Original Article

Unipolar Endocardial Voltage Mapping in the Right Ventricle

Optimal Cutoff Values Correcting for Computed Tomography–Derived Epicardial Fat Thickness and Their Clinical Value for Substrate Delineation

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Background—Low endocardial unipolar voltage (UV) at sites with normal bipolar voltage (BV) may indicate epicardial scar. Currently applied UV cutoff values are based on studies that lacked epicardial fat information. This study aimed to define endocardial UV cutoff values using computed tomography–derived fat information and to analyze their clinical value for right ventricular substrate delineation.

Methods and Results—Thirty-three patients (50±14 years; 79% men) underwent combined endocardial–epicardial right ventricular electroanatomical mapping and ablation of right ventricular scar–related ventricular tachycardia with computed tomographic image integration, including computed tomography–derived fat thickness. Of 6889 endocardial–epicardial mapping point pairs, 547 (8%) pairs with distance <10 mm and fat thickness <1.0 mm were analyzed for voltage and abnormal (fragmented/late potential) electrogram characteristics. At sites with endocardial BV >1.50 mV, the optimal endocardial UV cutoff for identification of epicardial BV <1.50 mV was 3.9 mV (area under the curve, 0.75; sensitivity, 60%; specificity, 79%) and cutoff for identification of abnormal epicardial electrogram was 3.7 mV (area under the curve, 0.88; sensitivity, 100%; specificity, 67%). The majority of abnormal electrograms (130 of 151) were associated with transmural scar. Eighty-six percent of abnormal epicardial electrograms had corresponding endocardial sites with BV <1.50 mV, and the remaining could be identified by corresponding low endocardial UV <3.7 mV.

Conclusions—For identification of epicardial right ventricular scar, an endocardial UV cutoff value of 3.9 mV is more accurate than previously reported cutoff values. Although the majority of epicardial abnormal electrograms are associated with transmural scar with low endocardial BV, the additional use of endocardial UV at normal BV sites improves the diagnostic accuracy resulting in identification of all epicardial abnormal electrograms at sites with <1.0 mm fat. **(*Circ Arrhythm Electrophysiol*. 2017;10:e005175. DOI: 10.1161/CIRCEP.117.005175.)**

Key Words: catheter ablation ■ epicardial mapping ■ heart ventricles ■ ventricular tachycardia

The substrate for ventricular tachycardia (VT) in patients with right ventricular (RV) cardiomyopathy is often located epicardially.[1] During electroanatomical mapping (EAM), endocardial unipolar voltage (UV) at sites with normal endocardial bipolar voltage (BV) may detect epicardial scar, which may have important clinical implications.[2,3] Prior studies, using various methodologies, have suggested different endocardial UV cutoff values to detect epicardial scar defined as sites with abnormal BVs. Polin et al[2] have suggested 5.5 mV by using the 95% confidence interval in healthy control patients, and Tokuda et al[3] have suggested 4.4 mV by direct comparison of adjacent endocardial and epicardial points. Both studies lacked important epicardial fat information. In particular, the surface of the epicardial RV is covered by a thick fat layer.[4–6] An epicardial fat layer can attenuate the epicardial voltages and may thereby lead to overestimation of the epicardial scar.[7] Computed tomographic (CT) scans can be used to identify and quantify epicardial fat.[5] The aim of this study is (1) to define optimal cutoff values for UV to detect epicardial low BV and epicardial sites with fragmented electrograms and late potentials (LP), correcting for epicardial fat thickness using CT-derived fat information, and (2) to analyze the clinical value of endocardial UV during substrate mapping of the RV.

Methods

Patients

The study cohort consisted of consecutive patients who underwent combined endocardial–epicardial RV EAM with CT image integration for ablation of RV scar–related VT between 2006 and 2015. All patients underwent a comprehensive evaluation according to the revised Task Force Criteria of arrhythmogenic right ventricular cardiomyopathy (ARVC).[8] Mutations were classified as previously described.[9] Cardiac sarcoidosis was diagnosed according to the Heart

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WHAT IS KNOWN

- The substrate for ventricular tachycardia in right ventricular cardiomyopathies is often located at the epicardium, which can be detected by low endocardial unipolar voltage.
- Current cutoff values for unipolar voltages are based on studies without epicardial fat information and thus potentially overestimate the epicardial substrate.

