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Very-high-power short-duration ablation for treatment of premature ventricular contractions – The FAST-AND-FURIOUS PVC study

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ABSTRACT

Objectives: We sought to assess the efficacy, safety and short-term clinical outcome of very high-power short-duration (vHP-SD) radiofrequency (RF) catheter ablation for the treatment of idiopathic PVCs originating from the cardiac outflow tract (OT).

Background: Power-controlled RF ablation is a widely used technique for the treatment of premature ventricular contractions (PVCs). A novel ablation catheter offers three microelectrodes and six thermocouples at its tip and provides temperature-controlled vHP-SD (90 Watts/4 s,) with the opportunity to switch to moderate-power mode.

Methods: In this pilot study, twenty-four consecutive, prospectively enrolled patients underwent PVC ablation utilizing the vHP-SD ablation (study group) and were compared with 24 consecutive patients previously treated with power-controlled ablation (control group). Each group included 12 patients with PVCs originating from the right ventricular OT (RVOT) and 12 patients with PVCs originating from the left ventricular OT (LVOT). The acute endpoint was PVC elimination and was achieved in all patients.

Results: In 16/24 (67%) patients (study group) it was achieved by using vHP-SD only. The median RF delivery time was 52 (interquartile range [IQR] 16, 156) seconds (study group) and 350 (IQR 240, 442) seconds (control group, $p < 0.0001$). No difference was observed regarding procedure duration ($p = 0.489$) as well as 6-months follow-up ($p = 0.712$). One (4%, study group) and 2 (8%, control group) severe adverse events occured ($p = 0.551$).

Conclusion: In this study, vHP-SD PVC ablation was similarly effective and safe as compared to conventional power-controlled ablation. The RF time was significantly shorter.

1. Introduction

Catheter ablation (CA) is a widely used strategy for the treatment of ventricular arrhythmias (VA) [1–4]. The right and left ventricular outflow tracts (OTs) are the most common origins of idiopathic premature ventricular contractions (PVCs) [3,5–8]. Current strategies for ablation of PVCs are based on the standard power-controlled radiofrequency (RF) delivery, using either contact-force (CF) or non-CF-sensing ablation catheters [5,9]. Very-high-power short-duration (vHP-SD) CA has recently been introduced and was found to be safe, effective and fast for pulmonary vein isolation (PVI) [1,2]. This strategy aims at creating shallower but wider lesions in a very short time by simultaneously reducing conductive heating and increasing resistive heating of tissue. Additionally, the area with reversible injury and tissue edema was shown to be smaller which is causing more durable lesions [2,22]. Furthermore, collateral damage might be reduced [2]. The novel

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QDOT MICRO® ablation catheter (Biosense Webster, Inc., Irvine, California, USA) allows for temperature-controlled ablation in two different ablation modes. Conventional temperature-controlled ablation (QMODE, maximum 50 W) and vHP-SD ablation (QMODE+, 90 W/4 s). The six thermocouples of the QDOT MICRO® precisely monitor and adjust the catheter-tip temperature to a maximum of 55 °C by titrating the power (QMODE+), and the power and irrigation flow (QMODE), respectively. This offers the opportunity to prevent tissue overheating, steam-pop formation and perforation [2,22]. Although vHP-SD concepts have been evaluated for atrial procedures, ablation within the ventricles has not been reported in humans to date [1,2,10]. In this pilot study, we sought to investigate the efficacy, safety and short-term clinical outcome of vHP-SD ablation for the treatment of idiopathic PVCs originating from the right and left ventricular OTs. The data was compared to standard power-controlled ablation strategy using conventional contact-force sensing ablation catheters.

2. Methods

2.1. Patients

Since January 2021, 24 consecutive patients with symptomatic idiopathic PVCs originating from the cardiac OTs were prospectively enrolled and underwent PVC ablation utilizing the QDOT MICRO® (study group). Consecutive patients with OT PVC previously treated with conventional power-controlled ablation served as the control group. To achieve comparability of the groups the last 12 patients with PVC originating from the RVOT and the last 12 patients with PVC originating from the LVOT were evaluated. Finally, each group included 12 patients with PVCs originating from the left ventricular OT (LVOT) and 12 patients with PVCs originated from the right ventricular OT (RVOT). The patients were prospectively and consecutively enrolled, but not randomized. In patients on vitamin K antagonists the procedure was performed under therapeutic INR values of 2–3. In patients on direct oral anticoagulants the morning dose on the day of the procedure was omitted. For patients receiving antiarrhythmic (AA) therapy, the AA drugs were withdrawn at least 5 half-lives before the procedure. All patients gave written informed consent and all patient information was anonymized. The study was approved by the local ethics committee (Lübeck ablation registry ethical review board number: WF-028/15) and was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

