainty from a careful analysis of the surface ECG (3). Moreover, analysis of the ECG obtained during the initiation and termination of an arrhythmia can provide not only valuable information concerning its mechanism, but also important clues to the choice of rational, specific therapy.

Analysis of the surface electrocardiogram. The treatment of cardiac arrhythmias has taken a new direction with the refinement of catheter (4) and surgical (5) ablative techniques. Paramount to the successful treatment of arrhythmias with these nonpharmacologic methods is the accurate localization in the heart of the tissue that is responsible for the genesis of the arrhythmia or critical to its perpetuation. Currently, localization procedures are performed during the arrhythmia and require either catheter or direct cardiac mapping (6,7). An increasing number of studies, however, have examined the extent to which features of the surface electrocardiogram can be relied on to localize the cardiac tissue responsible for specific arrhythmias. Several algorithms, for example, have been proposed to pinpoint the location of the accessory pathway in patients with the Wolff-Parkinson-White syndrome (8-13). Although not without limitations (14), analysis of the surface ECG has proved reasonably successful for this purpose.

Localization of ventricular tachycardia. The power of the surfac ECG to localize the area in the heart responsible for ventricular tachycardia, in contrast to that responsible for the Wolff-Parkinson-White syndrome, has been less extensively evaluated. One obvious reason relates to the more complex anatomic substrate associated with ventricular tachycardia. Although the QRS pattern of a totally preexcited complex from a patient with a normal left ventricle and Wolff-Parkinson-White syndrome mimics ventricular tachycardia arising at a point adjacent to the atrioventricular ring, the electrophysiologic and anatomic derangements associated with ventricular tachycardia in patients with coronary artery disease and myocardial infarction are considerably more complex, although less well defined (15-19).

It has been demonstrated, for example, that a patient may manifest two distinct configurations of ventricular tachycardia that arise from an area <1 cm² (20).

Early attempts to localize the cardiac tissue responsible for ventricular tachycardia by analyzing the surface ECG (21-26) suffered from many technical limitations. The most important of these was the lack of a direct and reliable method to identify the site of origin of the tachycardia. Subsequent attempts to localize the source by surface ECG analysis relied on the technique of pace-mapping (27-31). With this technique, surface ECGs are obtained while pacing is performed at preselected ventricular sites. This technique has several limitations, especially in the setting of the anatomic distortions caused by myocardial infarction and aneurysm formation (32-34).

Only three studies based on direct mapping of ventricular tachycardia have attempted to localize the site of origin of the tachycardia by analyzing the 12 lead ECG. The first, by Josephson et al. (35), was a qualitative retrospective analysis of the surface ECG obtained from 34 patients (41 ventricular tachycardia configurations). Results demonstrated that the analysis of the surface ECG is often useful for identifying regions of the heart responsible for ventricular tachycardia. Specifically, certain morphologic features were identified...
that distinguished apical from basal, anterior from inferior and septal from free wall sites. In the study by Miller et al. (36), an algorithm to localize the site of origin of ventricular tachycardia to 1 of 10 endocardial regions of the left ventricle was derived from retrospective analysis of the surface ECGs of 149 distinct configurations of ventricular tachycardia. The algorithm was based on the locus of infarction and characteristics of the surface ECG during the tachycardia, which included type of bundle branch block, quadrant axis and frontal plane and patterns (seven distinct) of precordial R wave progression. The performance of this algorithm was then tested prospectively by four blinded observers who used it to analyze the surface ECG of 110 distinct configurations of ventricular tachycardia. With this approach, the endocardial region of the left ventricle from where the ventricular tachycardia originated was predicted successfully in 93% of the cases in which the algorithm could be applied (59% of all configurations). When it was not possible to make use of the algorithm there was only a 71% success rate in estimating the site of origin.

Present study. In this issue of the Journal, a new algorithm to predict the site of origin of ventricular tachycardia from the analysis of the surface ECG is presented by Kuchar et al. (37). The algorithm is derived from analysis of the surface ECGs obtained from 93 left ventricular sites at which pace-mapping was performed in 22 patients, and is based on the analysis of the maximal QRS voltage (that is, positive, negative or isoelectric) observed in eight surface ECG leads (five limb, three precordial). The mapping grid these investigators used divided the endocardium of the left ventricle into 24 regions. It is, therefore, not surprising that the overall success rate with regard to localization of the site of origin of ventricular tachycardia with such precision was only 39%. In another 36% of cases the site of origin was localized to an adjacent site. Thus, the overall success of this particular algorithm to a more regionalized area was 75%. It is not possible to directly compare these results with those reported by Miller et al. (36) because of some differences in the methods used. For example, Miller et al. could apply their algorithm to only 59% of the ventricular tachycardia configurations under investigation. In the study by Kuchar et al., because of the number of branch points (their Fig. 3) that exclude the possibility of an isoelectric complex, it is unclear how often their algorithm could be applied to the patients in their study.

The main limitation of this and similar studies is related to the use of catheter mapping as the definitive standard to identify the site of origin of ventricular tachycardia. There is no question that catheter mapping can better locate the region of origin than can analysis of the surface ECG, but new evidence suggests that presystolic activity alone is not sufficiently precise to define the location to perform catheter ablation. It also appears that successful catheter ablation requires more precise localization than does surgical endo-cardial resection. The finding of regional areas of slow conduction (38), mid-diastolic potentials (39) and concealed entrainment (40) may be more specific to the site of origin of ventricular tachycardia. Finally, care must be taken in fluoroscopically defining heart borders that are not well delineated. Kuchar and coworkers have introduced a more precise mapping grid. It must be emphasized, however, that the anatomic distortions that occur with aneurysm formation will always limit the precise localization of a catheter.

Conclusions. These limitations are not meant to detract from the clinical value of the study by Kuchar and coworkers. Their introduction of this simplified algorithm independently confirms the work of others and further demonstrates the power of the 12 lead ECG. These studies firmly establish that analysis of the surface ECG during ventricular tachycardia often provides clinically useful data relevant to the regions of the ventricle from which tachycardias arise. Such data can be utilized to corroborate the results of catheter and intraoperative mapping or help guide mapping procedures that must be restricted because of technical or clinical reasons. Accordingly, we must continue to emphasize to our house staff and referring physicians the importance of obtaining a 12 lead ECG during all tachycardias. As always, however, caution should be exercised with the use of any individual test. Although useful information can be extracted from the interrogation of the surface ECG, it cannot as yet supplant direct mapping techniques. Studies such as the one by Kuchar and coworkers (37) that relate ECG features to the results of catheter and pace-mapping maximize the power of the 12 lead ECG in localizing the site of origin of ventricular tachycardia. Additional studies using similar techniques are unlikely to result in more accurate algorithms. The next issue is not whose algorithm is best, but what is required to augment the power of the surface ECG. Improved algorithms must await new insights into the pathophysiology of ventricular tachycardia, and will require as well more sophisticated approaches including body surface (41) and high density, transmural ventricular mapping (42).

References
Surface electrocardiography characteristics and radiofrequency catheter ablation of idiopathic ventricular arrhythmias originating from the left infero-septal papillary muscles: Differences from those originating from the left posterior fascicle. Article in Europace 20(6) April 2017 with 6 Reads. DOI: 10.1093/europace/eux071.