Europace (2015) **17**, 591–597
doi:10.1093/europace/euu282

Clinical impact of a novel three-dimensional electrocardiographic imaging for non-invasive mapping of ventricular arrhythmias—a prospective randomized trial

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Received 25 June 2014; accepted after revision 16 September 2014; online publish-ahead-of-print 27 October 2014

Aims ECVUE™ technology, a novel, three-dimensional, non-invasive mapping system, offers a unique arrhythmia characterization and localization. We sought to evaluate the clinical impact of this system in routine clinical mapping and ablation of ventricular arrhythmias (VAs).

Methods and results Patients with monomorphic premature ventricular contractions with or without monomorphic ventricular tachycardia were enrolled prospectively and randomized into two groups: ventricular ectopy localization using either 12-lead electrocardiogram (ECG) algorithms or with ECVUE™, followed by conventional guided ablation. Forty-two patients were enrolled in the study. The ECVUE™ system accurately identified both the chamber and sub-localized the VA origin in 20 of 21 (95.2%) patients. In contrast, using 12-lead ECG algorithms, the chamber was accurately diagnosed in 16 of 21 (76.2%) patients, while the arrhythmia origin in only 8 of 21 (38.1%), ($P = 0.001$ vs. ECVUE™). Acute success in ablation was achieved in all patients. Regarding the number of radiofrequency-energy applications (in total 2 vs. 4, $P = 0.005$) in the ECVUE™ arm, ablation was more precise than the ECG group which used standard of care activation and pace mapping-guided ablation. Three months success in ablation was 95.2% for the ECVUE™ and 100% for the ECG group (P = ns). Time to ablation was 35.3 min in the conventional arm and 24.4 min in ECVUE Group, ($P = 0.035$). The X-ray radiation exposure was 3.21 vs. 0.39 mSv, $P = 0.001$ for the ECVUE™ group and ECG group.

Conclusion ECVUE™ technology offers a clinically useful tool to map VAs with high accuracy and more targeted ablations superior to the body surface ECG but had significantly higher radiation exposure due to computed tomography scan.

Keywords Ablation • Ventricular arrhythmia • Premature ventricular contraction • Electrocardiographic mapping • Non-invasive 3-D mapping

Introduction

Ventricular arrhythmias (VA) are often associated with clinical deterioration and may lead to sudden cardiac death. Underlying cardiac disease, VA location, and VA mechanisms all play a decisive role in choosing adequate therapy.[1] The 12-lead electrocardiogram (ECG) has been the tool of choice for non-invasive diagnosis and localization of cardiac arrhythmias for over 100 years.[2] However, measuring electrical potentials from only few points of the body surface by conventional 12-lead ECG is limited in specificity and sensitivity. This may

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constrain invasive procedural planning, and could influence the efficiency and outcome of ablation therapy.

We aim to evaluate the accuracy and impact on clinical outcomes of a novel, 3D, non-invasive, single-beat, body surface mapping system (ECVUE™: CardioInsight) as a diagnostic tool for VA.[3]

Methods

This was a prospective randomized study. Randomization was done via a sealed envelope system. The study protocol was approved by the local Ethics Committee Giessen, Germany. All patients consented to participate in the study. Patient data were collected and stored in an anonymized fashion.

Study population

Patients with monomorphic premature ventricular contractions (PVCs) with a documented 12-lead ECG were eligible to participate in this electrophysiology (EP) study if they met the following inclusion criteria: (i) symptomatic patients refractory to, or refusal to take antiarrhythmic drugs, (ii) asymptomatic patients with reduced left ventricular (LV) function due to tachycardiomyopathy, and (iii) age between 18 and 80 years. Exclusion criteria were defined as (i) reversible causes of PVCs/VTs (e.g. relevant electrolyte disorders, acute ischaemia, peri-/myocarditis, or hyperthyroidism), (ii) ventricular thrombus, and (iii) pregnancy.