2.2. Intraprocedural management

The detailed intraprocedural management for 3D mapping and ablation of VAs has been described in previous studies from our group [5,9,11]. In brief, the procedure was performed under deep sedation using propofol and fentanyl. One ultrasound guided right femoral artery puncture was performed and a 6F short sheath was inserted. The arterial access was used for invasive blood pressure monitoring and for the retrograde LV access approach. Three ultrasound guided femoral vein punctures were performed (3 × 8F). One diagnostic catheter was introduced and positioned inside the coronary sinus. The chamber of interest was determined based on the electrocardiographic aspect of the documented PVC [5]. If the origin of the PVC was not clear, the operator started with mapping of the RV. If the LV was assumed as the origin of PVC, a single TSP was performed under fluoroscopic guidance using a modified Brockenbrough technique. After TSP, heparin boluses were administered targeting an activated clotting time of >300 s. In cases where the aortic sinus of Valsalva was considered as the potential origin, a retrograde transaortic approach was used and an angiography of aortic root and coronary arteries was performed directly via the ablation catheter before any RF delivery to avoid coronary ostia damage.

Periprocedural complications were defined according to latest guidelines. Only adverse events adjudicated as possible, probable, or definitely related to the ablation procedure were mentioned as safety events. An adverse event was considered serious if it resulted in permanent injury or death, required an intervention for treatment, or required hospitalization for >24 h [3].

2.3. PVC mapping

Three dimensional electroanatomic reconstruction (CARTO 3 V7; Biosense Webster) of the ventricle was performed via multi-electrode fast anatomical mapping (FAM) using either a linear decapolar mapping catheter (DECANAV; Biosense Webster) or a twenty-pole mapping catheter (PENTARAY; Biosense Webster). Either the MOBICATH sheath (Biosense Webster) or the CARTO VIZIGO sheath (Biosense Webster) was used for antegrade LV access.

If the clinical PVC was present at the beginning of the procedure, a local activation time (LAT) map using LAT hybrid (CONFIDENSE module, Biosense Webster) to allow simultaneous mapping of the clinical PVC (pattern matching) and sinus rhythm was performed. Pacemapping, as well as the QS morphology on the unipolar recordings were used to confirm the PVC focus. When spontaneous PVCs were not present or were not frequent enough to perform the activation map, ventricular stimulation as well as isoproterenol infusion were used to increase the arrhythmia burden [5]. Body surface leads V1-V6 (center of energy) were utilized as reference and the COHERENT module (Biosense Webster) provided a more precise LAT interpretation. In both groups an additional mapping utilizing the individual ablation catheter was performed after FAM mapping to further specify the point of earliest activation. In the study group the three microelectrodes of the QDOT MICRO® catheter were additionally utilized to define the target area. In patients in whom the clinical PVC was not inducible, pacemapping was used to determine the PVC focus.

2.4. Ablation protocol

Radiofrequency energy was delivered at the point of earliest activation according to the LAT map or in the area where a perfect pacemap was obtained. In case of a no effect or recurrence for PVC originated from a septal area of the RVOT the opposite within LVOT site was mapped and targeted. In case of no effect or recurrence within the LVOT, ablation within the coronary sinus was performed if the point of earliest activation was found within it and in QMODE with 20 W and 20 ml/min flush to prevent overheating and perforation.

The successful site was denoted as the origin of the individual PVC. In case of >1 PVC the dominant PVC was targeted first followed by the PVC with lower frequency. The acute procedural endpoint was the absence of PVCs during a waiting period of 15–20 min with the patient both sedated and awake, with and without isoproterenol infusion. The catheter tip was carefully evaluated concerning charring and coagulum after each procedure.

2.5. Study group

In the study group, the QDOT MICRO® catheter was utilized. The QDOT MICRO® allows for vHP-SD ablation mode (QMODE+, 90 W, 4 s) and a conventional temperature controlled ablation mode (QMODE, 50 W maximum), where the system adjusts the irrigation flow rate and power based on the measured temperature to stabilize the catheter tip temperature [1,2]. In the QMODE+ mode only the power is adapted to achieve the target temperature [1,2]. After additional mapping via the QDOT MICRO® catheter utilizing the microelectrodes RF ablation was performed at the site of earliest activation or the best pacemap. The initial approach was to use QMODE+, with a target temperature of 60 °C and a CF range of 10–40 g for 5–10 RF applications. If the QMODE+ ablation was not effective, the mode was changed to QMODE and the RF delivery was continued in the same area utilizing 30–40 W for up to 60–120 s. Fig. 1 provides an example of PVC ablation within the LVOT

