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CLINICAL RESEARCH

Epicardial only mapping and ablation of ventricular tachycardia: a case series

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Aims Ventricular tachycardia (VT) ablation for ventricular arrhythmias is a validated approach, typically performed endocardially, or combined with an epicardial approach if endocardial ablation failed or in case of non-ischaemic cardiomyopathy. We report our experience with epicardial only procedure in a subset of patients with incessant VT or VT storm.

Methods and results This was a single centre retrospective study. Between 2011 and 2014, all patients referred for VT ablation were reviewed at CHU Bordeaux. All patients with an epicardial only (anterior percutaneous approach) mapping and ablation procedure were included. In total, 296 patients underwent a VT ablation and 4 (all male, 70 $\pm$ 7 years, 27 $\pm$ 11% left ventricular ejection fraction) of them underwent an epicardial only procedure: two ischaemic patients had an endocardial left ventricular thrombus and incessant VT. One patient post-myocarditis had a failed a previous endocardial procedure without local abnormal ventricular activity (LAVA). The fourth patient had a dilated cardiomyopathy and a complicated epicardial puncture followed by mild continuous bleeding (200 mL) precluding anticoagulation associated with left ventricular endocardial access. Local abnormal ventricular activity elimination was verified only epicardially in all and obtained in two patients and non-inducibility was tested and achieved in the two patients without thrombus. No further complications occurred. After a mean follow-up of 21 $\pm$ 12 months, one patient (25%) had recurrence of VT and no patient death was observed.

Conclusion Epicardial only ablation seems feasible and effective and useful in a limited subset of patients with incessant VT. However, endpoints are more difficult to evaluate and long-term follow-up is needed.

Keywords Ablation • Endocardial thrombus • Epicardial • Imaging • LAVA • Ventricular tachycardia

Introduction

Ablation of scar-related ventricular tachycardia (VT) is a validated technique, often in conjunction with implantable cardioverter-defibrillator (ICD) therapy.[1,2] Substrate-based ablation widened the use of VT ablation for both ischaemic ischaemic cardiomyopathy (ICM) and non-ischaemic cardiomyopathy (NICM).

An endocardial only ablation approach is the most used technique.[1,3] The epicardial access is usually used after a failed endocardial approach and rarely as a combined approach during the index procedure.[4,5] Epicardial ablation is a relatively safe approach with a major complication rate around 8% in tertiary centres.[6] Moreover, an epicardial only ablation has been reported to be safe and effective after a failed endocardial approach.[7]

In ICM—with subendocardial or transmural scar and because of wall thinning—an endocardial only approach is effective in the vast majority of patients.[8] However, more than two-thirds of patients selected for an epicardial approach after a failed endocardial procedure showed an epicardial ablation target.[9]

In NICM—with subepicardial or intramural scar—an epicardial access can be of added value.[8] In arrhythmogenic right ventricular cardiomyopathy, epicardial scar is larger than endocardial scar and epicardial access can be used to map epicardial scar and local abnormal ventricular activity (LAVA) from the epicardium, while ablating from the endocardium, due to wall thinning.[10] In patients post-myocarditis with subepicardial scar only, endocardial LAVA is usually absent and epicardial only ablation is needed in most if not all.[11,12]

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What's new?

- This is to our experience the first case series of epicardial only mapping and ablation of VT feasible in a very limited subset of patients.
- Specific problems to evaluate endpoints are encountered.

Pre-procedural imaging with multidetector computed tomography (MDCT) and delayed enhancement magnetic resonance imaging (DE-MRI) can help to visualize scar, important anatomical structures (such as the phrenic nerve and the coronary artery system), wall thinning, ventricular aneurysm, ventricular (and atrial) thrombus, and calcification MRI.[13–16] The knowledge of the presence of a subepicardial scar can help the operator to use an epicardial approach.[17] A left ventricular endocardial thrombus is a contra-indication for endocardial mapping and ablation, due to the risk for stroke.

In this study, we report our experience of an epicardial only approach for mapping and ablation in a very limited subset of patients.

Methods

All VT ablations between 2011 and 2014 were reviewed at CHU Bordeaux. All epicardial only (both mapping and ablation) procedures were included irrespective of an earlier endocardial mapping. Procedure time, radiofrequency time, electroanatomical substrate and activation maps, endpoints (LAVA elimination and inducibility), complications, and follow-up were analysed.

