Development of a magnetocardiography-based algorithm for discrimination between ventricular arrhythmias originating from the right ventricular outflow tract and those originating from the aortic sinus cusp: A pilot study

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BACKGROUND Although several reports address characteristic 12-lead electrocardiographic findings of outflow tract ventricular arrhythmias (OT-VAs), the accuracy of electrocardiogram-based algorithms to predict the OT-VA origin is sometimes limited.

OBJECTIVE This study aimed to develop a magnetocardiography (MCG)–based algorithm using a novel adaptive spatial filter to differentiate between VAs originating from the aortic sinus cusp (ASC-VAs) and those originating from the right ventricular outflow tract (RVOT-VAs).

METHODS This study comprised 51 patients with an OT-VA as the target of catheter ablation. An algorithm was developed by correlating MCG findings with the successful ablation site. The arrhythmias were classified as RVOT-VAs or ASC-VAs. Three parameters were obtained from 3-dimensional MCG imaging: depth of the origin of the OT-VA in the anteroposterior direction; distance between the earliest atrial activation site, that is, sinus node, and the origin of the OT-VA; and orientation of the arrhythmia propagation at the QRS peak. The distance was indexed to the patient's body surface area (in mm/m^2).

RESULTS Origins of ASC-VAs were significantly deeper (81 ± 6 mm/m^2 vs 68 ± 8 mm/m^2; $P < .01$) and farther from the sinus node (55 ± 9 mm/m^2 vs 41 ± 9 mm/m^2; $P < .01$) than those of RVOT-VAs. ASC-VA propagation had a tendency toward rightward axis. Receiver operating characteristic analyses determined that the depth of the origin was the most powerful predictor, with a sensitivity of 90% and a specificity of 73% (area under the curve = 0.90; $P < .01$). Discriminant analysis combining all 3 parameters revealed the accuracy of the localization to be 94%.

CONCLUSION This MCG-based algorithm appeared to precisely discriminate ASC-VAs from RVOT-VAs. Further investigation is required to validate the clinical value of this technique.

KEYWORDS Premature ventricular contraction; Right ventricular outflow tract; Aortic sinus cusp; Magnetocardiography; Catheter ablation; Spatial filter

ABBREVIATIONS **ASC** = aortic sinus cusp; **AUC** = area under the curve; **ECG** = electrocardiogram/electrocardiographic; **MCG** = magnetocardiography/magnetocardiographic; **OT-VA** = outflow tract ventricular arrhythmia; **RF** = radiofrequency; **ROC** = receiver operating characteristic; **RVOT** = right ventricular outflow tract; **TZ** = transitional zone; **VA** = ventricular arrhythmia; **VT** = ventricular tachycardia

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Introduction

Radiofrequency (RF) catheter ablation has been established as an effective and curative therapy for ventricular arrhythmias (VAs) originating from the outflow tract (OT-VAs) in structurally normal hearts.[1,2] Most of these arrhythmias originate from the septal aspect of the right ventricular outflow tract (RVOT)[1,2] or the aortic sinus cusp (ASC).[3,4] In reported case series, success rates of RF catheter ablation of left ventricular outflow tract ventricular tachycardia (VT) are lower than those of RVOT-VT, and left heart catheterization is associated with risks of thromboembolism and coronary artery or aortic valve injury.[5] Precise discrimination of ASC-VAs from RVOT-VAs before the ablation procedure helps electrophysiologists to decide on necessary arterial or

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venous punctures, to plan an appropriate ablation strategy, and to inform patients about risks, benefits, and success rates of the procedures.

Although electrocardiogram (ECG)–based algorithms have successfully been developed that can identify the origin of VAs,[3,4,6] it is possible that their accuracy is impaired by physical characteristics of the patients,[7] cardiac rotation,[8] and offset of lead placement.[9] Therefore, neighboring anatomic structures can result in ECG characteristics that may be similar to those of RVOT-VAs.[10]

We developed a novel spatial filter to reconstruct a source distribution from bioelectromagnetic data, which can provide a spatial resolution considerably higher than that of conventional methods. The robustness of this method to the source correlation was already validated in our computer simulation and in our experiments using auditory-evoked magnetoencephalographic data.[11] The objectives of this study were to apply this novel spatial filter to magnetocardiography (MCG), to calculate the coordinates of the VA origin itself, and to demonstrate the ability of MCG to discriminate ASC-VAs from RVOT-VAs.