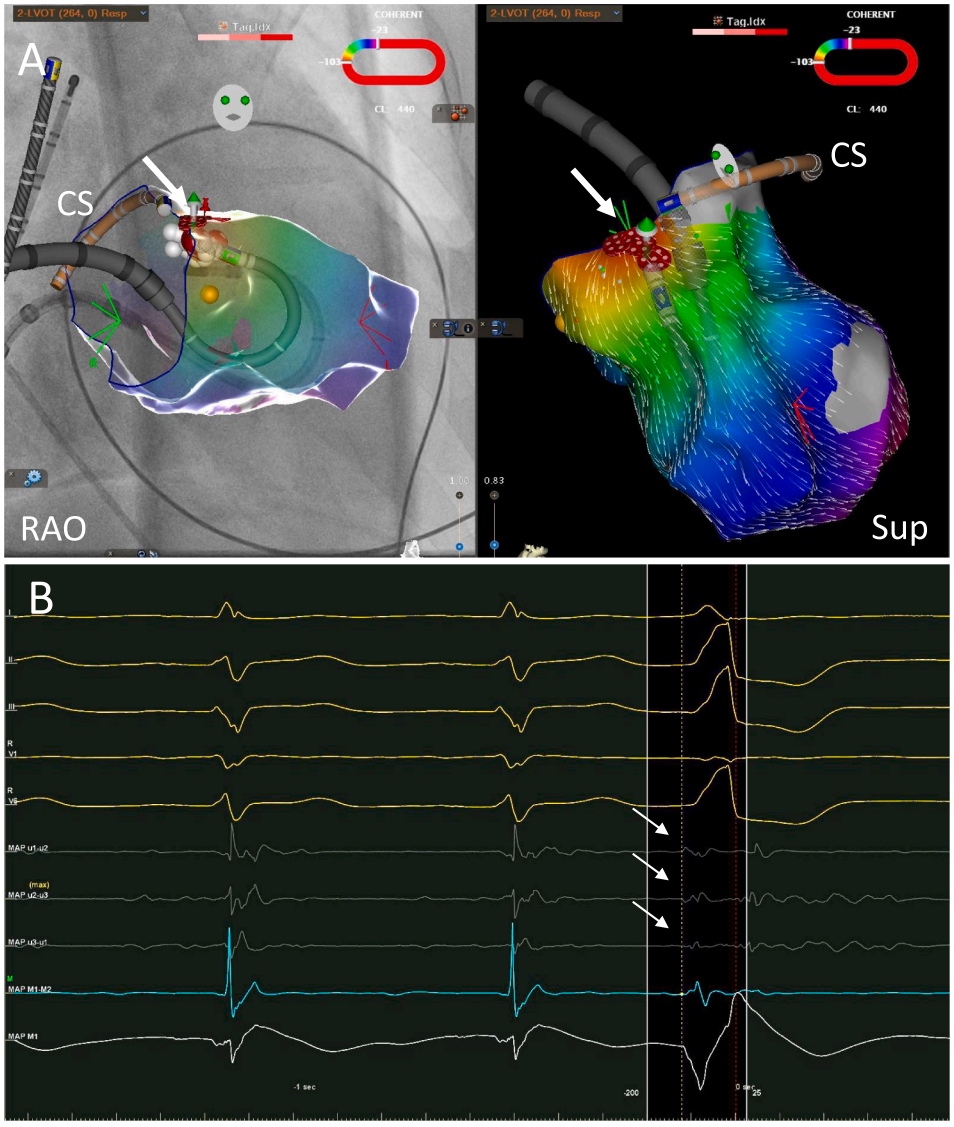

Fig. 1. A: Electroanatomic map of the left ventricle utilizing CARTO 3, V7 (Biosense Webster) and COHERENT mapping (study group). Left side RAO view, right side superior view. CS = coronary sinus catheter placed distal in the coronary sinus. White arrow = location of earliest activation with very high-power short duration application (red-white dot) at the LV-summit. RAO = right anterior oblique, SUP = superior view. B: Surface and intracardiac electrocardiograms with the QDOT MICRO ablation catheter at the location of earliest activation of the PVC within LVOT. Please note the potentials on the micro-electrodes (pointed out by white arrows). MAP M1-M2 = distal electrodes on the map catheter. MAP M3-M4 = proximal electrodes on the map catheter. MAP u1-u2, MAP u2-u3, MAP u1-u3 = micro-electrodes. Speed 200 mm/s.

utilizing the QDOT MICRO®.

2.6. Control group

In the control group, a CF-sensing open-irrigated tip catheter (ThermoCool SmartTouch surround flow, Biosense Webster) was used for conventional power-controlled ablation. Energy application was limited to 30–40 W, depending on the location, with a CF range of 8–40 g. The maximum application time was set to 60–120 s.

2.7. Postprocedural care

A figure-of-eight suture and pressure bandage were used to prevent femoral bleeding. The pressure bandage was removed after 4 h and the suture was removed on the next day. Following ablation, all patients underwent transthoracic echocardiography immediately, after 2 h, and on day 1 to rule out a pericardial effusion. New oral anticoagulants were reinitiated 6 h post ablation. No AA drug was further prescribed. All patients received a 24-h Holter ECG immediately after procedure. Follow-up was performed via 24-h Holter ECG after 3,6 and 12 months.