ECVUE™ mapping

The computational methods used in the reconstruction of ECVUE maps using multiple body surface electrodes have been already described.[4] Briefly, a 252-electrode vest was applied to the patient's torso to record surface potentials. Following a non-contrast, low-dose thoracic computed tomography (CT) scan, the heart and vest electrodes are segmented. The electrode positions and the three-dimensional epicardial biventricular geometry are used by the ECVUE system to reconstruct epicardial potentials and unipolar electrograms for each beat of interest.[5,6]

Body surface electrocardiogram mapping

Twelve-lead ECG analysis was performed by an experienced electrophysiologist using a combination of previously published algorithms to predict PVC origin.[7]

The first step was to localize the PVC origin to either the RV or LV. The second step was to sub-localize the origin within the ventricular chambers: LV *was divided into 17 segments*: LV outflow tract (LVOT) septal, aortomitral continuity (AMC), right coronary cusp (RCC), left coronary cusp (LCC), LCC/RCC junction, mitral annulus: anterior, posterior, septal or lateral, and LV mid- or inferoseptal, lateral, anterior or posterior. *Right ventricle (RV) was also divided into 17 segments*: RV outflow tract (RVOT) posteroseptal, anteroseptal, posterior free wall, anterior free wall, parahissian, tricuspid annulus (TA) septal, lateral (free-wall), anterior, posterior and RV mid- or inferoseptal, lateral, anterior or posterior.

Study design

Patients who were eligible for the study were randomized into two groups (*Figure 1*):

***Group A*:** Ectopy localization using 12-lead ECG, followed by conventional guided ablation

***Group B*:** Ectopy localization using ECVUE™, followed by ECVUE™ guided intracardiac confirmation, and ablation.

For patients randomized into Group B (wearing multi-electrode vest), CT scans were performed the morning before the ablation procedure, followed by segmentation of detailed ventricular anatomy. Signal recording from the multi-electrode vest was done before and throughout the ablation. The electrocardiographic mapping data were analysed systematically as previously described.[8]

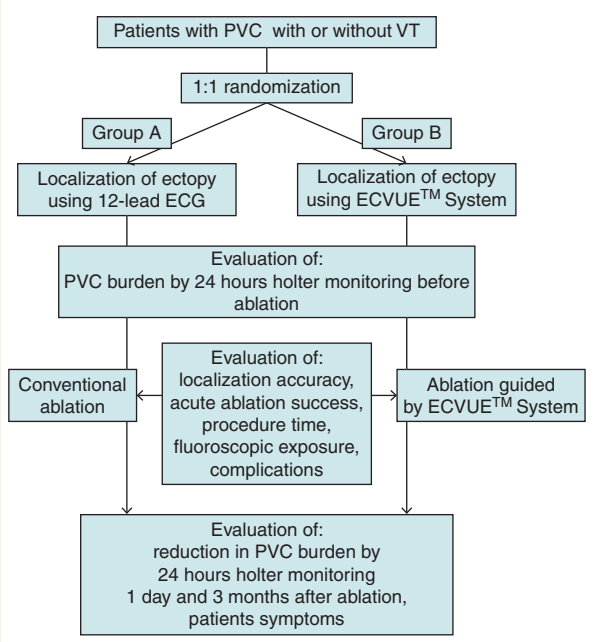

Figure 1 Study design. PVC, premature ventricular contraction; ECG, electrocardiogram; VT, ventricular tachycardia.

Cardiac computed tomography scan

All scans were performed on a 64-detector row dual-source CT scanner (Somatom Definition, Siemens). Initially, a cardiac topogram was acquired on the field of view which included all torso electrodes and the heart. Afterwards an unenhanced, ECG-gated, cardiac CT scan was acquired in cranio-caudal direction using a detector collimation of 32 9 0.6 mm and slice acquisition 64 9 0.6 mm by means of a z-flying focal spot. The gantry rotation time was 330 ms and the pitch was 0.2–0.43. Tube current was adapted automatically to each patient's weight using CareDose 4D automatic exposure control and a reference tube current of 320 mAs. Tube voltage was 120 kV for both tubes, and the ECG pulsing window was fixed to 35–70% of the RR interval for all patients. Image data were reconstructed with a slice thickness of 0.75 mm and an increment of 0.3 mm using a single RR-interval reconstruction approach, resulting in a temporal resolution of 83 ms. Retrospective gating was performed to synchronize reconstructed data with the ECG signal. Image reconstructions were rendered in 5% increments from 35 to 70% of the RR cycle and for each patient, the data set with least motion was identified and used for further processing and analysis.