WHAT THE STUDY ADDS

- This is the first study directly comparing endocardial and epicardial voltages and electrogram characteristics corrected for local computed tomographic–derived fat thickness.
- The optimal endocardial unipolar voltage cutoff to detect epicardial scar was 3.9 and 3.7 mV to detect the more clinically relevant fragmented electrograms and late potentials.

Rhythm Society expert consensus.[10] The study was approved by the local ethical committee. All patients provided informed consent before the mapping and ablation procedure.

CT Acquisition and Pre-Processing

Before combined endocardial–epicardial ablation, ECG-gated cardiac CT imaging was performed with an intravenous iodinated contrast agent. The epicardial and pericardial contours were manually traced on short-axis reformatted CT slices to create 3-dimensional meshes color-coded for fat thickness (FT, distance between epicardial and pericardial contours).[5,7] Subsequently, the original CT data and the 3-dimensional meshes were imported into the EAM system. The CT-derived images and EAM were aligned using the left main as a landmark as previously described.[5,7] These images were used during epicardial VT ablation procedures to avoid radiofrequency applications in the close vicinity of coronary arteries and to provide detailed information on epicardial FT, which may facilitate the interpretation of electrograms and explain ineffective radiofrequency applications.[5]

Electrophysiological Evaluation

All antiarrhythmic drugs were discontinued for ≥5 half-lives if possible with the exception of amiodarone. Epicardial access was obtained through subxiphoid puncture. EAM of the RV endocardium and epicardium was performed during sinus rhythm or RV pacing if pacing dependent (n=3), using a 3.5-mm irrigated-tip catheter (NaviStar Thermocool, Biosense Webster Inc, Diamond Bar, CA) and the CARTO system. All studies were performed by a single highly experienced operator using a steerable long sheath (Agilis, St. Jude Medical, St Paul, MN) to ensure adequate contact. Electrograms were filtered at 30 to 400 Hz (bipolar) and 1 to 240 Hz (unipolar). Electroanatomical data from remaps after radiofrequency ablation were not used for the current study.

Electrogram Analysis

All bipolar electrogram were displayed at the same gain (scale bar at 0.14 mV/1 cm) and sweep speed (200 mm/s). Electrogram duration was measured from the first to the last sharp peak.[7,11] BV with an amplitude >1.5 mV were considered normal both at the endocardium and epicardium. Abnormal electrograms were defined as fragmented (amplitude/duration ratio <0.05 and duration >50 ms) or LP (inscribing after QRS and separated by isoelectric segment >20 ms; Figure 1).

Post-Procedural Analysis

After electrogram analysis, all electroanatomical points were exported and superimposed on the corresponding short-axis CT slice to evaluate local epicardial FT using in-house develop software (Mass, V2013-EXP LKEB, Leiden). In Matlab (software-version 2014b), each endocardial point was linked to the closest epicardial mapping point based on the shortest Euclidian distance between the 3-dimensional coordinates. To avoid over-representation of densely mapped epicardial areas with abnormal electrogram, only endocardial points were linked to the closest epicardial point. The corresponding epicardial FT was subtracted from the Euclidian distance between the point pairs to optimize the selection of directly opposite endocardial and epicardial mapping points.

Endocardial and epicardial point pairs with a distance <10 mm were selected for analysis. For the purpose of UV cutoff value determination, point pairs with a fat layer ≥1.0 mm were excluded to avoid inclusion of epicardial points with false low BV electrograms because of voltage attenuation by an epicardial fat layer.

Scar Type

Point pairs were classified as no scar (normal BV [>1.5 mV] at endocardium and epicardium), endocardial scar (low endocardial BV, normal epicardial BV), epicardial scar (normal endocardial BV, low epicardial BV), or transmural scar (low BV at endocardium and epicardium; Figure 1). BV, UV, and electrograms were compared for different scar types.

Statistical Analysis

Categorical variables are displayed as number (percentage) and continuous variables are expressed as mean±SD or median (interquartile range [IQR]). The matched point pairs were compared with the Wilcoxon signed-rank test and the McNemar test. Continuous variables were compared using the Kruskal–Wallis for the omnibus test and the Dunn–Bonferroni for the pairwise comparisons with the Bonferroni Correction. Receiver operating characteristics curve analysis was performed to determine the optimal cutoff value, defined as the value maximizing the sum of sensitivity and specificity. All tests were 2 sided, and $P<0.05$ was considered statistically significant. All analyses were performed with SPSS version 23.0 (IBM SPSS, Armonk, NY).