2.8. Statistical analysis

Continuous variables are presented as median with interquartile range (IQR; first quartile [Q1], third quartile [Q3]) and were compared using the Wilcoxon-Mann-Whitney test. Categorical variables are presented as absolute and relative frequencies and were compared using the chi-square test or Fisher's exact test (in case of small expected cell frequencies). All p values are two-sided and a p-value < 0.05 was considered statistically significant. All calculations were performed with the statistical analysis software SPSS (version 26; IBM SPSS Statistics).

3. Results

3.1. Patient characteristics

Twenty-four consecutive patients underwent ablation with either QMODE+ only or QMODE+ followed by QMODE, using the QDOT MICRO® catheter. The data were compared with those from 24 consecutively enrolled patients treated with conventional CF-sensing power-controlled CA either from the RVOT or LVOT. Patient baseline characteristics are detailed in Table 1. No significant differences were noted between the groups. Each group consisted of 12 patients with

Table 1
Baseline patient characteristics (all patients).

	Study	Control	P
Patients	24	24	
Age, years	66.5 (55, 79)	54.5 (41.5, 72)	0.119
Female gender	11 (46)	9 (38)	0.770
Arterial hypertension	11 (46)	8 (33)	0.556
Diabetes mellitus type 2	4 (17)	0 (0)	0.109
Coronary artery disease	7 (29)	3 (13)	0.286
Cardiomyopathy	6 (25)	7 (29)	1.000
Previous PVC ablation	2 (8)	2 (8)	1.000
Previous cardiac surgery	2 (8)	0 (0)	0.489
Previous antiarrhythmic therapy	10 (42)	17 (71)	0.080
PVC burden, %	19 (7.5, 30)	16.5 (7, 23)	0.359

Values are counts, n (%) or median (first quartile, third quartile).
PVC = premature ventricular contraction, RVOT = right ventricular outflow tract.

PVCs originating from the RVOT and 12 patients with PVCs originating from the LVOT, including the aortic sinus of valsalva (ASV). The comparison between the two subgroups is depicted in Table 2.

3.2. Procedural characteristics

Procedural data are depicted in Table 3 and Table 4. The acute procedural endpoint (termination of PVCs) was achieved in all patients. The clinical PVC was present or inducible during the procedure in 23 patients from each group (p = 1.000). Isoproterenol was used to increase the PVC burden in 19 (79%) patients in the control group and 14 (58%) patients in the study group (p = 0.21). The DECANAV (Biosense Webster) mapping catheter was used in 22 (92%) patients in the study group and in 19 (79%) patients of the control group (p = 0.41). The PENTARAY (Biosense Webster) was utilized in one patient in each group (p = 1.000). While the total procedure time and total fluoroscopy time were similar between the groups (p = 0.489 and p = 0.386, respectively), the RF time was significantly shorter in the study group (52 [IQR 16, 156] vs. 350 [IQR 240, 442] seconds; p < 0.0001; Fig. 2). When comparing the RVOT PVC patients from either group, the total RF delivery time was significantly shorter in the study group (24 [IQR 10, 52] vs. 320 [IQR 180, 402] seconds; p < 0.0001), while there was no difference regarding the total procedure and total fluoroscopy time. Comparing the LVOT PVC patients, the ablation time was also shorter in the study subgroup (p = 0.004).

When analyzing the study group, the median recorded contact force was 10 [IQR 8, 22] grams for RVOT procedures and 9 [IQR 8, 12] grams for LVOT procedures (p = 0.45). The maximum tissue interface temperature was similar between the two subgroups treated with QDOT (48 [IQR 44, 55] °C for RV vs. 46 [IQR 42, 48] °C for LV, p = 0.22), while the maximum delivered power per application was significantly higher in

Table 2
Baseline patient characteristics (RVOT and LVOT subgroups).

RVOT PVCs

	Study	Control	p
Patients	12	12	
Age, years	56 (42, 81)	43 (33, 54.5)	0.149
Female gender	6 (50)	4 (33)	0.68
Arterial hypertension	6 (50)	1 (8)	0.069
Diabetes mellitus type 2	1 (8)	0 (0)	1.000
Coronary artery disease	4 (33)	1 (8)	0.317
Cardiomyopathy	2 (17)	3 (25)	1.000
Previous ablation	1 (8)	1 (8)	1.000
Previous cardiac surgery	1 (8)	0 (0)	1.000
PVC burden, %	19 (11, 30)	16 (6, 20)	0.326

LVOT PVCs

	Study	Control	p
Patients	12	12	
Age, years	71.5 (61.5, 78.5)	69 (54, 76)	0.355
Female gender	5 (42)	5 (42)	1.000
Arterial hypertension	5 (42)	7 (58)	0.684
Diabetes mellitus type 2	3 (25)	0 (0)	0.217
Coronary artery disease	3 (25)	2 (17)	1.000
Cardiomyopathy	4 (33)	4 (33)	1.000
Previous ablation	1 (8)	1 (8)	1.000
Previous cardiac surgery	1 (8)	0 (0)	1.000
PVC burden, %	19 (6, 30.5)	19.5 (7, 25)	0.862

Values are counts, n (%) or median (first quartile, third quartile).
RVOT = right ventricular outflow tract, LVOT = left ventricular outflow tract, PVC = premature ventricular contraction.

