Hourly variability versus ECG morphological criteria in predicting the site of origin of ventricular outflow tract ectopy

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Introduction

Outflow tract ventricular arrhythmias (OTVA) are the most common form of idiopathic ventricular arrhythmias encountered in clinical practice. The 12-lead electrocardiogram (ECG) is a vitally important tool that allows rapid and noninvasive localization of the most likely site of origin (SOO) when planning ablation procedures. Different ECG criteria have been validated for this purpose.[1] However, their accuracy may be reduced by variations in body habitus and cardiac orientation.[2]

Recently, our group published a new algorithm based on the variability of arrhythmic events over a 24-hour period rather than QRS morphology.[3] This case report illustrates its practical applicability.

KEY TEACHING POINTS

- The location of ventricular arrhythmias in the outflow tracts based on morphological criteria may be ineffective in certain patients.
- In patients with cardiac rotation, the location of the arrhythmia may be more limited with only morphological criteria.
- The hourly variability of the ventricular arrhythmic events seems to be a good tool to locate these arrhythmias.

Case report

A 40-year-old woman with no relevant medical history presented with palpitations during the second trimester of pregnancy caused by ventricular ectopy (VE) and runs of nonsustained monomorphic ventricular tachycardia (NSVT) of outflow tract origin. Her heart was structurally normal on echocardiography. She was treated with metoprolol 25 mg twice a day, which suppressed the ectopy for the remainder of the pregnancy. However, a subsequent 24-hour Holter monitor on beta-blocker therapy still showed a moderate VE burden of 4% with some runs of NSVT of identical morphology and with significant accompanying symptoms in the form of palpitations mainly. The VE showed an atypical right bundle branch block morphology, right inferior axis, and V_2–V_3 transition on the 12-lead ECG (Figure 1A). She was therefore referred for catheter ablation. The ECG morphology of the VE was assessed and measured before ablation using the electronic calipers in the recording system at 25 mm/s speed and a standard gain of 1 mV/cm with a filter setting of 0.05 Hz (high pass) and 100 Hz (low pass) (C.R. Bard, Inc, Lowell, MA). The most widely used criteria for localizing OTVA SOO pointed to the left side as the most likely origin. However, the recently published criteria, based on the behavior of the ectopy over a 24-hour period, determined the origin to be on the right side. Specifically, the CoV (standard deviation divided by mean) was 2.5, higher than the cut-off of 0.7, and the presence of any hour with less than 50 VEs, another even more sensitive and specific determinant, also pointed to a right-sided SOO (Table 1).[3]

An electrophysiology study to map and ablate the VE under local anesthesia was performed. Frequent, spontaneous VE was noted at baseline without any form of stimulation. Following femoral venous access, a decapolar catheter was placed in the coronary sinus (CS) up to the junction of the great cardiac vein and the anterior interventricular vein. A marked clockwise rotation of the heart was obvious with the true left anterior oblique projection at 75o (Figure 1B). Pace mapping was performed from the distal CS bipole

KEYWORDS Hourly variability; Outflow tract ventricular arrhythmia; Radiofrequency ablation; Right ventricle outflow tract; Ventricular ectopy

(Heart Rhythm Case Reports 2023;9:227–231)

Funding Sources: G.C. and M.W. are receiving funding from the Advanced Ventricular Arrhythmia Training and Research program administered by The St. George's Hospital Charity. A.L. and M.S. have received funding from Abbott Laboratories. Disclosures: The authors have no conflict of interest. **Address reprint requests and correspondence:** Dr Gala Caixal, St. George's Hospital NHS Foundation Trust, Blackshaw Rd, London SW17 0QT, UK. E-mail address: caixalgala@gmail.com.

https://doi.org/10.1016/j.hrcr.2023.01.001

with less than 90% match. Right ventricular outflow tract (RVOT) activation mapping was performed using a mapping/ablation catheter (ThermoCool SmartTouch SF; Biosense Webster, Diamond Bar, CA) via an 8.5F long sheath and the 3-dimensional electroanatomical mapping system (CARTO; Biosense Webster, Diamond Bar, CA). The earliest myocardial activation pre-QRS (-25 ms) was located in the anteroseptal wall, immediately below the pulmonary valve (PV) (Figure 1C). Good pace mapping, matching between 95% and 98%, was demonstrated in this area. Brief additional mapping of the aortic root and the left ventricular outflow tract, via retrograde transaortic approach, showed late, far-field activation and less than 90% match on pace mapping. Radiofrequency (RF) energy was applied at