Methods

Patients

This study comprised 51 patients (20 men and 31 women; mean age 49 ± 15 years) who underwent successful catheter ablation for symptomatic idiopathic VT or premature ventricular contractions originating from the outflow tracts between January 2009 and October 2012. Patients with structural heart disease or atrial arrhythmias were excluded from the study. Surface ECGs of the OT-VAs showed left bundle branch block morphology and inferior axis in all patients. The origins of the VAs were identified in the RVOT (n = 41 [80%]) or the ASC (n = 10 [20%]). There were no significant differences with regard to baseline patient characteristics (Table 1). All patients had a normal ECG during sinus rhythm except for rotation of the R-wave transition, and no structural abnormalities were found by physical examination, echocardiography, and coronary angiography. All antiarrhythmic drugs were discontinued for at least 5 half-lives of each drug before the procedure. All patients gave written informed consent for their participation in this study, and the study protocol was approved by the local institutional review board.

Electrophysiological study and RF catheter ablation

Electrophysiological evaluation and catheter ablation were performed as described previously.[12] Briefly, catheters were introduced into the His bundle region and right ventricular apex under fluoroscopy via the right femoral vein. If the clinical arrhythmia did not occur spontaneously, intravenous isoproterenol was administered to induce it. Activation mapping and pace mapping were performed during the clinical arrhythmia. Mapping of the OT-VA was initially started in the RVOT area. If suitable ablation sites were not found in the RVOT, the ASC was mapped. A 7-F quadripolar catheter with a 4-mm distal electrode and a deflectable tip (Cordis Webster Inc, Baldwin Park, CA; EP Technologies Inc, San Jose, CA) or a 7-F irrigated-tip catheter (ThermoCool, Biosense Webster, Inc, Diamond Bar, CA) was used for mapping and ablation. The RF energy was delivered using a maximum power of 50 W and a maximum temperature of 55°C with use of the non–irrigated-tip catheter as well as using a maximum power of 40 W and a maximum temperature of 42°C with use of the irrigated-tip catheter. The *VA origin* was defined as the site where the earliest ventricular activation was recorded and/or a perfect pace map was obtained and VAs were successfully eliminated through ablation. After successful ablation, right atrial CARTO mapping (Biosense Webster, Inc, Diamond Bar, CA) was performed to identify the location of the sinus node in 5 patients for the validation of the accuracy of the MCG measurements described below. Procedural success was confirmed by the absence of symptoms suggestive of a tachycardia and of episodes of the OT-VA as documented on

Table 1 Baseline characteristics

Variable	Total (n = 51)	RVOT (n = 41)	ASC (n = 10)	P
Age (y)	49 ± 15	48 ± 15	53 ± 17	.43
Sex: women/men	31/20	23/18	8/2	.28
Body mass index (kg/m^2)	23.4 ± 3.3	23.1 ± 3.3	24.6 ± 3.6	.25
BSA(m^2)	1.7 ± 0.2	1.7 ± 0.17	1.6 ± 0.13	.14
Holter ECG				
Patients with repetitive PVCs (>3 beats)	24 (52)	19 (53)	5 (50)	1.00
Patients with sustained VT	4 (9)	2 (6)	2 (20)	.20
PVC%	20 ± 15	19 ± 16	22 ± 14	.69
Echocardiographic parameters				
LV ejection fraction (%)	64 ± 8	64 ± 8	64 ± 9	.92
LV diameter (mm)	49 ± 6	49 ± 6	50 ± 5	.54
LV volume (mL)	113 ± 33	112 ± 33	115 ± 34	.84

Values are presented as mean ± SD and as n (%).

ASC = aortic sinus cusp; BSA = body surface area; ECG = electrocardiogram; LV = left ventricular; PVCs = premature ventricular contractions; RVOT = right ventricular outflow tract; VT = ventricular tachycardia.

the 12-lead ECG or 24-hour Holter monitoring during the follow-up period of 24 ± 13 months.

ECG-based algorithms

Surface 12-lead ECGs were recorded in all patients during sinus rhythm and during the clinical arrhythmia at a paper speed of 25 mm/s, with chest and limb leads placed in standard positions. The morphology of the sinus beats and OT-VAs was analyzed on the same 12-lead ECG using electronic calipers. We applied a recently reported ECG-based algorithm, the transitional zone (TZ) index, which is considered to more accurately discriminate RVOT-VAs from ASC-VAs than do other previously reported algorithms.[8] The *TZ index* is defined as the TZ score of the VA minus the TZ score of the sinus beat, where the TZ score is graded in 0.5-point increments according to the site of the TZ in the precordial leads.[6,8]