Results

Patients

A total of 33 patients (age, 50±14 years; 26 [79%] men; body mass index, 25±4 kg/m^2) with combined endocardial–epicardial EAM and CT integration for ablation of RV scar–related VT were included. The underlying disease was definite ARVC according to the Task Force Criteria in 17 (52% [pathogenic mutation in 13/17]), borderline ARVC in 1 (3%), cardiac sarcoidosis in 3 (9%), scar of unknown origin in 2 (6%), athlete's right ventricular outflow tract scar in 9 (27%),[12] and myocarditis in 1 (3%). The baseline characteristics are summarized in Table 1.

Electroanatomical Mapping

Epicardial mapping with successful CT image integration was performed in all patients. The average number of mappings points was 215±87 at the RV endocardium and 293±139 at the corresponding epicardium. The majority had subtricuspid scar with variable involvement of apex and right ventricular outflow tract, and 9 patients had an isolated epicardial right ventricular outflow tract scar.

Post-Procedural Analysis

A total of 6889 endocardial points were coupled to the closest epicardial points, and 4225 (61%) point pairs had a distance

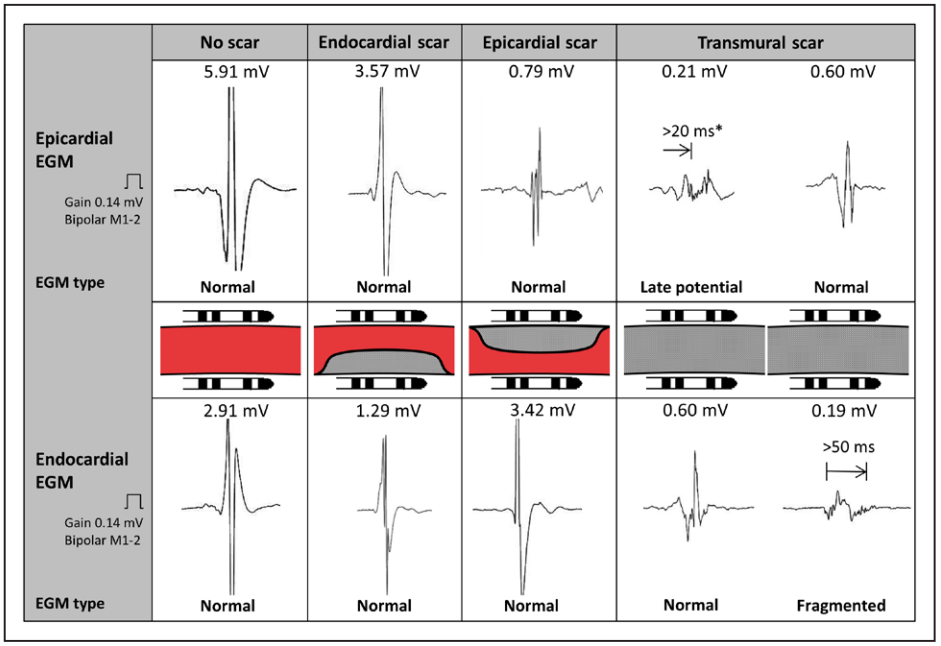


Figure 1. Scar patterns and corresponding bipolar electrograms (EGMs). Examples of EGMs recorded at coupled point pairs in areas with no scar, endocardial scar, epicardial scar, and transmural scars. Examples of fragmented EGM and late potential from areas with transmural scar are provided. The late potential definition is inscribing after QRS and separated by an isoelectric segment, measured from end of QRS complex until onset of local EGM (*).

<10 mm. FT was ≥2.8 mm at 2204 (52%) point pairs and between 1.0 and 2.7 mm at 1474 (35%) point pairs. The remaining 547 (13%) point pairs had an FT <1.0 mm and were selected for determination of UV cutoff values. The electrogram characteristics of the point pairs are displayed in Table 2. The epicardial points had a lower median BV and UV compared with endocardial points, and more abnormal electrograms were observed at the epicardium.

Electrogram Characteristics According to Scar Type

Of the 547 point pairs, no scar was present in 126 (23%) pairs, endocardial scar in 27 (5%), epicardial scar in 144 (26%), and a transmural scar in 250 (46%; Figure 2). The endocardial BV and UV and distribution of abnormal electrograms for each scar pattern are displayed in Figures 3 and 4. Abnormal electrograms at the endocardium were almost exclusively observed in areas with endocardial or transmural scar, and abnormal electrograms at the epicardium were almost exclusively observed in areas with epicardial or transmural scar (Figure 4). Of 151 endocardial or epicardial abnormal electrograms, 130 (86%) were located in areas with transmural scar.