A pre-procedural mesh with scar and anatomical information was integrated in the mapping system and ICD therapy was disabled before the procedure. After obtaining groin access, a RV apex catheter was positioned as anatomical landmark and for pacing. An anterior percutaneous subxyphoidal puncture approach was used to obtain access to the pericardial space.[18,19] A steerable short curve—regular size or epicardial sheath (Agilis, St Jude Medical)—was used to access the pericardial space. Suction was applied on the sheath when needed to increase catheter stability, contact, and electrogram quality. An irrigated multipolar mapping catheter (PentaRay, Biosense Webster) was used for high-density mapping.

Local abnormal ventricular activity was manually tagged on the substrate maps. Local abnormal ventricular activities are surviving fibres inside the scar tissue and often have a lower bipolar voltage and sharp appearance.[6] They can be fractionated and late but can in fact appear everywhere during the QRS complex, depending on their anatomy and position inside the scar, as previously demonstrated.[7] Their main characteristic is poor electrical coupling to the surrounding tissue, which manifests as local delay or Wenkebach behaviour during pacing at faster rates. This is the reason why we prefer to use the term LAVA and not late potentials, since this implies performance of active pacing manoeuvres to unmask/identify LAVA in doubt. All late potentials are LAVA, but not all LAVAs are late potentials.

Although different epicardial voltage cut-offs are suggested (<1.81 and <1 mV), we used the usual epicardial bipolar low-voltage threshold of <1 mV and unipolar low-voltage thresholds of <7.95 mV.[1,4] We used unipolar voltage in this subset to have a better understanding of the endocardial and/or transmural scar extent and to improve our image merge.

After completion of the substrate map in sinus rhythm, the electroanatomical mapping (EAM) map was merged with the three-dimensional image model and the mapping catheter was exchanged for an irrigated ablation catheter (Thermocool SF, Biosense Webster or Coolpath Duo, St Jude Medical).

When the merged image demonstrated a phrenic nerve within 5 mm, we performed detailed high output (10 mA, 2 ms) pacing to tag the phrenic nerve on the EAM map. In case we expect a close distance (<5 mm) from a coronary artery on the merged image, a coronary angiogram was performed in different views by an experienced invasive cardiologist. If LAVAs were found >5 mm away from the major coronary arteries or no phrenic nerve capture was confirmed, LAVA-based ablation was performed in that region. If LAVAs were found <5 mm from the phrenic nerve, an injection of saline (with close monitoring of signs of tamponade) was performed to displace the phrenic nerve from the potential ablation site.

In the absence of an endocardial thrombus, a VT induction protocol was performed from the RV apex (600–500–400 ms drive train with up to three extrastimuli) and an activation map was made when tolerated. Furthermore, entrainment mapping was performed to identify the critical isthmus, based on a short post-pacing interval <30 ms, a stimulus-to-QRS duration of 40–70 ms and concealed entrainment. Ablation was started with the aim to terminate VT during ablation. When an induction protocol was contra-indicated, the critical isthmus was detected based on substrate mapping, manual LAVA tagging, pacemapping, and prolonged stimulation-to-QRS duration.

Ablation was performed using a conventional ablation catheter without contact force, using a power-controlled mode is used with mean power delivery of 25 W with an irrigation at 8 mL/min during 60–90 s. We did not titrate to achieve certain impedance changes.

After LAVA-based ablation, a re-map was made, using the multipolar PentaRay mapping catheter to confirm the endpoint of complete LAVA elimination and an additional ablation was performed when needed.

At the end of the procedure, the epicardial Agilis sheath was replaced by a pigtail catheter and an active suction was performed to evacuate all intrapericardial liquid. A routine transthoracic ultrasound evaluation of the pericardial space was then performed and if re-assuring, the pigtail catheter was removed without application of intrapericardial corticoids. All patients routinely received a therapeutic dose of non-steroidal anti-inflammatory drugs (NSAIDs) during 5 days.

Follow-up data (in months) after procedures were collected using device logs, hospital admissions, and data from the general practitioner and cardiologist. All patients were routinely seen in clinic at 1, 3, 6, 12, and 24 months. Records were kept of all instances of VT (sustained and non-sustained), with or without the need of therapy [anti-tachycardia pacing (ATP) or shock], as well as any deaths.