Invasive electrophysiology study

All patients underwent an invasive EP procedure by a single experienced electrophysiologist. The procedures were performed under conscious sedation and analgesia with appropriate doses of diazepam and dipidolor. All patients underwent transthoracic echocardiography to exclude ventricular thrombi as well as cardiac magnetic resonance imaging (MRI) for evidence or exclusion of ventricular scar. Antiarrhythmic drugs were discontinued at least 48 h before the invasive EP study**.** After local anaesthesia in the right femoral groin, depending on the suspected location of VA

(left or right ventricle) diagnosed from 12-lead ECG or ECVUE™ Mapping, one 7 F vascular sheath was inserted into the right femoral vein or 8 F vascular sheath into the right femoral artery. If LV access was necessary, the procedure was performed under the targeted activated clotting time of >250 s. Access to the LV was performed via a retrograde transaortal approach with a non-steerable sheath (SR-0, SJM™). The invasive EP study in Group A was performed conventionally (by activation- and pace mapping, Bard EP Mapping System, Boston Scientific) without support of a three-dimensional-electroanatomic mapping system. In Group B, the invasive EP study was guided by the ECVUE™ mapping System. Ablation was performed in both groups with a 7 F thermo cool catheter (Biosense Webster) with a 3.5 mm irrigated tip. Power delivery ranged from 30 to 40 W with a cutt-off temperature of 42°C. If radiofrequency (RF)-energy application was required within the coronary cusps, coronary angiography was performed to rule out a distance of <10 mm to the coronary artery ostia. Power delivery in this area ranged from 15 to 30 W. Acute ablation success was defined as no recurrence of targeted PVC/VT within 30 min of ablation, either occurring spontaneously or provoked by intravenous isoproterenol infusion. The number of RF applications to first effect was defined as the number of irrigated RF-energy deliveries until the termination of PVC/VT with or without previous acceleration and no recurrence for at least 5 min. Time to ablation was defined as the time from local anaesthesia in the femoral groin to first energy delivery.

Follow-up

In each patient, a 12-lead and 24 h-Holter ECG was performed 1 day before, 1 day after and 3 months after the invasive EP study (*Figure 1*). Recurrence of VA was defined as documented monomorphic and symptomatic PVC >1000 in 24 h on Holter monitoring or as documented sustained monomorphic ventricular tachycardia. Symptomatic VA was defined as palpitation, exercise intolerance, dizziness, pre-/syncope, angina, and/or new onset of dyspnoea perceived by the patient, which was correlated to results of the Holter monitoring.

Statistical analysis

Baseline characteristics were compared between Groups A and B using a χ^2 test for categorical variables and by continuous variables by median, interquartile ranges and Mann–Whitney *U* test for continuous variables.

The primary endpoint of the study was the accuracy of VA localization using the ECVUE™ non-invasive 3-D Mapping System in comparison to the conventional 12-lead ECG algorithms. The secondary endpoints evaluated the ECVUE™ system's clinical impact on (i) acute and 3-month success of ablation therapy, (ii) procedure time savings, (iii) peri-procedural complications, and (iv) fluoroscopic exposure.

Results

Patient population

A total of 42 consecutive patients were enrolled in this study. Patient characteristics are displayed in *Table 1*. All patients presented with monomorphic PVCs, the vast majority were without structural heart disease. Magnetic resonance imaging showed ventricular scar in all four patients with known coronary artery disease, and in one of two patients with history of myocarditis. However, in these five patients the origin of PVC was not in the ventricular scar. The remaining 37 patients showed no evidence of a ventricular scar. In addition to the symptomatic PVCs, five patients in Group B and four patients in Group A had additional non-sustained monomorphic VTs. The majority of patients (74%) had failed previous antiarrhythmic drug therapy. None of the patients had previous ablations. There were no statistically relevant differences between patient groups.