Optimal Unipolar Cutoff Value to Detect Epicardial Scar

The optimal cutoff value for endocardial UV, independent of the corresponding endocardial BV, to detect epicardial low BV (<1.5 mV) was 2.7 mV (area under the curve, 0.83; sensitivity, 71%; specificity, 84%; Figure 5). Previously reported cutoff values yielded a higher sensitivity but lower specificity when calculated in the present study (cutoff, 4.4 mV; sensitivity, 85%; specificity, 65%; cutoff, 5.5 mV; sensitivity, 92%; specificity, 48%; Figure 5).

An additional receiver operating characteristic curve analysis was performed excluding sites with endocardial scar based on endocardial BV. Selecting only the 270 point pairs with endocardial BV >1.5 mV, the best endocardial UV cutoff value to detect epicardial low BV was 3.9 mV (area under the curve, 0.75; sensitivity, 60%; specificity, 79%; Table 3; Figure 5).

Endocardial Detection of Epicardial Abnormal Electrograms

Not all epicardial areas with low voltage are consistent with slow conduction as a potential substrate for VT.

Table 1. Baseline Characteristics and Procedural Data

	All Patients (n=33)
Age, y	50±14
Sex (male)	26 (79%)
BMI, kg/m^2	25±4
ICD (before ablation)	20 (61%)
Genetic testing	32
ARVC associated	13/32 (41%)
Any pathogenic	15/32 (47%)
EAM points	
RV endocardium	215±87
Epicardium	293±139
Combined	509±205

Variables are expressed as number (percentage), mean±SD. ARVC indicates arrhythmogenic right ventricular cardiomyopathy; BMI, body mass index; EAM, electroanatomical mapping; ICD, implantable cardioverter defibrillator; and RV, right ventricle.

Table 2. Electrogram Characteristics

	Endocardial (n=547)	Epicardial (n=547)	*P* Value
Bipolar voltage, mV	1.5 (0.3–3.2)	0.6 (0.3–2.0)	<0.001
Unipolar voltage, mV	2.4 (1.6–4.8)	2.0 (1.3–3.7)	<0.001
Abnormal electrogram	64 (12%)	87 (16%)	<0.001
Fragmented electrogram	8 (2%)	22 (4%)	<0.001
Late potential electrogram	56 (10%)	65 (12%)	<0.001

Variables are expressed as number (percentage) or median (interquartile range).

Eighty-seven of 547 point pairs (16%) had abnormal electrogram characteristics at the epicardium. The majority of endocardial BV and UV were low at sites with abnormal electrograms at the epicardium (for BV median 0.24 mV [IQR, 0.13–0.67 mV] and for UV median 1.52 mV [IQR, 1.2–2.0 mV]). Of the 87 point pairs with abnormal electrograms at the epicardium, 75 (86%) had low BV at the endocardium. Of the remaining 12 (14%) point pairs with normal endocardial BV and abnormal epicardial electrogram, all demonstrated low endocardial UV (median, 1.9 mV; IQR, 1.4–3.2 mV; maximum, 3.7 mV). The optimal endocardial UV cutoff value to detect epicardial abnormal electrograms was 3.7 mV (area under the curve, 0.88; sensitivity, 100%; specificity, 67%; Table 3; Figure 4). The combined use of endocardial BV and UV cutoffs resulted in detection of all abnormal epicardial electrogram.

Analysis in Areas With a Thicker Fat Layer

Abnormal electrogram characteristics are less affected by fat compared with BVs,[13] with the exception of low amplitude LPs that may be obscured by a thick fat layer. When all point pairs with any FT were selected, 546 point pairs had an abnormal electrogram at the epicardium, of which 390 (71%) point pairs had a low endocardial BV. Of the remaining 156 points pairs with normal endocardial BV and an abnormal electrogram at the epicardium, 102 (65%) showed low UV (<3.7 mV) at the endocardium with a median voltage of 3.1 mV (IQR, 2.0–4.2 mV). The combined use of endocardial BV and UV results in detection of 492 (90%) of all abnormal epicardial electrogram.