Spatial filter and MCG-based algorithms

All patients underwent MCG testing during sinus rhythm 1 day before ablation. The MCG methodology has been described in detail previously.[13,14] An MC-6400 MCG system (Hitachi High-Technologies Corporation, Tokyo, Japan) with 64 magnetic sensors was used. The magnetic sensors were in an 8 × 8 matrix with a pitch of 25 mm and a measurement area of 175 × 175 mm. The MCG signals from each patient were recorded in the resting state in the anteroposterior direction in a magnetically shielded room

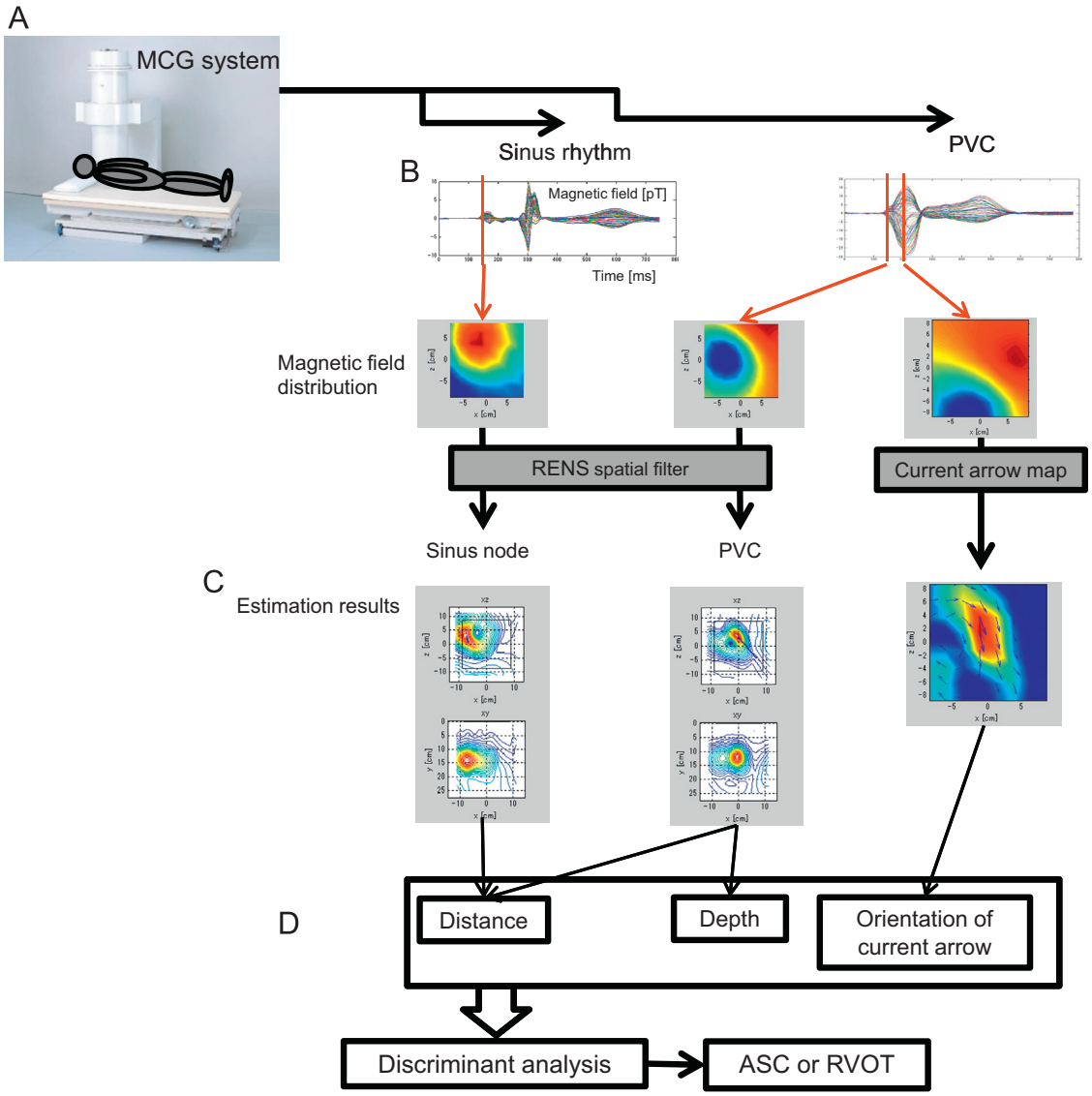

Figure 1 **A:** MC-6400 MCG system (Hitachi High-Technologies Corporation, Tokyo, Japan) with 64 magnetic sensors to measure the normal component of the magnetic field. **B:** MCG signals from the VA and normal sinus rhythm were averaged separately. These averaged signals were used to reconstruct 2 distinctive points by applying the RENS spatial filter algorithm. **C:** The location of the sinus node was obtained using an MCG field map at the beginning of the P wave of the normal sinus rhythm. The origin of the VA was obtained by reconstructing an MCG field map at the beginning of the QRS complex in the averaged VA signal. **D:** The 3 parameters were obtained: depth of the origin of the VA with respect to the sensor array, distance between the sinus node and the origin of the VA, and orientation of the magnetic field at the peak of the QRS complex. ASC = aortic sinus cusp; MCG = magnetocardiography; PVC = premature ventricular contraction; RENS = resolution near-field structure; RVOT = right ventricular outflow tract; VA = ventricular arrhythmia.

Table 2 Parameters related to catheter ablation

Variable	Total ($n = 51$)	RVOT (n = 41)	ASC (n = 10)	P
Procedure time (min)	124 ± 49	119 ± 43	152 ± 63	.06
Irrigation catheter	19 (37)	15 (37)	4 (40)	1.00
Preceded electrogram (ms)	29 ± 12	29 ± 12	31 ± 14	.72
Perfect or near-perfect map	47 (92)	38 (93)	9 (90)	.60
Catheter ablation site	14 ± 9	14 ± 8	11 ± 12	.29
Duration of radiofrequency energy applications (min)	15 ± 10	16 ± 10	10 ± 11	.12

Values are presented as mean ± SD and as n (%).
ASC = aortic sinus cusp; RVOT = right ventricular outflow tract.

(Figure 1A). The sampling rate was 1 kHz, and the measurement period was 2 minutes. The MCG signals were passed through a 0.1- to 50-Hz band-pass filter and a 50-Hz power line noise filter. The outline of the proposed method is presented in Figure 1. The MCG signals from the VA and normal sinus rhythm were averaged separately. These averaged signals were then used to reconstruct 2 distinctive points by applying the resolution near-field structure spatial filter algorithm (Figure 1B).[11] The location of the sinus node was obtained using an MCG field map at the beginning of the P wave of the normal sinus rhythm. The origin of the VA was obtained by reconstructing an MCG field map at the beginning of the QRS complex in the averaged VA signals (Figure 1C).