Table 1 Patient characteristics prior to invasive EP study

	Patients with ECVUE™ guided ablation (Group B)	Patients with conventional ablation (Group A)	*P*-value
Age (years)	49 (36, 62)	52 (45, 66)	0.273
Female gender (%)	38	43	0.999
BMI (kg/m^2)	26 (24, 31)	26 (24, 29)	0.734
LVEF (%)	55 (55, 60)	55 (55, 60)	0.727
CAD (%)	14	5	1.000
Hypertension (%)	43	48	1.000
Myocarditis in history (%)	0	10	0.488
Pulmonary disease (%)	10	5	1.000
Renal dysfunction (%)	5	0	1.000
Diabetes mellitus (%)	0	5	1.000
AAD total (%)	76	71	1.000
Class I (*n*)	1	3	
Class II (*n*)	15	12	
Class III (*n*)	1	1	
None	5	6	

Data given as median (IQR), *n* or as %.
EP, electrophysiology; BMI, body mass index; CAD, coronary artery disease; LVEF, left ventricular ejection fraction; AAD, antiarrhythmic drug.

Primary study endpoint

In total 15 of 42 patients (35.7%) had left-sided PVCs: 10 in Group A and 5 in Group B. *Figure 2* illustrates the encountered sites of PVC origin: 52.4% of the PVCs were located at the RVOT: 28.6% of which were posteroseptal, 11.9% anteroseptal, 7.1% posterior free wall, and 4.8% on the anterior free wall. Furthermore, 11.9% PVCs were located at other locations in the right chamber: 2.4% were parahissian, 2.4% inferoseptal and 2.4% mid-anterolateral, and 4.7% at the tricuspidal annulus free wall. The LV outflow tract harboured 16.6% of PVCs: 7.1% septal and 9.5% at the LCC. The remaining PVCs (16.7%) from the left chamber were located in 11.9% at the aortomitral continuity, and in 2.4% anterolateral and 2.4% posterior of the mitral annulus.

The chamber and sub-localization of the ventricular arrhythmia were correctly diagnosed in 20 of 21 (95.2%) patients with the non-invasive ECVUE™ System (Group B) (*Table 2*, *Figure 3*). The one failed PVC localization of the system predicted ectopy in the left coronary cusp, but arrhythmia was successfully ablated at the septal RVOT. In comparison to Group B, conventional 12-lead ECG

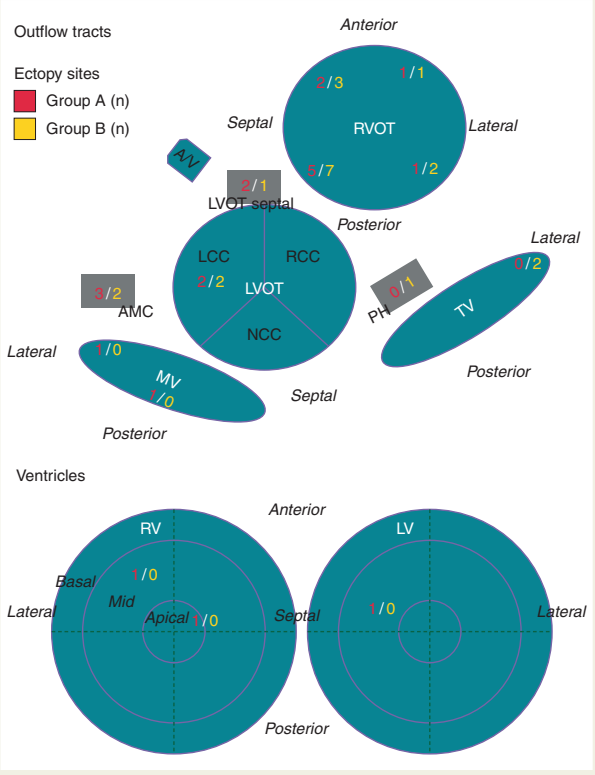

Figure 2 Distribution of PVC ectopy sites according to Groups A and B. RVOT, right ventricular outflow tract; LVOT, left ventricular outflow tract; AIV, anterior inverventricular vein; LCC, left coronary cusp; RCC, right coronary cusp; NCC, non-coronary cusp; AMC, aortomitral continuity; PH, parahissian; MV, mitral valve; TV, tricuspid valve; RV, right ventricle; LV, left ventricle.