Table 3
Procedural details (all patients).

	Study	Control	p
Patients	24	24	
Frequent PVC during procedure	23 (96)	23 (96)	1.000
Earliest activation on standard electrodes, ms	35 (30, 36)	35 (32, 35)	0.963
Earliest activation on microelectrodes, ms	45 (35, 55)		
Pacemapping	17 (71)	19 (79)	0.740
Isoproterenol	14 (58)	19 (79)	0.212
Decanav catheter	22 (92)	19 (79)	0.416
Pentaray catheter	1 (4)	1 (4)	1.000
Mobicath sheath	10 (42)	12 (50)	0.772
Vizigo sheath	6 (25)	3 (13)	0.461
Total number of applications	10 (5.5, 16.5)	7 (5, 12)	0.094
QMODE+ only	16 (67)		
Total RF duration, sec	52 (16, 156)	350 (240, 442)	<0.001
Number of target PVC			
1st ablation attempt in RVOT failed, change for LVOT	4 (17)	4 (17)	1.000
PVC origin:			
RVOT: antero-lateral	4 (17)	3 (13)	0.683
RVOT: mid-lateral	0 (0)	1 (4)	0.567
RVOT: postero-lateral	2 (8)	2 (8)	1.000
RVOT: antero-septal	1 (4)	4 (17)	0.156
RVOT: mid-septal	1 (4)	1 (4)	1.000
RVOT: postero-septal	4 (17)	1 (4)	0.156
LVOT: summit below LCC	4 (17)	7 (29)	0.303
LVOT: summit below RCC	1 (4)	1 (4)	1.000
LVOT: antero-lateral	2 (8)	1 (4)	0.551
LVOT: antero-septal	1 (4)	0 (0)	0.567
Aortic sinus: LCC	2 (8)	1 (4)	0.551
Aortic sinus: RCC	2 (8)	0 (0)	0.172
Aortic sinus: RCC/LCC junction	0 (0)	2 (8)	0.172
Total procedure time, min	96.5 (76,120)	91.5 (72,124)	0.489
Total fluoroscopy time, min	7 (5.5,12)	7 (4,10)	0.386
First-day recurrence	4 (17)	3 (13)	0.683
6 months follow-up	5 (21)	4 (17)	0.712
Periprocedural complications			
Serious adverse events	1 (4)	2 (8)	0.551
Cardiac tamponade	0 (0)	1 (4)	0.567
Major bleeding	1 (4)	1 (4)	0.567
Adverse events	1(4)	1 (4)	1.000
Minor bleeding	1(4)	1 (4)	1.000
Charring on catheter tip	0 (0)	0 (0)	1.000
Steam pop	0 (0)	0 (0)	1.000
Perforation	0 (0)	0 (0)	1.000

Values are counts, n (%) or median (first quartile, third quartile).
RVOT = right ventricular outflow tract, PVC = premature ventricular contraction, RF = radiofrequency, sec = seconds, min = minutes, vHP-SD = very high-power short-duration.

Table 4
Procedural details (Subgroups).

RVOT PVCs			
	Study	Control	p
Patients	12	12	
PVC during procedure	12 (100)	11 (92)	1.000
Earliest activation, milliseconds	40 (27.5, 40)	35 (35, 35)	0.645
Pacemapping	10 (83)	11 (92)	1.000
Isoproterenol used	7 (58)	9 (75)	0.667
Total number of applications	7.5 (4, 13)	8.5 (5, 13.5)	0.434
Total RF duration, sec	24 (10, 52)	320 (180, 402)	<0.0001
QMODE+ only	11 (92)		
Total procedure time, min	79.5 (71, 110)	100 (65.5, 166)	0.435
Total fluoroscopy time, min	6 (5, 11)	6 (4, 11.5)	0.954
First-day recurrence	0 (0)	1 (8)	1.000
6-months recurrence	1 (8)	1 (8)	1.000
LVOT PVCs			
	Study	Control	p
Patients	12	12	
PVC during procedure	11 (92)	12 (100)	1.000
Earliest activation, milliseconds	33.5 (30, 40)	32 (25, 40)	0.718
Pacemapping	7 (58)	8 (67)	1.000
Isoproterenol used	7 (58)	10 (83)	0.371
Total number of applications	12 (7.5, 21.5)	7 (5, 11)	0.063
Total RF duration, sec	150 (43, 288)	415 (240, 555)	0.004
QMODE+ only	5 (42)		
Total procedure time, min	120 (96, 125)	86.5 (73,106)	0.028
Total fluoroscopy time, min	9 (6, 14)	8 (5, 10)	0.194
First-day recurrence	4 (33)	2 (17)	0.346
6-months recurrence	4 (33)	3 (25)	0.653

Values are counts, n (%) or median (first quartile, third quartile).
RVOT = right ventricular outflow tract, LVOT = left ventricular outflow tract, PVC = premature ventricular contraction, RF = radiofrequency, sec = seconds, min = minutes, vHP-SD = very high-power short-duration.