The first parameter is the depth of the VA origin with respect to the sensor array, and the second parameter is the distance between the sinus node and the origin of the VA. The first and second parameters are corrected by each patient's body surface area. The third parameter is obtained as the orientation of the magnetic field at the peak of the QRS complex of the VA signal. The discriminant function was obtained using these 3 variables from patients with a VA of known origin, and the analysis was applied to a data set obtained from a patient with a VA of unknown origin (Figure 1D).

Statistical analysis

Continuous variables are expressed as mean ± SD and were compared using the Student t test. Categorical variables were compared by using the χ^2 test. A P value of $< .05$ was considered statistically significant.

Discriminant analysis was based on the Mahalanobis distance. To simultaneously compare groups using multiple variables, it is insufficient to consider the variables singly because this ignores the correlations between them. To measure the distance of a patient from the "multivariate mean point" (centroid) of the RVOT and ASC groups in the multidimensional space, a statistically generalized distance is required. A suitable measure is the Mahalanobis distance.[15] The Mahalanobis distance standardizes the scales, and so the results are independent of the units of measurement of any variable. Using 3 variables (depth, distance from the sinus node, and orientation), the Mahalanobis distances from the centroid of each group (RVOT or ASC) were calculated for each patient. Herein, if one patient was closer to the centroid of the RVOT group compared to that of the ASC group, the arrhythmia origin of that patient was determined to be the RVOT.[16]

Results

Catheter ablation

In 41 patients, the VA was eliminated by ablation in the RVOT: in the septal aspect in 28 patients and in the free wall in 13 patients. The earliest ventricular activation recorded with the ablation catheter preceded the onset of the QRS complex by 29 ± 12 ms. In the other 10 patients, the VA was eliminated by ablation in the ASC: in the left coronary cusp in 8 patients and the right coronary cusp in 2 patients. The earliest ventricular activation recorded with the ablation catheter preceded the onset of the QRS complex by 31 ± 14 ms. Comparisons of procedure-related parameters between RVOT-VAs and ASC-VAs are summarized in Table 2. There was a trend toward longer procedure time in the ASC group vs the RVOT group ($P = .06$).

