1	Combined complex electrophysiological interventions due to improved					
2	standardization and efficiency: proof of concept.					
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The field of cardiac electrophysiology (EP) is evolving rapidly. Over the years, with the evolution of ablation technologies, including the development of irrigated ablation catheters with contact force sensing, steerable sheaths, 3-dimensional mapping systems, multipolar mapping catheters and pre- and peri-procedural imaging, the treatment of complex arrhythmias with catheter ablation has expanded significantly. Implementation of lean management strategies for complex EP procedures, with standardized, simplified, shorter and more predictable workflows, has the potential to significantly enhance procedural efficiency. (1-6)

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Multiple arrhythmias may co-exist in the same patient. The co-existence of arrhythmias may 10 present unique management problems. For instance atrial arrhythmias are a common causes of 11 12 inappropriate ICD therapy.(7) These inappropriate shocks are potentially responsible for an 13 increased mortality. (8, 9) Eliminating atrial fibrillation and atrial flutter, could reduce appropriate and inappropriate therapy and potentially reduce mortality. Multiple co-existing arrhythmias 14 15 could be treated during the same procedure, using the same EP material and with standardized 16 workflows. Combinations of VT ablation with PVI or CTI could have potential advantages, 17 including a reduction in the number of procedures, a reduction in complication rates, and more 18 effective utilization of healthcare resources.

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The aim of the present study was to analyze the feasibility, safety and effectiveness of combined complex endocardial only VT ablation procedures with atrial ablation procedures. VT ablation was performed using an image-integration guided and substrate-based ablation in sinus rhythm (50W; QDOT catheter). The MUSIC/inHEART technology, was used for image integration as
 described previously.(2)

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Nine patients were included between April 2020 and April 2022 (8 [89%] male; 8 [89%] structural 4 heart disease; age 66±7 years, Table 1). Four (44%) underwent AF ablation and CTI-dependent 5 6 flutter ablation in addition to VT ablation, 3 (33%) underwent AF ablation in combination with VT 7 ablation and 2 (22%) had CTI-only ablation in addition to VT ablation. All patients had a history of AF (7 [77%] paroxysmal AF; 2 [22%] persistent AF). One third of the patients (n=3) had 8 inappropriate defibrillator shocks for rapidly conducted atrial fibrillation. All patients who 9 underwent VT ablation had appropriate therapy (sustained VT with V1- in n=3 and V1+ in n=3) 10 and two patients came with electrical storm. Three patients had inappropriate shocks. Among 11 12 the cohort of AF ablation patients three individuals had symptomatic atrial fibrillation, three 13 patients were ablated prior to CRT upgrade to increase chances of synchronization obtaining biventricular pacing of >98%. Two patients had severe mitral regurgitation and AF ablation was 14 15 performed prior to Mitraclip. One patient had a tachycardiomyopathy with a LVEF of 35% due to 16 fast persistent atrial fibrillation.

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The predefined procedure endpoints for AF (pulmonary vein isolation) and VT ablation (CT channel elimination and non-inducibility of any VT) were reached in all 9 patients (Examples in Figure 1). There were no acute procedure-related complications. Skin-to-skin duration was 162.9±40.7 min. The incremental procedure time to complete the atrial ablation was 23±4 min. Of note, atrial FAM mapping is routinely performed as part of the image integration protocol prior to VT ablation. Ablation time (first to last ablation application) for PVI was comparable to the previously reported POWER-PLUS study.(10) The remaining time of the skin-to-skin duration was counted as the procedural time for VT ablation. There were no significant differences in procedure time for the VT ablation procedure in comparison to the previously reported MUSIC-VT study.(2) The RF-time for VT ablation was also not significantly different in our cohort, although we observed a trend towards lower ablation time.

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After a mean follow-up of 8.1±8.3 months, 6 patients were free of any atrial or ventricular arrhythmia. One patient underwent cardioversion for atypical atrial flutter. Two patients had recurrence of sustained VT, one of which was terminated by ATP and the other one by administration of Amiodarone. One patient had recurrent PVCs. Recurrence rates did not differ significantly from the matched patients in the POWERPLUS and MUSIC VT study, respectively (Table 5). No procedure-related complications were identified during follow-up.

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The main findings of our study are as follows: 1. In experienced centers and well selected patients, a combined VT ablation and PVI is feasible with an average combined procedure time of less than three hours; 2. With streamlined and efficient workflows, the increase in procedure time associated with atrial ablation procedures, including PVI, is less than 30 minutes; 3. Despite the reduced cardiac reserve in patients undergoing VT ablation, combined VT and atrial ablation procedures do not appear to increase complication rates or compromise efficacy.