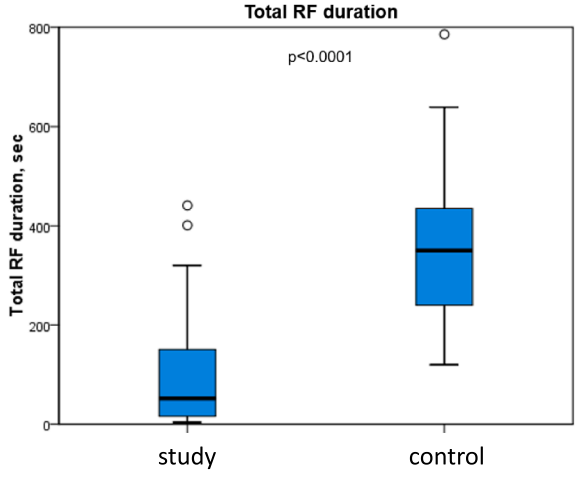

Fig. 2. Total radiofrequency duration. RF = radiofrequency, sec = seconds.

the RV subgroup (90 [IQR 90, 91] W vs. 90 [IQR 40, 90] W, p = 0.01). This finding might be explained by the higher incidence of QMODE+ only procedures in this subgroup.

3.3. Mapping capabilities

Utilizing the QDOT MICRO® the electrograms of earliest activation of the microelectrodes (measured to the onset of PVC QRS complex) were compared to the standard electrodes. Within the area of earlies activation, electrograms recorded with microelectrodes showed significantly earlier activation (35 ms [30,36 ms] vs. 45 ms [35,55 ms] respectively; p < 0.0001). Fig. 3 shows an example of electrograms recorded with standard electrodes and microelectrodes within the area of earliest activation.

3.4. Efficacy

The acute procedural endpoint was reached in all patients. In 16 (67%) patients of the study group the acute procedural endpoint was achieved using QMODE+ only. Eleven (92%) patients with PVCs originating from the RVOT and 5 (42%) patients with PVCs originating from the LVOT were treated with the QMODE+ only (p = 0.027). The operators did not report subjectively evaluated observations regarding catheter maneuverability and stability. On the 24-h Holter ECG, 4 patients in the study group and 3 patients in the control group had recurrences (p = 0.683). The recurrent PVC burden was similar between the groups (p = 0.136). The first-day recurrence rate was also similar when the two subgroups were analyzed (p = 1.000 for RVOT and p = 0.346 for LVOT). For six-months follow-up a total of 5 patients (21%, study group) and 4 patients (17%, control group) showed recurrence of the clinical PVC (p = 0.712).

3.5. Safety

No charring was detected on the catheter tip in either group and no steam pops were observed. A total of three serious adverse events occurred: In the control group one patient had cardiac tamponade treated with pericardiocentesis and one patient developed a puncture site pseudoaneurysm that required thrombin injection. In the study group one patient experienced a retroperitoneal hematoma which was treated conservatively, yet was related to a prolonged hospital stay. Adverse events occurred as follows: Groin hematoma in one patient from each group, both treated conservatively. When analyzing the LV and RV subgroups no difference was observed in terms of acute complications.

4. Discussion

The Fast and Furious PVC study sought to compare the acute efficacy, safety and short-term clinical outcome of a vHP-SD temperature-controlled approach utilizing the novel QDOT MICRO® catheter versus the conventional power-controlled approach for RVOT and LVOT originating PVC ablation. To the best of our knowledge, this is the first study to report the use of this novel technology for the treatment of ventricular arrhythmias. The main findings of this study are:

1. The RF delivery time was significantly shorter in the study group.
2. There were no differences regarding total fluoroscopy time and total procedure time between the groups.
3. The complication rate was low and similar between the groups. No charring or steam pops were observed
4. A QMODE+ only approach was successful in 67% patients (RVOT: 92%, LVOT 42%)
5. The earliest activation found on the microelectrodes was significantly earlier than on the standard electrodes.