Differentiation based on the ECG-based algorithm

A cutoff value for the TZ index of < 0 predicted an ASC origin with 95% sensitivity and 80% specificity in this study (Table 3). The area under the curve (AUC) obtained by receiver operating characteristic (ROC) analysis was 0.88.

Differentiation based on the MCG-based algorithm

Depth of the VA origin in the anteroposterior direction

The VA origin in the ASC group was significantly deeper than that in the RVOT group (81 ± 6 mm/m^2 vs 68 ± 8 mm/m^2;

Table 3 Differentiation based on the TZ index

Variable	Total ($n = 51$)	RVOT (n = 41)	ASC (n = 10)	P
TZ score of the OT-VA	3.3 ± 1.1	3.7 ± 0.4	1.8 ± 1.6	.005
TZ score of the sinus beat	3.1 ± 0.8	3.1 ± 0.8	3.3 ± 0.8	.55
TZ index	0.2 ± 1.3	0.6 ± 0.9	−1.5 ± 1.6	.002

Values are presented as mean ± SD.
ASC = aortic sinus cusp; OT-VA = outflow tract ventricular arrhythmia; RVOT = right ventricular outflow tract; TZ = transitional zone.

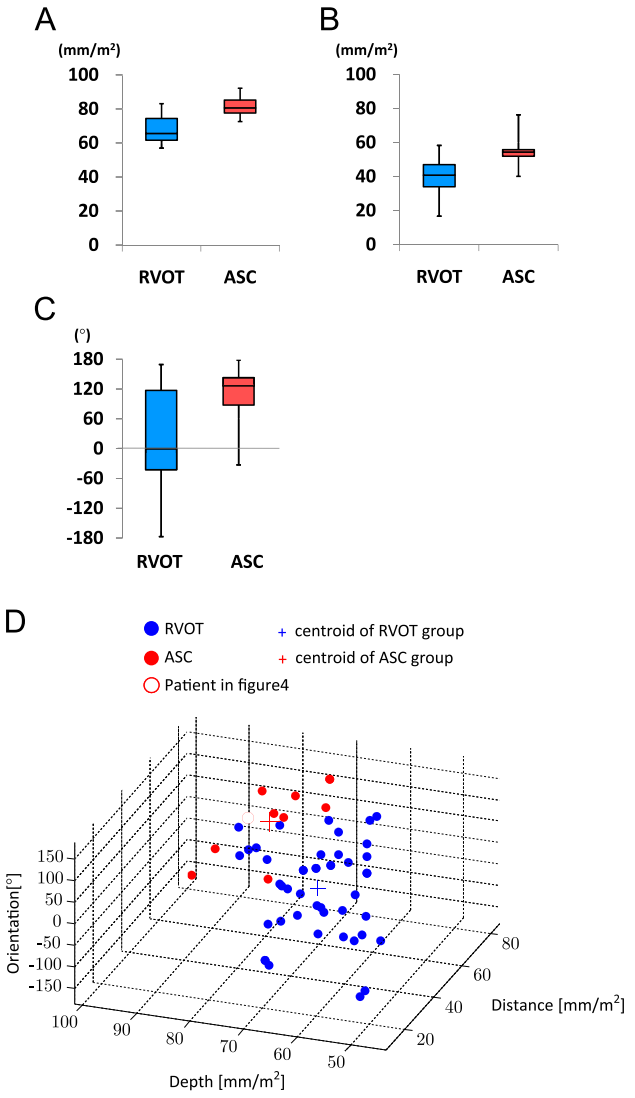

Figure 2 Box plots of the 3 parameters in the RVOT and ASC groups and 3-dimensional scatter plot. **A:** Depth of the VA origin **B:** Distance between the sinus node and the origin of the VA **C:** Orientation of arrhythmia propagation **D:** Three-dimensional scatter plot of the 3 parameters. ASC = aortic sinus cusp; RVOT = right ventricular outflow tract; VA = ventricular arrhythmia.

$P < .01$; Figures 2A and 2D). ROC analyses determined the best cutoff value to be 73 mm/m^2, with a sensitivity of 90% and a specificity of 73% (AUC = 0.90; $P < .01$; Figure 3, green line). The positive predictive and negative predictive values were 97% and 41%, respectively (Table 4). Discriminant analysis also revealed that the cutoff distance had an accuracy of 77% for differentiating an ASC-VA from a RVOT-VA (Table 5).