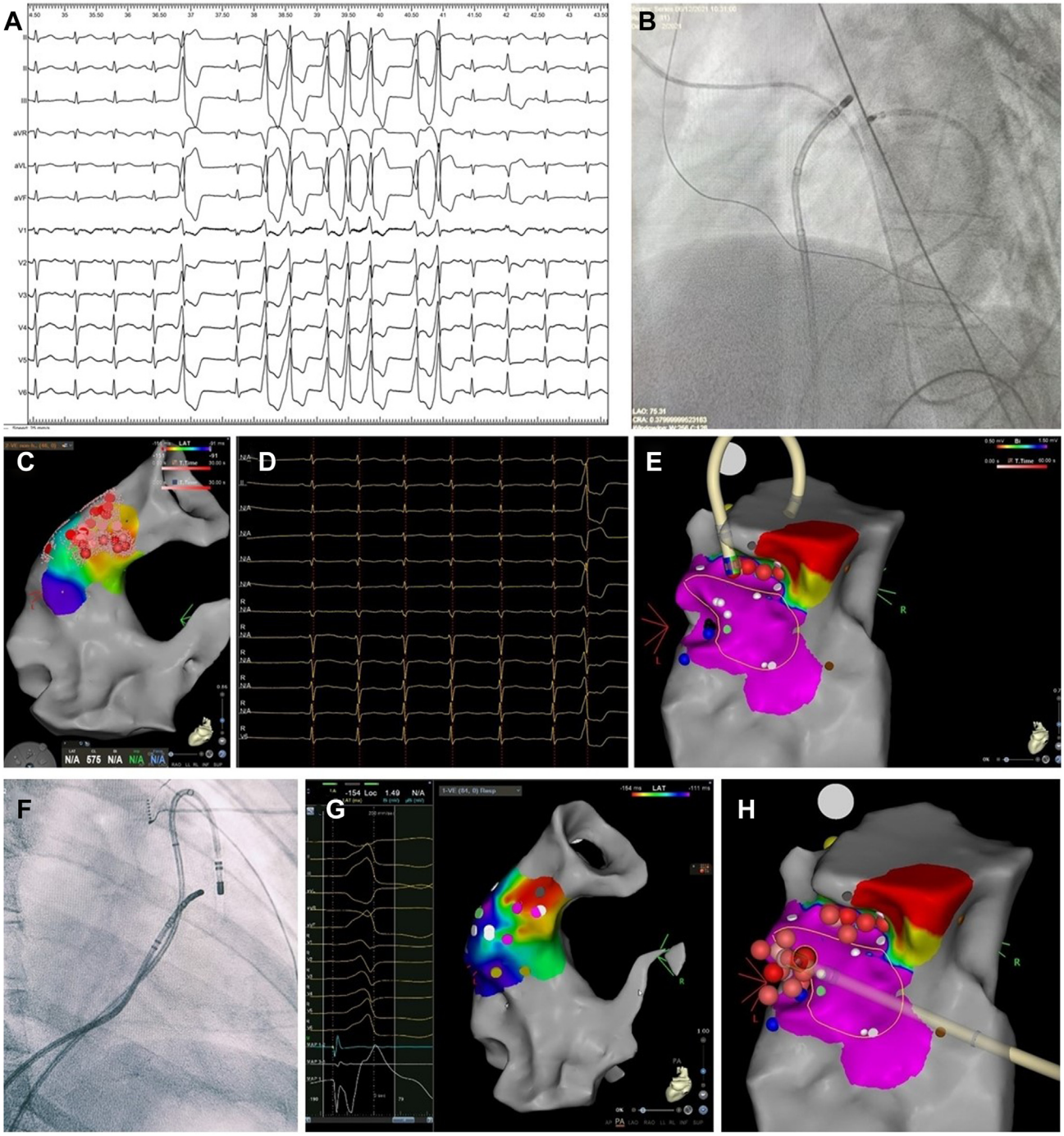

Figure 1 **A:** Twelve-lead electrocardiogram (ECG) with the ectopic beats. **B:** Left anterior oblique projection at 75o. **C:** Initial activation map of the right ventricular outflow tract and lesion set during the first procedure. **D:** Twelve-lead ECG with the ectopic beat during the second procedure. **E:** Activation map showing the earliest activity in the left cusp of the pulmonary valve and the ablation lesions at this site. **F:** Right anterior oblique projection during ablation in the left cusp of the pulmonary valve with catheter in reverse U position. **G:** Endocavitary signals with the bipolar and unipolar electrograms at the earliest site. **H:** Final set of ablation lesions located above and below the pulmonary valve.

Table 1 Criteria described to predict the site of origin of outflow tract ectopy

Algorithm	Value	SOO prediction	Predictive value	
R-wave duration index[4]	0.57	LVOT	Se 88%	Sp 95%
R/S-wave amplitude index[4]	0.66	LVOT	Se 88%	Sp 95%
V2S/V3R index[5]	1.20	LVOT	Se 89%	Sp 94%
TZ index[2]	-3	LVOT	Se 88%	Sp 82%
S-R amplitude difference[7]	0.38	LVOT	Se 95%	Sp 85%
Minimum hourly VEs[3]	<50	RVOT	Se 96%	Sp 94%
CoV[3]	2.50	RVOT	Se 78%	Sp 94%

LVOT = left ventricular outflow tract; RVOT = right ventricular outflow tract; Se = Sensitivity, SOO = Site of origin, Sp = Specificity, TZ = transition zone; VE = Ventricular ectopy.

30 W at the earliest RVOT activation site. This induced more ectopy and some runs of NSVT identical to the clinical VE. However, definitive abolition of the ectopy was not achieved despite a series of lesions in the entire target area. Therefore, more extensive mapping of the anteroseptal RVOT and above the PV was carried out, showing bipolar signals with significantly earlier activation (-40 ms pre-QRS) during ectopy and excellent unipolar electrograms. This area located above the PV, with only far-field low-voltage electrograms in sinus rhythm, also showed an excellent pace map with a 99% match and its subsequent ablation led to the disappearance of VE within 10–15 seconds. To perform the ablation