(Group A) accurately diagnosed the chamber in 16 of 21 (76.2%) and the sub-localization in only 8 of 21 (38.1%) cases ($P = 0.001$, respectively).

In all patients with left-sided PVCs, access to the LV was performed via a retrograde transaortal approach after puncture of the right femoral artery. The remaining 27 patients with right-sided PVCs had only one venous access without additional puncture of the femoral artery. In Group A, three patients had unnecessary arterial puncture due to preprocedural misguided mapping using body surface 12-lead ECG leading the physician to believe the site of ectopy was located in the LV. However, in these three patients, the PVC origin was right sided. Also in this group, additional arterial puncture was necessary because despite RV prediction, the PVC origin was later determined to be localized in the LV. In Group B, the ECVUE System accurately predicted the site of origin in all but one patient. In this case, initial arterial access was unnecessary due to right-sided PVC origin. In total, incorrect localization and/or sublocalization of PVC origin was higher in Group A vs. Group B (23.8 vs. 4.7%).

Secondary study endpoint

Acute ablation success was achieved in all patients. The mean number of earliest activation mapping and pace mapping was −38 ms and 99% in Group A and −41 ms and 99% in Group B, P = ns and P = ns, respectively, (*Table 3*). The mean number of energy applications to first effect on PVCs was two in Group A and one in Group B, $P = 0.023$, followed by one additional safety application in each case. Therefore, mean number of ablations during the procedure amounted to a total of four (Group B) and two (Group A) applications, $P = 0.005$. Patients in Group B, guided by ECVUE™, had fewer PVC relapses during the 30 min waiting period compared with Group A (14.3 vs., 33.3%). Patients in Group B also required less mapping time, as evidenced by fewer time to first energy application (24.4 vs. 35.3 min in Group A, $P = 0.035$). Total procedure time (skin to skin) was 89 in Group A and 78 in Group B ($P = 0.021$). In total, the mean X-ray dose of EP procedure in Group A was 0.39 mSv compared with 3.21 mSv in Group B, including CT scan, $P = 0.001$.

Despite acute success in all patients, one patient in Group B developed symptomatic PVC relapse 1 day after ablation which persisted even at 3-month follow-up. In this patient, we performed a second procedure with successful ablation at the initial ablation side (tricuspidal annulus, free wall). In contrast to the first procedure power of 30 W, delivery with 40 W and a cut-off temperature of 42°C were used to sufficiently eliminate the PVC. No PVC relapse occurred in the following months.

The mean number of monomorphic PVCs during Holter monitoring 24 h before, 1 and 3 months after the ablation procedure was 9891, 28, and 27 in Group A and 6788, 12, and 8, in Group B, respectively.

No peri-procedural complications occurred in either group.

Discussion

Main findings

The current prospective, randomized study underlines the superiority of the ECVUE™ non-invasive 3D Mapping System in preprocedural localization of VA origin compared with conventional body surface 12-lead ECG algorithms. Furthermore, peri-procedural ECVUE™ System guided PVC origin confirmation followed by ablation was faster and more precise than conventional activation and pace mapping-guided ablation. However, regarding ablation outcome by acute and 3-month success, ECVUE™ System showed no additional advantage over conventional ablation in index routine cases, while having significantly higher radiation exposure.

Localization accuracy

Interpretation of arrhythmia ectopy origin from 12-lead ECG is assumes an almost identically configured heart shape and size, in an almost identically configured torso. Therefore it is not surprising that even an experienced electrophysiologist will pre-procedurally fail to accurately localize the origin of VA by using established ECG algorithms. In this study, the chamber was correctly diagnosed in only 76.2% using 12-lead ECG algorithms compared with 95.2% with the ECVUE™ System. Sub-localization of the VA within chambers was even less precise using standard 12-lead ECG with 38.1% accuracy compared with 95.2% using the ECVUE™ System. These data are in alignment with the observations of Jamil-Copley *et al.* who reported accurate identification of correct chamber of origin in 50–88% and sub-localization within the RVOT in 37–58% using