The most common origin of idiopathic PVCs is the cardiac OT [3,6,7]. Approximately 70% of them originate from the RVOT [3,8] and the remaining from the LVOT and adjacent structures such as pulmonary artery, the ASV and LV summit [6–8,12]. It has been shown that a high burden of PVCs is associated with a decline in LV ejection fraction (LVEF) [13,14]. According to the latest guidelines, CA is recommended for the treatment of Vas originating from the cardiac OT in symptomatic patients or in those exhibiting arrhythmia-induced cardiomyopathy [3,4]. The superiority of CA over AA therapy has been demonstrated in clinical studies [15–17]. Current ventricular RF ablation strategies are based on the power-controlled guided approach, using a power of 20–50 W [5,9,11,18]. Recently, vHP-SD CA using the novel QDOT MICRO®

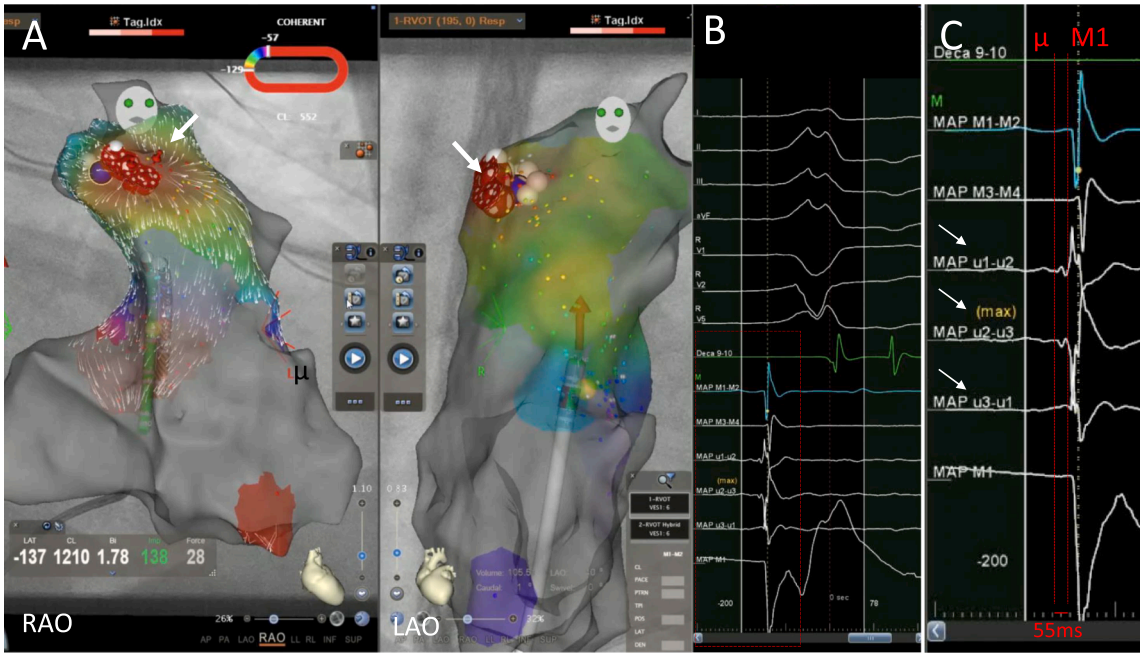

Fig. 3. A: Electroanatomic map of the right ventricle utilizing CARTO 3, V7 (Biosense Webster) and COHERENT mapping (study group). Left side RAO view, right side LAO view. White arrow = location of earliest activation with very high-power short duration application (red-white dot). RAO = right anterior oblique, LAO = left anterior oblique. Please note the red pin which was found to be the point of earliest activation. B: Surface and intracardiac electrocardiograms with the QDOT MICRO ablation catheter at the location of earliest activation of the PVC within RVOT. C: Magnification of the red dotted area in B. Please note the early potentials on the micro-electrodes (pointed out by white arrows) preceding the signal on the distal and proximal electrodes by 55 ms. MAP M1-M2 = distal electrodes on the map catheter. MAP M3-M4 = proximal electrodes on the map catheter. MAP u1-u2, MAP u2-u3, MAP u1-u3 = micro-electrodes. Speed 200 mm/s.

catheter has been introduced in clinical practice and it was shown to be safe, effective and fast for PVI [1,2]. The QDOT MICRO® catheter is equipped with six thermocouples symmetrically embedded in the circumference of the tip electrode, allowing for a precise temperature monitoring of the tissue interface and a power modulation aiming to prevent tissue overheating, collateral damage, catheter tip charring and steam pops [1,2,10,19].