Distance between the earliest atrial activation site, that is, the sinus node, and the origin of the VA

The distance between the sinus node and the VA origin in the ASC group was longer than that in the RVOT group (55 ± 9 mm/m^2 vs 41 ± 9 mm/m^2; $P < .01$; Figures 2B and 2D). ROC analyses determined the best cutoff value to be 48 mm/m^2, with a sensitivity of 90% and a specificity of 78% (AUC = 0.88; $P < .01$; Figure 3, orange line). The positive predictive and negative predictive values were 97% and 50%, respectively (Table 4). Discriminant analysis also revealed that the cutoff distance had an accuracy of 78% (Table 5).

Orientation of VA propagation

Arrhythmia propagation was superior or rightward axis in most patients with an ASC-VA, whereas it was variable and showed no certain tendency in the RVOT group (Figures 2C and 2D). ROC analyses determined the best cutoff value to be 82°, with a sensitivity of 80% and a specificity of 59% (AUC = 0.73; $P = .03$; Figure 3, blue line). The positive predictive and negative predictive values were 92% and 32%, respectively (Table 4). Discriminant analysis also revealed that the cutoff angle had an accuracy of 61% for localizing the ASC-VA from the RVOT-VA (Table 5).

Finally, a discriminate analysis that combined all 3 parameters could discriminate VA origins with a high accuracy of 94% (Table 5). A representative case is presented in Figure 4.

Validation of the MCG-based algorithm

The distance between the sinus node and the VA origin measured by MCG mapping almost completely correlated with that measured by CARTO mapping (Y = 0.903X − 0.652; $R = .94$; $P < .01$). However, the distance measured by CARTO mapping was significantly shorter than that determined by MCG mapping (50 ± 14 mm vs 62 ± 15 mm; $P = .005$).

Discussion

Major findings

A novel MCG-based algorithm using an originally developed spatial filter could precisely identify the side of VA origin with a diagnostic accuracy of more than 90%. Deeper origin, longer distance from the sinus node, and rightward direction of arrhythmia propagation were observed in ASC-VAs. These results may lead to a better understanding of the anatomy related to OT-VAs and to optimal approaches for catheter ablation. There was almost perfect correlation between distances calculated from MCG signals and those measured with a 3-dimensional mapping system, thus supporting the accuracy of this MCG-based algorithm. To our knowledge, this is the first report demonstrating the usefulness of MCG to differentiate an ASC-VA from a RVOT-VA in clinical practice.

Depth of the VA origin

In this study, the origins of VAs from the ASC were significantly deeper than those of VAs from the RVOT, and this finding showed the most significant difference between the 2 VA types. Knowledge of the anatomic relation between the RVOT and the ASC is essential for accurate diagnosis of the VA origin. An anatomical study[17] demonstrated that in a transverse section of the adult thorax at the

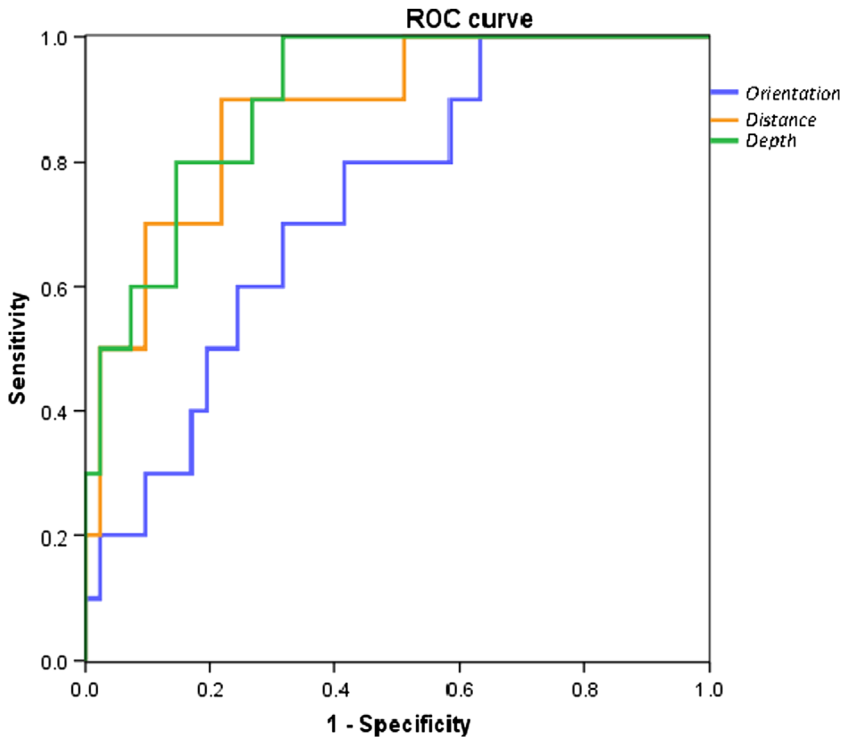

Figure 3 ROC curve of the depth of the VA origin, the distance between the sinus node and the origin of the VA, and the orientation of arrhythmia propagation. ROC = receiver operating characteristic; VA = ventricular arrhythmia.