Table 2 Ventricular arrhythmia localization accuracy: comparison of 12-lead ECG and ECVUE™ System with invasive EP study

Patient no.	GROUP A			GROUP B			*P*-value
	12-lead ECG localization		EPS	ECVUE localization		EPS	
	Ectopy origin	Sub-localization		Ectopy origin	Sub-localization		
1	LV	LCC	MA al	RV	RVOT ps	RVOT ps	
2	RV	RVOT ps	RVOT ps	LV	AMC	AMC	
3	LV	LVOT s	LVOT s	RV	RVOT pfw	RVOT pfw	
4	LV	MA al	MA p	LV	AMC	AMC	
5	RV	RVOT ps	RVOT ps	RV	RVOT ps	RVOT ps	
6	RV	RVOT afw	RVOT as	LV	LVOT s	LVOT s	
7	LV	AMC	AMC	LV	LCC	RVOT as	
8	LV	LV is	RV is	RV	RVOT ps	RVOT ps	
9	LV	LCC	RVOT ps	RV	RVOT pfw	RVOT pfw	
10	RV	RVOT afw	LCC	RV	RVOT ps	RVOT ps	
11	LV	LV ms	LV ms	LV	LCC	LCC	
12	LV	LCC	AMC	RV	RVOT afw	RVOT afw	
13	RV	RVOT afw	LCC	RV	TA fw	TA fw	
14	RV	RV ms	RV mal	RV	Parahissan	Parahissan	
15	LV	LCC	LVOT s	RV	TA fw	TA fw	
16	LV	LCC	AMC	RV	RVOT ps	RVOT ps	
17	LV	LVOT s	RVOT pfw	LV	LCC	LCC	
18	RV	RVOT ps	RVOT ps	RV	RVOT ps	RVOT ps	
19	RV	RVOT pfw	RVOT as	RV	RVOT ps	RVOT ps	
20	RV	RVOT pfw	RVOT afw	RV	RVOT as	RVOT as	
21	RV	RVOT ps	RVOT ps	RV	RVOT as	RVOT as	
Localization accuracy confirmed by EPS Total *x/n* (%)	16/21 (76.2%)	8/21 (38.1%)		20/21 (95.2%)	20/21 (95.2%)		0.001

EPS, electrophysiologic study; LV, left ventricle; RV, right ventricle; LCC, left coronary cusp; RCC, right coronary cusp; RVOT, right ventricular outflow tract; LVOT, left ventricular outflow tract; MA, mitral annulus; TA, tricuspidal annulus; s, septal; p, posterior; ps, posteroseptal; as, anteroseptal; al, anterolateral; fw, free wall; afw, anterior free wall; pfw, posterior free wall; AMC, aortomitral continuity; ms, midseptal; is, inferoseptal; mal, mid-anterolateral.

published ECG algorithms. In their experience, the ECVUE™ System allowed them to correctly identify the chamber in 96% harbouring the arrhythmia and sub-localize the PVC origin in 100% of the cases.[9] However, their data were based on a single-centre study which included 24 patients with outflow tract ventricular tachycardias without a control group (conventional guided ablation or with invasive three-dimensional mapping System). Wang *et al.* [10] studied 26 VAs in 25 patients with predominantly structural heart disease and reduced ejection fraction. In that report, the ECVUE™ System was used to accurately indentify the right or LV location of the arrhythmia in all cases. Subsequently, sub-localization was correctly indentified in 91% within the RV and 92% within the LV. Also in this single-centre study there was no comparison with a control group.

The novel ECVUE™ non-invasive three-dimensional mapping system incorporates each patient's individual heart torso geometry, allowing for high spatial mapping resolution. By virtue of its ability to accurately map arrhythmia origins, the ECVUE system may help plan the invasive procedure (e.g. choice of vascular access) and has the potential to reduce possible procedure-related risks. While we did not observe any peri-procedural complications in our study, there were five vs. one unnecessary venous access in Group A, which may be the cause for complications.