Discussion

This is the first study directly comparing electrograms of opposing endocardial and epicardial mapping points correcting for CT-derived epicardial fat. Of importance, 52% of epicardial mapping points were located in areas covered by ≥2.8 mm fat, a value previously associated with a significant impact on BV.[5,14] In areas with normal endocardial BV, the optimal endocardial UV cutoff value for the detection of epicardial scar, defined by low epicardial BV (<1.5 mV) not caused by fat, is 3.9 mV. The optimal endocardial UV cutoff value to detect fragmented electrogram and LP at the epicardium, which may be considered clinically more relevant, is 3.7 mV. These new cutoff values have a significantly higher specificity with an only minor decrease in sensitivity compared with prior suggested cutoff values. In RV cardiomyopathies, the majority of epicardial abnormal electrogram are found in areas with transmural scar and corresponding low endocardial BV. However, the additional use of endocardial UV increases the diagnostic accuracy allowing detection of all epicardial abnormal electrogram in RV areas without epicardial fat and 90% of all abnormal electrogram in RV areas with thicker fat layers, typical for the atrioventricular groove.

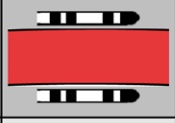
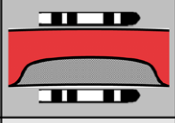
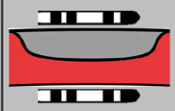
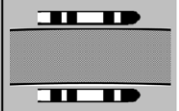
RV scar pattern	No scar	Endocardial scar	Epicardial scar	Transmural scar
				
Point pairs (n)	126	27	144	250
Unipolar voltage				
- Epicardium, mV	4.6 (3.4-6.7)	3.8 (2.1-4.5)	1.9 (1.3-2.9)	1.5 (1.1-2.0)
- Endocardium, mV	5.8 (4.4-8.9)	2.7 (1.6-3.0)	3.5 (2.4-5.4)	1.7 (1.2-2.1)
Abnormal EGM				
- Epicardium	0 (0%)	0 (0%)	12 (8%)	75 (30%)
- Endocardium	0 (0%)	3 (11%)	6 (4%)	55 (22%)

Figure 2. Electrogram (EGM) characteristics per scar pattern. Variables are expressed as median (interquartile range) or number (percentage). RV indicates right ventricle.

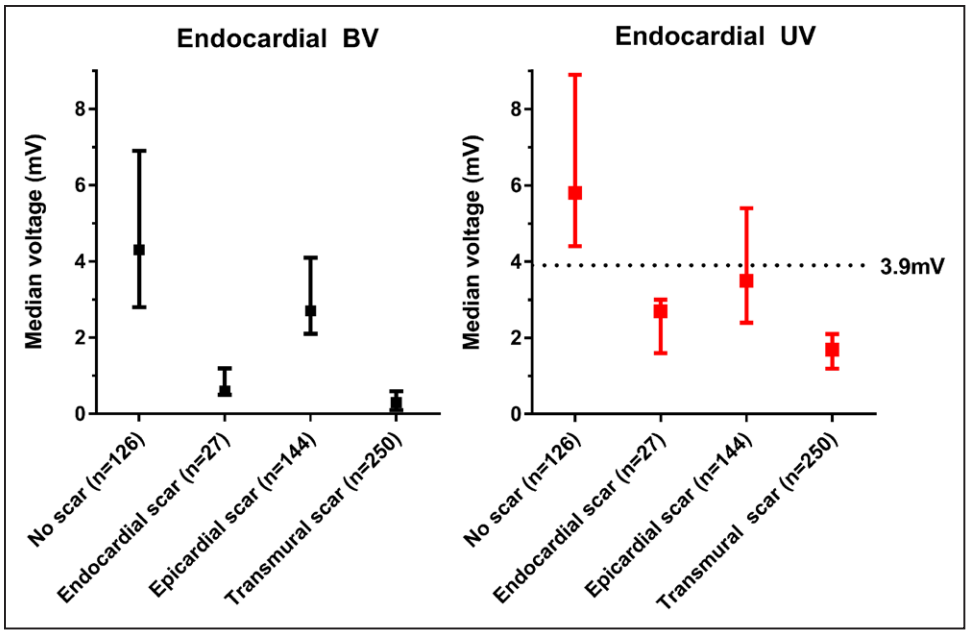


Figure 3. Endocardial bipolar voltage (BV) and unipolar voltage (UV) according to scar type. Median and interquartile range of endocardial UVs and BVs for different scar types. All scar types showed significantly lower BV and UV than nonscar sites (all $P<0.05$), and transmural scar demonstrated lower endocardial BV and UV than epicardial scar (both $P<0.001$).