in this area, we did not perform prior coronary angiography, but we used a maximum of 30 W of RF energy for 30–60 seconds, with careful ECG monitoring. Consolidation lesions were delivered surrounding the first lesion at the level of the PV. The procedure concluded 25 minutes later, with the ectopy remaining noninducible despite aggressive stimulation with burst ventricular pacing and isoprenaline infusion at a dose of 4 mcg/min.

However, 1 month later, the patient presented with recurrent symptoms and the repeat 24-hour Holter showed a VE burden of 10% of the same previous morphology (Figure 1D). A new ablation procedure was performed, mapping with the CARTO system and a multielectrode catheter (PentaRay; Biosense Webster, Diamond Bar, CA). The PentaRay catheter–induced ectopy at the anteroseptal RVOT that was identical to the clinical VE and the activation mapping of the spontaneous ectopy confirmed the exit site to be in close proximity, just above the PV. The left ventricular outflow tract was briefly mapped once again, showing late activation, as well as the distal CS catheter at the great cardiac vein–anterior interventricular vein junction, both sites producing pace maps with <90% match. As the PentaRay catheter could not be positioned above the PV and curved down into the pulmonic cusp, it was replaced with the ablation catheter (ThermoCool SmartTouch SF; Biosense Webster), which was advanced up to the pulmonary artery, curved down (reverse U fashion), and brought to the level of the PV. The earliest local activation (-40 ms) was found at the level of the left cusp of the PV (Figure 1E and 1F). RF ablation at 30 W in this area induced NSVT identical to the clinical VE, which disappeared during the first lesion. Subsequent RF ablation at the adjacent RVOT at the subvalvular level was performed at all the neighboring sites with precocity (Figure 1G). No new VE appeared during a 30-minute waiting period and the procedure was concluded. Overnight telemetry showed no further ectopy. At follow-up, the patient has been symptom-free and the Holter at 3 months showed 0% ectopy.