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1 We demonstrate that a single ablation catheter can be used for ablation of not only multiple 2 atrial arrhythmias but also ventricular tachycardia during the same procedure. A very high power 3 short duration AF ablation has a low risk for stroke and silent emboli and can be performed in a safe and efficient workflow as demonstrated in the FAST AND FURIOUS PVI Study. (6, 11, 12) 4 Additionally, a substrate-based VT ablation approach in sinus rhythm can be performed in around 5 6 two hours with a favourable safety profile.(2, 13) Due to increased standardization (CLOSE-PVI 7 and substrate-based CT channel ablation in sinus rhythm), new ablation power strategies (50-90W) and additional tools as preprocedural imaging, and multipolar mapping catheters for 8 efficient high-density mapping and specific pacing manoeuvres, both AF and VT procedures 9 became shorter and more predictable. (6, 12, 14, 15) However, our findings need to be validated 10 in larger studies, with potential additional data on resource utilization and patient satisfaction. 11 12 Finally, it is important to note that while the use of standardized AF ablation strategies is 13 widespread, there remains heterogeneity in terms of VT ablation strategies. For instance, the use of inHeart image integration-based VT ablation is currently limited to specific centres and the 14 15 data supporting the approach is limited to single centre studies.

16

17 Conflicts of interest

18 I have read the journal's policy and the authors of this manuscript have the following competing 19 interests: BB received proctoring, lecture, travelling and consulting fees from Biosense Webster. 20 RK and SNM received research grants and consulting fees from Biosense Webster. HP has 21 received honoraria/consultation fees from Abbott, Biosense Webster, Boston Scientific, 22 Medtronic. None of the other authors declared a conflict of interest.

1 Financial disclosure

2 No funding was received.

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4 Data availability statement

- 5 All relevant data appear in the manuscript. Other data are available upon reasonable request at
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Table 1.

	Combined EP	MUSIC VT	POWERPLUS	p value
Clinical characteristics				
total number of patients	9	49	90	
Age, mean (SD) years	66 (7.5)	63 (15)	64.2 (8.9)	0.708
Male, n (%)	8 (89)	44 (90)	61 (67.8)	0.009
Paroxysmal AF, n (%)	7 (77.8)	NK	64 (71.1)	0.672
Persistent AF (>7d) n,(%)	2 (22.2)	NK	26 (28.9)	0.672
BMI, mean (SD) kg/m ²	26.7 (5)	26.6 (3.7)	26.6 (3.1)	0.997
Hypertension, n (%)	3 (33.3)	29 (59)	41 (45.6)	0.188
Structural heart disease, n (%)	8 (89)	43 (88)	16 (17.8)	< 0.00001
Diabetes, n (%)	4 (44.4)	4 (8)	8 (8.9)	< 0.00001
CHA ₂ DS ₂ VAS _C , median (IQR)	4.0 (4)	4.1 (1.4)	2.0 (3)	< 0.00001
LAVI ml/m2, mean (SD) mm	46.9 (17.8)	19 (39)	38.9 (5.1)	< 0.00001
Inappropriate shocks, n (%)	3 (33.3)	NK	1	-
Appropriate shocks or ATP, n (%)	9 (100)	49 (100)		-
Procedural characteristics				
Net procedure time for PVI, median (IQR) min	27 (8)	NA	70 (20)	< 0.00001
Procedure time VT, mean (SD) min	140.2 (41.5)	172 (48)	NA	0.062
Steam pop during case	0	1 (4%)	1 (1.1)	-
Char at inspection	0	0	0	-
Ablation time mean (SD) - 1st to last tag, mins	22.8 (4)	80 (37)	32 (12)	<0.00001
RF delivery time LA required, mean (SD) mins	6.4 (1.5)	NA	4.5 (1.2)	0.005
RF-time VT, mean (SD) min	15.4 (9.1)	31 (17)	NA	<0.001
Overall Procedure time, mean (SD) min	163 (22.8)	172 (48)	70 (20)	< 0.00001
Safety and Effectiveness				
Major complications, n (%)	0	1 (2)	0	-
Minor complications, n (%)	0	1 (2)	0	-
Recurrence, n (%)	2 (22.2)	13 (27)	15 (16.6)	0.380
Mortality, n (%)	0	2 (4)	0	-

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- 2

3 Abbreviations:

- 4 SD, standard deviation, n, number; d, days; AF, atrial fibrillation; LAVI, left atrial volume; ATP,
- 5 antitachycardia pacing; VT, ventricular tachycardia; min, minutes; IQR, interquartile range; NA, not
- applicable; NK, not known; mm, millimeters;
- 8

1 Figure 1. Examples of combined complex EP procedures.

- 2 <u>Figure legend</u>: Six examples of combined atrial and ventricular ablation procedures using a 3D
- 3 mapping system (CARTO, Biosense Webster), a substrate model of the patients' ventricular scar
- 4 (inHEART), a dedicated mapping catheter (PentaRay or OctaRay, both Biosense Webster) and an
- 5 ablation catheter (QDOT, Biosense Webster and or Farapulse, Boston Scientific).
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