Clinical impact

Conventional invasive mapping and ablation of VAs using sequential activation and pace mapping has known limitations.[11–13] It is reported that, e.g. in ~20% of patients, pace mapping is unreliable in identifying the site of origin, possibly due a deeper site of origin and preferential conduction via fibres connecting the focus to the endocardial surface.[12] Due to the high mapping accuracy of the ECVUE™ System, it is expected to influence ablation procedure by simplifying mapping, reducing ablation, and procedural time and providing the potential to improve clinical outcomes.

Our study demonstrates that ECVUE™ is more precise in localizing arrhythmias than conventional approaches. In Group B, the PVCs were eliminated with the first RF application (followed by a safety application) while twice as many applications were needed in the conventional group. Moreover, there were more PVC relapses during the 30 min waiting period in the conventional group (33.3% vs. 14.3%), further highlighting the inaccuracy of activation- and pace

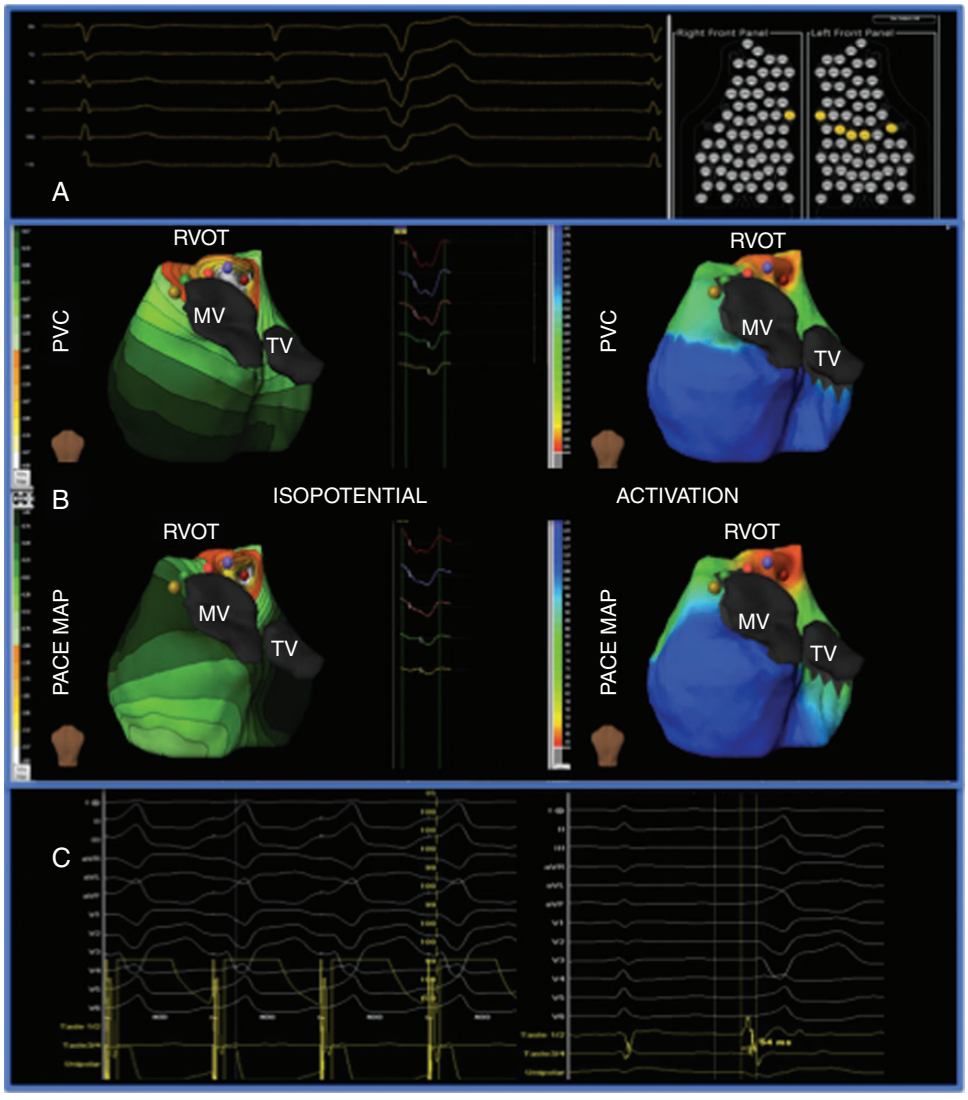

Figure 3 ECVUE™ based PVC origin localization confirmed by conventional invasive activation- and pace mapping. Note that (*A*) shows body surface ECG recording of the ECVUE™ System. (*B*) Isopotential during spontaneous PVC and during PACE-MAP (on the left) as well as activation (on the right) are displayed. Pace map electrogram morphology exhibit 99% correlation to PVC electrograms with origin at RVOT posteroseptal. (*C*) Conventional invasive pace mapping (on the left) with 99% match and earliest activation with −54 ms (on the right) confirm ECVUE™ localization accuracy. PVC, premature ventricular contraction; RVOT, right ventricular outflow tract; MV, mitral valve; TV, tricuspid valve.

mapping. Despite this, both groups achieved similar chronic freedom from arrhythmias.

Notably, the poor accuracy in pre-procedural arrhythmia origin localization in the conventional approach can negatively impact a procedure by either directing the physician to the wrong chamber and/or prolonging the mapping time to localize the arrhythmia origin. Of course, a highly experienced electrophysiologist may overcome such challenges. However, the use of ECVUE™'s highly reliable diagnostic information significantly simplifies the intracardiac mapping process and reduces time to first RF application.