Discussion

Idiopathic ventricular arrhythmias originate preferentially in the outflow tract areas of both ventricles. Current imaging techniques have made it possible to improve the understanding of these 2 closely related structures, allowing catheter ablation to be an effective and safe option for long-term control. However, careful preprocedural 12-lead analysis is important in localizing ectopic activity and procedural planning. Specifically, predicting ectopy SOO before the procedure can help identify the correct access and optimal ablation strategy, reducing risks, complications, and procedural duration.

Because idiopathic OTVA have a focal origin and occur in patients with a structurally normal heart, it is an arrhythmia that is particularly conducive to localization by ECG. For this reason, during the past decades, different morphology-based criteria have been proposed to differentiate left from right SOO.[4–7] However, these parameters can be complex and are influenced by variations in the 3-dimensional anatomical relationship of the outflow tracts, meaning that subtle variationsin the position of the surface ECG electrodes or cardiac orientation can alter the surface QRS morphology, both of the sinus and ectopic beats.[8,9] Parameters developed in an attempt to correct for cardiac rotation, such as the transitional zone index, correct some but not all of these limitations.[2]

We recently published nonmorphological criteria, based on the behavior of OTVA over a 24-hour period, demonstrating that they can predict the SOO with a high degree of precision. Specifically, it was observed that the presence of any hour with VE <50 is highly suggestive of SOO in the RVOT, as well as a high variability with a CoV ≥0.7.[3] It was hypothesized that this could be related to a difference in autonomic influence on ectopic activity, with a different balance between the sympathetic and parasympathetic systems between the 2 outflow tracts.

The present case showed ectopic activity with atypical right bundle branch block–like morphology. When applying the classical morphological algorithms previously described, they all pointed to a left-sided SOO (Table 1). However, when the behavioral criteria were applied, a right-sided SOO was predicted. As shown in the Holter records in Figure 2, the morning hours showed greater VE activity compared to night time, accounting for high variability (CoV = 2.5), as well as several hours throughout the day having a VE burden less than 50, both being predictive of a right-sided SOO. In this example, subsequent mapping confirmed the accuracy of these 2 parameters. Conversely,

A

Hourly Trend Summary

Hour	Pause	VT	R on T	V-Run	Triplet	Couplet	Bigeminy	Trigeminy	Brady	Prem VE	VE	V Escape	AF
Thu 10:16	0	21	0	0	3	22	0	1	0	35	13	0	0
Thu 11:00	0	16	0	0	4	28	0	0	0	9	14	0	0
Thu 12:00	0	43	0	0	99	83	0	3	0	85	93	0	0
Thu 13:00	0	30	0	0	113	191	0	1	0	115	91	0	0
Thu 14:00	0	3	0	0	32	44	0	0	0	29	34	0	0
Thu 15:00	0	5	0	0	5	14	0	0	0	4	11	0	0
Thu 16:00	0	0	0	0	2	5	0	0	0	2	1	0	0
Thu 17:00	0	0	0	0	0	0	0	0	0	1	2	0	0
Thu 18:00	0	0	0	0	0	0	0	0	0	1	0	0	0
Thu 19:00	0	0	0	0	0	0	0	0	0	1	0	0	0
Thu 20:00	0	0	0	0	0	0	0	0	0	0	1	0	0
Thu 21:00	0	0	0	0	0	0	0	0	0	4	0	0	0
Thu 22:00	0	0	0	0	0	0	0	0	0	0	1	0	0
Thu 23:00	0	0	0	0	0	0	0	0	0	0	0	0	0
Fri 00:00	0	0	0	0	0	0	0	0	0	1	0	0	0
Fri 01:00	0	0	0	0	0	0	0	0	0	1	0	0	0
Fri 02:00	0	0	0	0	0	0	0	0	0	0	0	0	0
Fri 03:00	0	0	0	0	0	0	0	0	0	0	1	0	0
Fri 04:00	0	0	0	0	0	0	0	0	0	1	1	0	0
Fri 05:00	0	0	0	0	0	0	0	0	0	0	2	0	0
Fri 06:00	0	0	0	0	0	0	0	0	0	0	1	0	0
Fri 07:00	0	0	0	0	0	0	0	0	0	0	0	0	0
Fri 08:00	0	0	0	0	0	0	0	0	0	0	1	0	0
Fri 08:27	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	118	0	0	258	387	0	5	0	289	267	0	0

