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EDITORIAL COMMENT

Is It the Same or a Different Ventricular Tachycardia?

An Additional Use for Defibrillator Electrograms*

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The introduction of stored electrogram (EGM) recordings from the sensing and/or shocking leads of implantable cardioverter-defibrillators (ICDs) provided the opportunity to document the "real world" of what triggers device therapy. Signal analysis could establish, independently of symptoms, if device therapy was appropriate for a ventricular arrhythmia or inappropriate for a nonventricular arrhythmia event or abnormal lead-related activity (1–5). The visual inspection of ICD EGMs could help differentiate if a tachycardia was ventricular or supraventricular in origin with a high degree of certainty (1–5). Furthermore, in subsequent years, a significant amount of research effort was implemented to establish effective automated device-based analysis of these EGMs to differentiate between ventricular and supraventricular tachycardias and minimize inappropriate ICD therapies (6–9).

See page 969

Importantly, analysis of ICD EGMs can be performed for other purposes. That different, configurationally distinct ventricular tachycardia (VT) on the basis of 12-lead electrocardiogram (ECG) analysis may also have configurationally different ICD EGMs has been suggested in prior reports but not completely investigated (10–12). These prior reports suggested that the ICD EGM recorded during VT can be used as a surrogate for the 12-lead ECG in differentiating among distinct monomorphic VTs and can be used to both help guide ablation targets and track the recurrence of specific VTs targeted at the time of ablation (10–12). In this issue of the *Journal*, Yoshida et al. (13) report on a rigorous analysis of ICD EGM configuration during monomorphic VT in a group of 21 patients referred for catheter ablation in the setting of prior myocardial infarction. This is the first study to report on the systematic use of ICD EGMs to distinguish among VT configurations. "Clinical" VTs had been documented by 12-lead ECGs in 15 patients, and in 13 of those patients, 12-lead ECG matching VTs could be induced during the electrophysiologic study. The investigators also recorded 12-lead ECGs and ICD EGMs from each induced VT. They then compared ICD EGMs from the 13 "clinically documented" VTs with the ICD EGMs from 64 other 12-lead ECG configurationally distinct induced VTs in these same patients. On the basis of a complex computerized analysis of ICD EGMs, 63 of 64 VTs (98%) not previously documented could be correctly identified as different from the clinical VTs. Of note, simple visual inspection of ICD EGMs was also highly accurate (96%) in distinguishing clinically documented VT from inducible and previously undocumented VT.

The possibility of identifying configurationally distinct VT on the basis of ICD EGM recordings has clinical relevance for a number of reasons. First, with the increased use of ICDs for the primary prevention of sudden death in patients with severe structural heart disease, an increasing proportion of patients will have ICD EGM recordings as the only documentation of monomorphic VT. Thus, "clinically documented VT" will probably be defined in the future only by the description of the ICD EGM. Second, pleomorphism, defined for VT by 12-lead ECG parameters, reportedly has clinical relevance related to ablation strategy and clinical outcomes (14–16). However, because of the limited number of VT episodes for which 12-lead ECGs are recorded, the incidence of pleomorphism may be underestimated and its clinical import not fully studied. To the extent that distinct ICD EGM configurations can be used as surrogates for distinct 12-lead ECG configurations, the storage and analysis of the majority of VT episodes would allow pleomorphism to be studied in more detail and its prognostic implications better defined. Third, recurrences after VT ablation procedures could be further characterized by comparison of pre-procedural, intraprocedural, and post-procedural ICD EGM configurations. The best VT ablation strategy might be better defined and the value of targeting specific ECG morphologies understood.

In addition, Yoshida et al. (13) go on to describe the spatial resolution of the ICD EGM as defined by detailed pace mapping over the entire area of bipolar EGM-defined low-voltage. Previous research on this same subject, using pacing from multiple left ventricular sites and blinded visual analysis to distinguish successive beats from the same pacing site from paced beats from a different site, found a relationship between distance from an index pacing site and accuracy to identify ICD EGM as coming from a different

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pacing site (17). Identification was found to be accurate if sites were ≥2 cm apart (17). In accordance with these observations, Yoshida et al. (13) found that the mean spatial resolution of computerized ICD EGM analysis was 8.7 cm^2, with the radius of a hypothetical circumference of such an area of 1.7 cm. The spatial resolution for the 12-lead ECG, using similar methodology, appeared to be better, with a mean value of 2.9 cm^2, and whether the much larger area (3 times) defined by a match in only the ICD EGM can be targeted for successful ablation without causing increased risk remains to be determined. Perhaps rather than an area of pace match, the linear extent of a pace match at the border zone of scar could be used to define the boundaries of a linear ablation strategy that could block exit to normal myocardium (18). This type of ablation would be more limited than a cluster of lesions aimed at covering an area of pace match as described by Yoshida et al. (13).

The methodology used to determine the spatial resolution in the present report has both unique value and limitations. First, the spatial resolution was calculated in relation to the identification of VT exit sites defined by pace mapping. This is an advantage over measurements in relation to any other ventricular site, because this methodology is intended to be used in patients with VT in the process of ablation. However, this methodology in turn has the general limitation related to the identification of VT exit sites with ECG analysis and pacing (19–24). Exit sites were identified by 12-lead ECG pace mapping during sinus rhythm, with these exit sites identified for only half of the VTs in the present report. Second, the methodology used computerized analysis of signals for both 12-lead ECG and ICD EGM analysis, but the cutoff values for the correlation coefficient and the root mean square difference were derived using the visually obtained classic "≥10 of 12 ECG leads pace match" as the gold standard. By doing so, the investigators include the limitations of this gross 12-lead ECG comparison in the final analysis. In addition, the methodology used to determine the spatial resolution for ICD EGM is not explained in detail ("ICD EGMs were analyzed in the same fashion as the 12-lead ECGs"), suggesting an identical set of limitations. Third, if the gold standard for ICD EGM analysis was derived from 12-lead ECG pace match, this could have biased the entire analysis in favor of 12-lead ECG analysis compared with ICD EGM.

If the conclusions of this study are to be implemented in general practice, several other limitations and possible sources of bias should be borne in mind. First, ICD EGM tracings were filtered in a specific way by the recording system (between 0.05 and 300 Hz), which is not the filtering used for standard ICD EGM tracings, at least by some manufacturers. Second, both the definition of the gold standard and the visual analysis were performed by 2 observers, but they were not blinded to other information. Third, ICDs from several manufacturers were included in the study. Although the investigators analyzed the potential impact of ICD manufacturer in spatial resolution and found no significant differences, the sample size was too small for a rigorous comparison. As a result, one cannot be assured of a lack of impact of ICD manufacturer. Furthermore, the near-field ICD EGMs are truly bipolar in some ICDs but not in others, and the superior vena cava coil participates in the coil-to-can configuration from some ICDs but not from others. In addition, it has been shown that the configuration of the ICD EGM during sinus rhythm differs between 2 of the defined brands, and these factors could potentially influence spatial resolution (5). Finally, all patients had post-myocardial infarction VT. It is unclear if the conclusions can be maintained for other VT substrates.

Despite the aforementioned limitations, we believe that the effort to delineate information from ICD EGM analysis as performed by Yoshida et al. (13) is seminal in nature and certainly a welcome investigation. Their work suggests that in the management of VT with catheter ablation procedures, ICD EGMs could become the new "standard" link between spontaneous phenomena and induced arrhythmias. The investigators are pioneers in what will probably evolve into "the new electrocardiography of the 21st century," and their work will be a much-referenced first step.

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