As already mentioned by the study group of Jamil-Copley *et al.* the benefit of accurate localization of ectopy origin should be weighed against the extra radiation exposure from CT scan. In our study, this was significantly higher compared with the conventional ablated group. However, due to the inability to visualize the ablation catheter in the current ECVUE™'s system, the investigator in our study used fluoroscopy-guided navigation. Therefore, radiation exposure during ECVUE™ guided mapping could be reduced in combination with an invasive 3-D Mapping System.

Since we used no invasive 3D Mapping Systems (e.g. CARTO or NaVX) in our study, for which the exact spatial resolution is validated, we are not able to make a statement about the mapping accuracy of ECVUE™'s resolution in millimeters. However, since an average of only one energy application was required to terminate the PVC in Group B, the ECVUE™ System was reliable in mapping PVCs. Certainly the ability to localize the PVC origin with only one beat is an advantage not only over the conventional approach but also over other invasive 3-D Mapping Systems which use point by point activation mapping.

Table 3 Comparison of procedure and clinical impact of conventional (Group A) and ECVUE™ (Group B) guided ablation

	Group A			Group B			*P*-value
	Median	Q1	Q3	Median	Q1	Q3	
PVCs before ablation (*n*/24 h)	9891	3810	23 366	6934	4325	9860	0.204
PVCs 1 day after ablation (*n*/24 h)	28	4	300	12	4	32	0.217
PVCs 3 months after ablation (*n*/24 h)	27	10	211	8	0	19	**0.020**
Earliest activation (ms)	−38	−32	−42	−42	−39	−43	0.071
Pace map (%)	99	95	99	99	98	100	0.121
Total RF applications (n)	4	3	5	2	2	3	**0.005**
Applications to first effect (*n*)	2	1	3	1	1	2	**0.023**
Time to ablation (min)	35.3	22	47.8	24.4	11.3	35.3	**0.035**
Skin-to-skin time (min)	89	73	114	78	64	100	**0.021**
X-ray dose during EPS	0.39	0.16	0.78	0.36	0.14	0.69	0.203
Total X-ray dose (mSV) (including CT scan)	0.39	0.16	0.78	3.21	2.93	3.70	**0.001**

PVCs, premature ventricular contractions; Q, quartile.

Despite higher radiation exposure in the ECVUE group, in patients with symptomatic but low PVC burden, or in challenging redo cases the ECVUE™ System has the potential to improve the clinical outcome.

Conclusion

We demonstrate the use of ECVUE™ technology to accurately characterize and localize VA with superior performance to the body surface ECG. Notably, this study demonstrates increased ablation procedure efficacy attributable to less RF applications required to terminate the arrhythmia, decreased time to first RF application as well as decreased total procedure time. However, due to its current higher radiation exposure, ECVUE™'s use in routine clinical practice might be limited to challenging cases of VA ablation procedures.

Conflict of interest: T.N. has received speakers' honoraria from CardioInsight.

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