Results

A total of 296 patients underwent a VT ablation procedure at CHU Bordeaux. A subset of four patients (all male, 70 ± 7 years old) underwent an epicardial only procedure for mapping and ablation. A three-dimensional mapping system was used in all patients (Ensite™: $n = 3$, St Jude Medical and CARTO® 3: $n = 1$, Biosense Webster) to create a high-density map (mean 696 ± 414 map points epicardial/map), using a multipolar mapping catheter (PentaRay, Biosense Webster). All patients had a diminished left ventricular ejection fraction (mean LVEF 27 ± 11%) and were on amiodarone and beta-blockers. Three patients had incessant VT and one had a ventricular storm. All patients carried an ICD and had multiple ICD shocks

Table 1 Baseline characteristics

Patient	Sex	Age (years)	Disease	Procedure number	Amiodarone	BB-ACE-statin	VTCL (ms)	Axis	ICD	ICD shocks	GFR (mL/min)	NYHA	LVEF	Reason for procedure	Reason for epi only procedure
1	M	70	MYO	2	1	1	490	RBBB	1	1	75	II	41%	Incessant VT	endo LAVA absent surgical epi access
2	M	73	ICM	1	1	1	300	RBBB	1	1	70	II	20%	Incessant VT	LV endocardial thrombus
3	M	60	ICM	1	1	1	350	RBBB	1	1	53	II	30%	VT storm	LV endocardial thrombus
4	M	77	DCM	1	1	1	350	RBBB	1	1	39	III	16%	Incessant VT	Bleeding after epi puncture

BB, beta-blockers; ACE, ace-inhibitors; VTCL, ventricular tachycardia cycle length; GFR, glomerulary filtration rate; NYHA, New York Heart Association Class; epi, epicardial; MYO, post-myocarditis; DCM, dilated cardiomyopathy; RBBB, right bundle branch block; endo, endocardial.

Table 2 Procedural data

Patient	EAM system	epi map points	epi bipolar LVA (cm^2)	epi LAVA	Imaging	Scar location	Ablation during VT	epi mapping	epi adhesions	Procedure time (min)	epi RF time (min)	Non-inducibility	LAVA elimination
1	Ensite	626	53	1	MDCT + DE-MRI	Apico-inferoseptal and lateral	1	PentaRay	1	175	38	1	Complete
2	CARTO 3	322	166	1	DE-MRI	Anterior	0	PentaRay	1	190	10	Not tested	Complete
3	Ensite + Mediguide	1140	121	1	MDCT	Anterior	0	PentaRay	1	240	21	Not tested	Incomplete
4	Ensite	NA	NA	1	MDCT	Basal-mid inferoseptal	1	PentaRay	0	120	9	1	Incomplete

epi, epicardial; LVA, low-voltage area.

before admission. Pre-procedural imaging was used in all (MDCT: $n = 3$ and DE-MRI: $n = 2$) and demonstrated a subepicardial scar in one patient, a transmural scar in one patient, and an endocardial left ventricular thrombus in two patients.

Baseline characteristics and procedural data are illustrated in *Tables 1* and *2*. All patients are discussed in detail as follows.

Myocarditis patient with recurrence of ventricular tachycardia after endocardial only procedure ($n = 1$)

Patient 1 (represented in *Figure 1*) presented with subepicardial only inferolateral scar. Multidetector computed tomography and DE-MRI imaging showed an anatomical isthmus between two regions of focal wall thinning. An earlier endocardial approach demonstrated the absence of endocardial LAVA. Because of incessant VT, a repeat procedure was proposed but without any endocardial access. An epicardial only procedure was conducted. After the completion of the substrate map and image integration, only the stable clinical VT was induced and the isthmus was confirmed using entrainment mapping, at the site of the anatomical isthmus, found on imaging. A coronary angiogram was made and confirmed a safe potential ablation site. Ablation was performed during VT and the clinical VT was stopped during the first RF application and was not inducible afterwards. Further LAVA elimination was performed until complete LAVA elimination was obtained. Only beta-blocker therapy was continued afterwards (*Table 3*).

Ischaemic patients with a left ventricular thrombus on multidetector computed tomography ($n = 2$)

Patients 2 and 3 (represented in *Figures 2* and *3*) were referred for VT ablation and had an endocardial left ventricular (LV) thrombus on MDCT imaging. None of them had undergone CABG.