Unipolar Voltage to Detect Epicardial Scar

Two prior studies, using different methodologies, have proposed different cutoff values for endocardial UV in the RV to detect epicardial scar. The first study by Polin et al[2] has suggested a cutoff value of 5.5 mV by using the 95% confidence interval derived from normal healthy control subjects. This cutoff resulted in a good correlation between the overall size of endocardial low UV area and epicardial low BV area, but directly corresponding endocardial and epicardial areas were not analyzed. Of note, the most severe cases (with scar >50% of the total RV free wall) were excluded from analysis, which may be a frequent finding in advanced ARVC. The second study by Tokuda et al[3] has suggested an endocardial UV cutoff value of 4.4 mV by direct comparison of adjacent endocardial and epicardial mapping points identified from CARTO maps analyzing voltages and electrogram characteristics.

In the previous studies, epicardial low voltage areas had to demonstrate additional scar features (LPs, a broad potential [≥80 ms], split potentials, or multicomponent [deflections ≥8]) to avoid selection of false low BV points in areas covered by epicardial fat.[2,3] Accordingly, these studies could not differentiate between epicardial true low voltage sites (ie, not explained by fat) without abnormal electrogram characteristics, which might have even been misclassified as false low

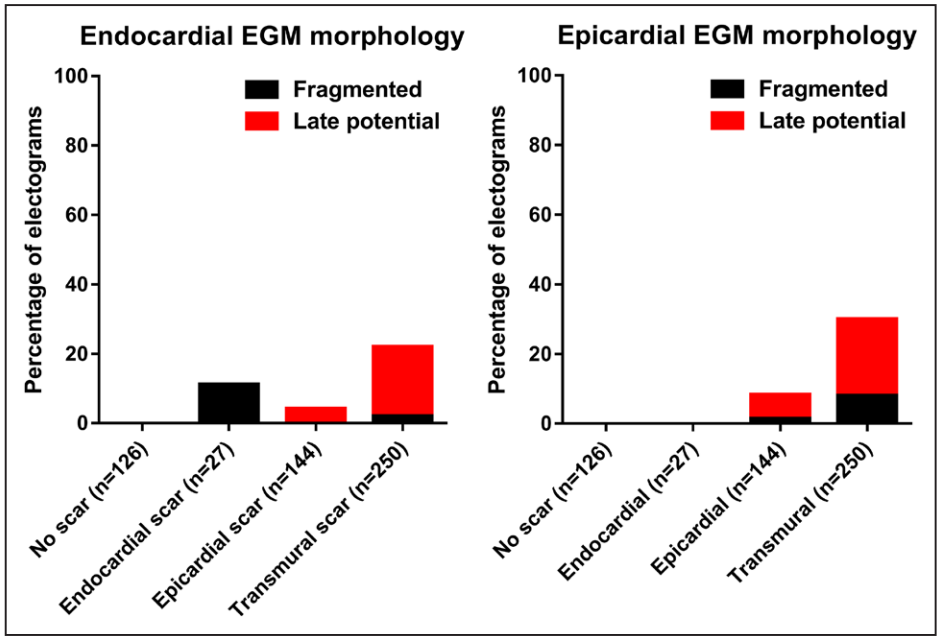


Figure 4. The percentage of the abnormal electrogram (EGM) morphologies according to scar type.