level of the fourth costal cartilages, the septa lie at an angle of approximately 45° to the median plane, and the right ventricle therefore lies as much in front of the left ventricle as it does to its right side. In the vertical section, as the terminal part of the RVOT ascends, it comes to lie increasingly more on the left side of the heart, and in this region, the 2 outflow tracts are separated by the anterior wall of the aortic vestibule. Also, the mechanism behind certain ECG-based algorithms, which determine that larger R waves are found in leads V_1 and V_2 of ASC-VAs, is considered to be due to the posterior location of the aorta.[18] These reports are consistent with the results based on our MCG-based algorithm, in which the depth of the VA origin was the important discriminator differentiating RVOT-VAs from ASC-VAs.

Distance between the sinus node and the origin of the VA

We measured the distance from the sinus node to the VA origin because this parameter appeared to be less affected by physical characteristics of the patients, such as body surface area or body mass index, than did the depth of the VA origin. As discussed above, the origin of ASC-VAs was farther from the sinus node compared with that of RVOT-VAs. The sinus node is a lateral structure relative to the superior cavoatrial junction and is remarkably constant in position,[19] making the sinus node favorable as a base point for this parameter.

Orientation of arrhythmia propagation at the QRS peak

In this study, the activation pattern of VAs was significantly different in axis between RVOT-VAs and ASC-VAs. One of the characteristics of the outflow tracts is known to be their crossover relationship. The outflow tract undergoes rotation during its development and remodeling. Rotation of the myocardium at the base of the outflow tract is essential to achieve normal positioning of the great arteries. In the coronal section of the adult thorax, the left ventricular outflow tract extends upward from the apex of the chamber to the aortic valve. However, the sagittal section of the adult thorax can show a characteristic U-shaped form of the whole right ventricle, indicating that the RVOT lies along the

Table 4 Parameters of magnetocardiography of ventricular arrhythmias

Variable	Sensitivity	Specificity	PPV	NPV	AUC	*P*	Accuracy
Depth	90%	73%	97%	45%	0.90	<.01	90%
Distance	90%	78%	97%	50%	0.88	<.01	80%
Orientation	80%	59%	92%	32%	0.73	.03	80%

AUC = area under the curve; NPV = negative predictive value; PPV = positive predictive value.

Table 5 Discriminant analysis

Variable	RVOT	ASC	Total
Depth	73%	90%	77%
Distance	78%	80%	78%
Orientation	56%	80%	61%
Depth and distance	88%	100%	90%
Depth and orientation	85%	80%	84%
Distance and orientation	88%	70%	84%
Combination of the 3 parameters	95%	90%	94%

ASC = aortic sinus cusp; RVOT = right ventricular outflow tract.