The present study shows that ablation of PVCs originating from the cardiac Ots using this novel temperature-controlled approach provides similar acute success rates, periprocedural complications rates and short-term clinical outcome when compared with the standard power-controlled protocol. As expected, the reduced RF delivery time for each application led to a dramatically shorter total ablation time. Previous studies focusing on vHP-SD for PVI also showed reduced total procedure and fluoroscopy times as compared to standard protocols [1,2]. This effect was not verified in our study and is probably explained by the significantly lower number of RF applications needed for PVC ablation than for PVI. In contrast to control, the QDOT MICRO® is equipped with three microelectrodes at its tip, which might provide a more precise electrogram characterization. We observed that the microelectrodes showed early fragmented potentials during local PVC activation throughout all patients. Those potentials were not or were potentially recorded later recorded by the standard bipolar electrodes. This might lead to a more accurate localization of the PVC origin. Thus, we strongly recommend the use of microelectrode signals in addition to the activation map to further improve the characterization of arrhythmic foci [20]. However, this need to be proven in further trials and studies.

Experimental studies demonstrated that HP-SD and vHP-SD approaches resulted in similar lesion volumes as compared to the standard approach, but in a significantly different lesion morphology [10,21]. Applying this strategy to ventricular ablation results in larger but shallower lesions [10]. This aspect might represent a drawback considering the fact that the PVCs might originate from the mid-myocardial or epicardial layers of the thick ventricular wall. However, the acute procedural efficacy was identical for the two groups in our study. Lesion formation utilizing vHP-SD results in less area of reversible injury and more durable lesions [22]. This observation might lead to improved patients outcome and less recurrence of PVC. The total number of applications was similar for both strategies, supporting the noninferiority of vHP-SD CA for the treatment of Vas.

The trend towards a higher number of applications as well as a lower rate of QMODE+ only applications needed to achieve procedural success in LVOT ablation procedures needs to be addressed in further studies. It is important to note that the QDOT MICRO® catheter can be switched to temperature-controlled QMODE, which reduces the power of application in exchange for a longer RF delivery time. Based on the previous finding [10], this mode produces a deeper, but more narrow lesion, which can be used to target arrhythmias arising from the more profound layers of the myocardium. In this study, the QMODE+ was used as the first approach. When this proved to be inefficacious, a switch to QMODE was made and the procedural endpoint was reached in all cases. The benefit of this strategy is reflected by the statistically significantly higher rate of QMODE+ only procedures performed in the RVOT than in the thick-walled LVOT. Therefore, it seems to be reasonable to consider QMODE+ for PVC originating from the RVOT and QMODE for PVC originating from the LVOT.

4.1. Safety

As shown in preclinical studies, the vHP-SD approach minimizes conductive heating, thereby reducing damage to collateral tissue [10,19,22,23]. Moreover, the temperature-controlled ablation aims to avoid tissue overheating, char formation and steam pop, which might increase the safety profile of ventricular CA [1,2,10]. In this relatively small analysis no steam-pops, charring or perforation has been observed which is confirming the possible increased safety of a temperature-controlled ablation compared to power-controlled ablation. Studies focusing on this novel technique used for PVI have shown safety profiles similar to the standard ablation protocols [1,2]. Our study is in line with

these findings. No difference was seen between the two groups in terms of the periprocedural complications. The most common complications – such as local or retroperitoneal hematoma and pseudoaneurysm formation – were those related to vascular access and are independent of the ablation technique. Only one case of cardiac tamponade was observed in the control group.

4.2. Short-term clinical outcome

The first-day recurrence rate was similar between the groups, with no difference in PVC burden on 24-h Holter monitoring. This finding is consistent with the acute procedural success rate and proves the efficacy of the vHP-SD ablation strategy for the treatment of PVCs originating from the cardiac OTs.

4.3. Limitations

The present study reflects a single-center initial experience and includes a relatively small number of patients. The two groups are not randomized, which might result in potential selection bias. The follow-up data are limited to one day postprocedurally, which might not reflect the complete efficacy profile of this technique. The lesion durability needs to be assessed by long-term follow-up. The current study only included patients with idiopathic PVCs originating from the cardiac OTs, thus it cannot establish if the results may be extrapolated to Vas resulting from structural heart disease or with origins other than the cardiac OTs.

4.4. Conclusions

To the best of our knowledge, this is the first study to report on the acute efficacy, safety and short-term follow-up of vHPSD ablation of PVCs as compared to standard power-guided strategies. This novel technology demonstrated similar procedural efficacy, with significantly reduced RF delivery time. No difference was observed regarding the safety profile and short term arrhythmia recurrence.

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None.

Data availability statement

Due to data privacy regulations the data will not be available to other researchers.

Ethics approval statement

The study was approved by the local ethics committee (Lübeck ablation registry ethical review board number: WF-028/15) and was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Patient consent statement

All patients gave written informed consent and all patient information was anonymized.

Authors contribution

The authors contribution are: CH Heeger: concept/design, data collection, data analysis and interpretation, drafting article. RR Tilz: concept/design, data analysis and interpretation, critical revision and approval, all other authors: critical revision and approval.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: CHH received travel grants and research grants from Boston Scientific, Biosense Webster and Cardiofocus and speaker honoraria from Boston Scientific, Biosense Webster and Cardiofocus.

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