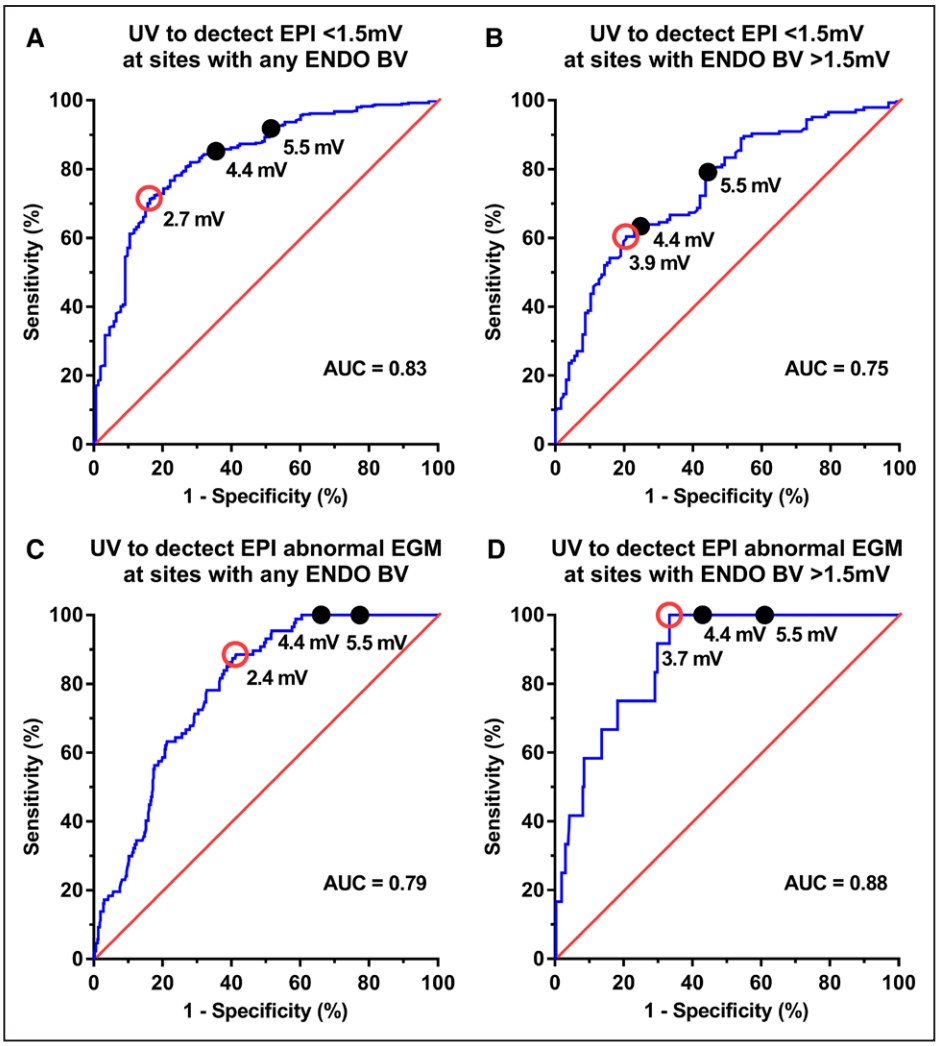


Figure 5. Receiver operating characteristic (ROC) curves to detect low voltages and abnormal electrogram (EGM). **A** and **C**, ROC curve analysis of endocardial unipolar voltage (UV) to detect low epicardial bipolar voltage (BV; <1.5 mV) and epicardial abnormal EGM regardless of the endocardial BV. **B** and **D**, ROC curve analysis in areas with endocardial BV >1.5 mV. AUC indicates area under the curve; and EPI, epicardium.

voltage sites, and epicardial true low voltage sites with abnormal electrograms.

Both studies lacked the important epicardial FT information, potentially resulting in overestimation of the epicardial scar size. In particular, the surface of the epicardial RV is covered by a thick fat layer.[4–6] An epicardial fat layer can attenuate voltages and may also affect the electrogram characteristics although to a lesser degree.[7]

The present study is the first directly comparing endocardial and epicardial mapping points with local epicardial fat information and a predefined Euclidian distance of <10 mm allowing for accurate point coupling. In areas with endocardial BV >1.5 mV, the best UV cutoff value for detection of epicardial low BV in areas devoid of fat was 3.9 mV. This was more specific (79%) compared with previous values when calculated in the present study (cutoff, 4.4 mV; specificity, 75%; cutoff, 5.5 mV; specificity, 56%).

Endocardial UV to Detect Epicardial Arrhythmogenic Substrate

Not all epicardial low BV sites have abnormal electrogram characteristics consistent with slow conduction as a potential

Table 3. Optimal Cutoff Value Current and Previous Studies

	Epicardium<1.5 mV		Abnormal Electrogram	
Cutoff	Sensitivity, %	Specificity, %	Sensitivity, %	Specificity, %
3.9 mV/3.7 mV (current study)	60	79	100	67
4.4 mV (Tokuda et al[3])	63	75	100	57
5.5 mV (Polin et al[2])	79	56	100	39

substrate for VT. In contrast to the prior studies, we could select areas without epicardial fat and could differentiate between epicardial points with only low BV and low BV with in addition abnormal electrogram characteristics. We demonstrated that fragmented and LP, in line with previous studies in the left ventricle,[7,13,15] are typically located in areas with transmural scar and low endocardial BV. However, the additional use of endocardial UV allowed detection of a potential epicardial arrhythmogenic substrate in areas with preserved endocardial BV. The optimal endocardial UV cutoff value to detect abnormal epicardial abnormal electrogram was 3.7 mV. This cutoff value had a 100% sensitivity to detect abnormal electrogram; the 67% specificity was higher than the previously suggested cutoff values when calculated in the present study (57% and 39% for 4.4 and 5.5 mV, respectively). The combined use of both endocardial BV and UV cutoffs resulted in the detection of all abnormal electrogram in areas without epicardial fat. At areas with epicardial fat, the combined use of endocardial BV and UV resulted in detection of 492 (90%) of all abnormal epicardial electrogram, of which 102 of 492 (21%) were only detected by endocardial UV.