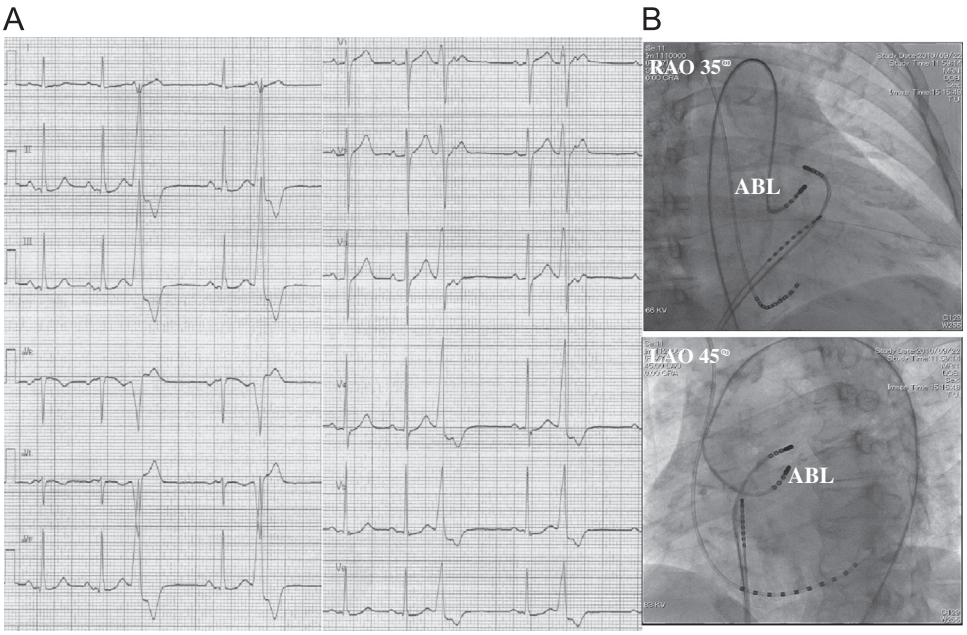

Figure 4 **A:** Representative 12-lead ECG from a patient with outflow tract ventricular arrhythmia. In this case, the TZ score of the arrhythmia was 2.5 and the TZ score of the sinus beat was 2.5 (TZ index = 0), suggesting that the VA origin is located in the RVOT. However, the depth calculated with the MCG-based algorithm was 92 mm/m^2, the distance between the sinus node and the VA origin was 51 mm/m^2, and the orientation was −33°, suggesting that the VA origin is located in the ASC (see also Figure 2D). **B:** Fluoroscopic views show the successful ablation site in the left coronary cusp. Another ablation catheter is located in the RVOT for mapping. ABL = ablation catheter, ASC = aortic sinus cusp; ECG = electrocardiogram; LAO = left anterior oblique; MCG = magnetocardiography; RAO = right anterior oblique; RVOT = right ventricular outflow tract; TZ = transitional zone; VA = ventricular arrhythmia.

cephalocaudal axis. This crossover arrangement suggests that the activation patterns of RVOT-VAs or ASC-VAs are different from each other, and this could be a discriminator for determining the VA origin.

Validation of MCG measurements

It was advantageous that the distance between the VA origin and the sinus node can be directly measured with a 3-dimensional electroanatomic mapping system (CARTO) during the procedure and can be used to validate the accuracy of MCG measurements. There was almost complete correlation between distances from the sinus node to the VA origin measured with both the MCG-based algorithm and the 3-dimensional mapping system. However, the distance derived from CARTO mapping was significantly shorter than that derived from the MCG measurements. One possible explanation is the difference in the patients' volume status. Fasting was required before ablation but not before MCG measurement, which could result in smaller chamber size during the ablation procedure. Another explanation is the effect of the isoproterenol infusion used during the ablation procedure to induce VAs. Isoproterenol increases cardiac contractility and heart rate, which may affect the chamber size and catheter contact with the endocardial wall.

Study limitations

Major limitations of this study were its small sample volume and the absence of a validation cohort. Because the discriminant power may be overestimated in this retrospective analysis, further prospective investigations to validate the ability of the MCG-based algorithm are needed. For these same reasons, we could not clarify statistical superiority of the MCG-based algorithm over the ECG-based algorithm. Currently, the only noninvasive method for the identification of arrhythmia origin in clinical practice is the ECG-based algorithm. The QRS morphology reflects arrhythmia propagation in the ventricles and indirectly estimates the arrhythmia origin, which is completely different from the MCG-based algorithm, which in turn directly identifies the arrhythmia origin itself. We believe that this methodological distinctiveness of MCG is of great interest to electrophysiologists.

With regard to discrimination of the side of VA origin—right or left—the diagnostic accuracy of the MCG-based algorithm appeared to be superior or noninferior to that of the ECG-based algorithm. However, the ECG-based algorithm can classify more detailed anatomical locations within the RVOT, such as septum vs free wall and anterior vs posterior wall. To make subdivision of the RVOT origin possible, further development of a method and algorithm is needed, such as merging of MCG mapping with 3-dimensional computed tomography.

Although VAs originating from the pulmonary artery or non–left coronary cusp (right coronary cusp or junction between the left and right coronary cusps) have been reported, these arrhythmias were hardly observed in the present study. The ability of this algorithm to differentiate such VAs remains to be evaluated.

The distance between the sinus node and the VA origin was found to be a reliable and useful parameter in this study.

However, this algorithm cannot be applied to patients whose baseline rhythm is not sinus rhythm.

Conclusion

We developed an MCG-based algorithm to differentiate RVOT-VAs from ASC-VAs with high sensitivity and specificity. The deeper origin and rightward direction of the activation pattern observed in ASC-VAs may lead us to a better anatomical understanding of this type of arrhythmia as well as to optimal catheter ablation of OT-VTs. Further investigation is required to validate the clinical value of this technique and to clarify the added value of MCG over ECG.

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