B

Hour	Pause	VT	R on T	V-Run AIVR	Triplet	Couplet	Bigeminy	Trigeminy	Bradycardia	Premature VE	VE	V Escape	AF
Tue 08, 09:23	0	0	0	0	0	242	0	2	0	53	27	0	0
Tue 08, 10:00	0	0	0	0	0	475	0	7	0	179	4	0	0
Tue 08, 11:00	0	0	0	0	0	362	0	15	0	260	0	0	0
Tue 08, 12:00	0	0	0	0	0	310	0	11	0	309	44	0	0
Tue 08, 13:00	0	0	0	0	1	138	0	24	0	381	31	0	0
Tue 08, 14:00	0	0	0	0	0	56	0	32	0	506	23	0	0
Tue 08, 15:00	0	0	0	0	0	149	0	8	0	339	16	0	0
Tue 08, 16:00	0	0	0	0	0	41	0	11	0	65	83	0	0
Tue 08, 17:00	0	0	0	0	0	34	0	9	0	100	109	0	0
Tue 08, 18:00	0	0	0	0	0	51	1	3	0	71	140	0	0
Tue 08, 19:00	0	0	0	0	1	104	0	0	0	70	49	0	0
Tue 08, 20:00	0	0	0	0	1	48	0	0	0	210	14	0	0
Tue 08, 21:00	0	0	0	0	0	81	7	0	0	218	50	0	0
Tue 08, 22:00	0	0	0	0	0	113	3	0	0	133	16	0	0
Tue 08, 23:00	0	0	0	0	0	30	1	0	0	122	5	0	0
Wed 09, 00:00	0	0	0	0	0	42	0	0	0	132	4	0	0
Wed 09, 01:00	0	0	0	0	1	10	0	0	0	38	1	0	0
Wed 09, 02:00	0	0	0	0	0	33	0	0	0	119	4	0	0
Wed 09, 03:00	0	0	0	0	0	13	0	0	0	46	11	0	0
Wed 09, 04:00	0	0	0	0	0	18	0	1	0	96	14	0	0
Wed 09, 05:00	0	0	0	0	0	5	0	0	0	28	14	0	0
Wed 09, 06:00	0	0	0	0	0	31	0	0	0	64	1	0	0
Wed 09, 06:54	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	4	2,386	12	123	0	3,539	660	0	0

Figure 2 Hourly trend summary of the number of ectopic beats on the 24-hour Holter monitor performed before the first (**A**) and the second (**B**) ablation procedures. Both summaries show hours with less than 50 ventricular ectopies (VE), as well as a high variability, with a CoV $\geq$0.7, suggesting a site of origin in the right ventricular outflow tract. AF = atrial fibrillation; VT = ventricular tachycardia.

the morphological criteria failed, likely owing to the marked clockwise rotation of the patient's heart.

In relation to the recurrence of the arrhythmia after the first ablation, it could be owing to the fact that in the first procedure the site of greatest precocity, located above the PV, was ablated after the first set of lesions at the earliest site in the high RVOT and without the catheter in reverse U shape above the PV. A pronounced edematous response to the initial lesions may have led to failure to deliver enough energy to the true SOO. In the second attempt, the first lesion was delivered above the PV, where the earliest activation site was located, coinciding with the findings of the previous procedure. However, this time the catheter was placed directly as an inverted U within the pulmonary cusp, which probably facilitated delivering more effective initial applications. In both procedures, the VE had an identical morphology and the preprocedure 24-hour Holter showed high hourly variability, pointing to a right-sided SOO.

This case illustrates the usefulness and reproducibility of the new behavior-based criteria, which are easily applicable to routine clinical practice.

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