UV Voltage Field of View

UV has a wider field of view compared with BV.[13] Data on the exact field of view are lacking. In a previous study by our group integrating cardiac magnetic resonance–derived scar thickness with EAM in the left ventricle, endocardial UV was affected if the epicardial scar extended toward the endocardium involving the endocardial 4-mm layer. UV was less affected if the scar was located >4 mm from the endocardium.[13] In the thin-walled RV, endocardial UV mapping may, therefore, be able to better detect epicardial scar compared with the left ventricle. A thicker wall generates a higher UV, which is supported by the higher UV cutoff values derived from healthy patients in the thicker walled left ventricle (8.27 mV) compared with the thinner walled RV (5.5 mV).[2,16]

The wall thickness of the RV is on average 2.7 mm but varies with thicker myocardium toward the tricuspid annulus.[1,6] The epicardial fat layer is also thickest at the basal RV near the tricuspid annulus, decreases toward the apex, and is almost absent at the inferior wall.[4,5,17] In the current study, a higher median endocardial UV was observed at point pairs with a thicker fat layer compared with point pairs with <1.0 mm of fat. This is likely because of basal RV sites with both a thicker RV wall and a thicker fat layer. Accordingly, our proposed endocardial UV cutoff to detect epicardial abnormal electrograms at sites covered by fat was less sensitive, likely because of the thicker RV wall.

Clinical Implications

The potential benefit of combined endocardial–epicardial EAM and ablation as the first approach in ARVC patients has been reported.[1,18] However, in many centers, the endocardial approach is still the first approach, which may be because of the lack of experience, operators preference', and a higher risk for major complications. The proposed UV cutoff values to detect a potential arrhythmogenic substrate may be of aid in the decision to obtain access to the epicardium. This is particularly relevant for the RV because endocardial electroanatomical voltage mapping has been described to be superior to late gadolinium enhanced–cardiac magnetic resonance imaging for detection of scars.[19] The detection of a potential epicardial VT substrate obscured by a thick epicardial fat layer may have additional important clinical implications for patients in whom epicardial catheter ablation fails. These patients may benefit from surgical ablation with the possibility of fat removal.

Limitations

Histology was not available as a gold standard for the presence of fibrofatty replacement. Cardiac magnetic resonance was not performed due to its limited value for delineation of fibrofatty replacement in the thin-walled RV. Instead, high-density endocardial and epicardial EAM with integrated CT-derived fat information was performed to assess the presence of scar and fat. Although an intramural substrate could not be ruled out using this approach, none of the mapping points with normal endocardial and epicardial BV demonstrated any electrogram abnormalities, which makes an intramural scar in the thin-walled RV unlikely. No distinction could be made between endocardial points overlying endocavitary structures or overlying the RV free wall. However, selecting only point pairs <10 mm apart in the analysis likely excluded the majority of the endocardial points overlying endocavitary structures. The analyses could not be corrected for RV wall thickness that may affect UV.

Conclusions

This is the first study using CT-derived fat information to analyze the optimal cutoff value for endocardial UV mapping to detect epicardial scar in the RV. The optimal cutoff value is 3.9 mV for detection of epicardial scar in areas with normal endocardial BV and 3.7 mV for detection of fragmented electrograms and LPs as potential substrate for VT. Although the majority of epicardial abnormal electrograms are associated with transmural scars and low endocardial BV, the additional use of endocardial UV improves the diagnostic accuracy for detection of a potential epicardial substrate at normal endocardial voltage sites. The currently reported cutoff values have a substantially higher specificity with only a minor decrease in sensitivity compared with prior cutoff values. Previously proposed cutoff values overestimate the size of the epicardial scar.

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Disclosures

None.

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Unipolar Endocardial Voltage Mapping in the Right Ventricle: Optimal Cutoff Values Correcting for Computed Tomography–Derived Epicardial Fat Thickness and Their Clinical Value for Substrate Delineation

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