Patient 2 presented with a persistent thrombus despite of anticoagulant therapy (warfarin) initiated 3 months ago. The thrombus was not visible on routine echocardiography. This patient was taken to the laboratory because of prior incessant VT episodes. He was therefore intubated and ventilated and received amiodarone intravenously. After extubation—1 week before the procedure—he did not show spontaneous VT episodes anymore.

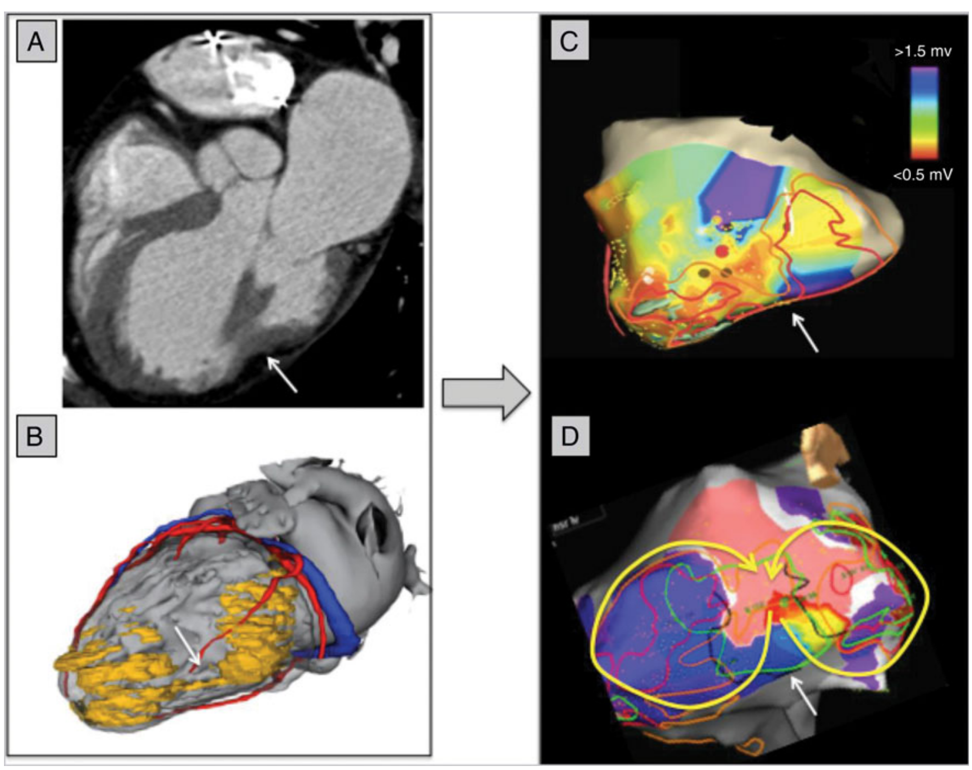

Figure 1 Patient 1 with post-myocarditis subepicardial only scar (lateral view). (*A*) Multidetector computed tomography image of the left ventricle, showing two lateral zones of focal wall thinning with an anatomical epicardial isthmus in between (white arrow). (*B*) Three-dimensional mesh (derived from merged information of MDCT and MRI) made using Music software (INRIA, Nice and CHU Bordeaux, France) with coronary artery system in red, coronary venous system in blue, and two zones of scar (wall thinning) in yellow with an isthmus in between (white arrow). (*C*) Epicardial bipolar voltage map, using the EnSite™ Velocity™ system (St Jude Medical). Purple is normal voltage >1.5 mV, green is borderzone >0.5 to <1.5 mV, and grey is dense scar <0.5 mV. Brown LAVA dots are manually tagged and seen inside the anatomical isthmus (white arrow). Successful ablation site is tagged in red. (*D*) Activation map of the clinical incessant VT, showing a figure-of-eight circuit trough the isthmus. Ablation is performed during VT and the first application at the narrow VT exit site stopped the VT.

Table 3 Complications and follow-up

Patient	Complications	VT recurrences	ATP	ICD shocks	LVEF 6 months later (%)	Follow-up (months)
1	0	0	0	0	50	30
2	0	0	0	0	36	32
3	0	0	0	0	33	6
4	200 mL epicardial bleeding	1	0	1	20	15

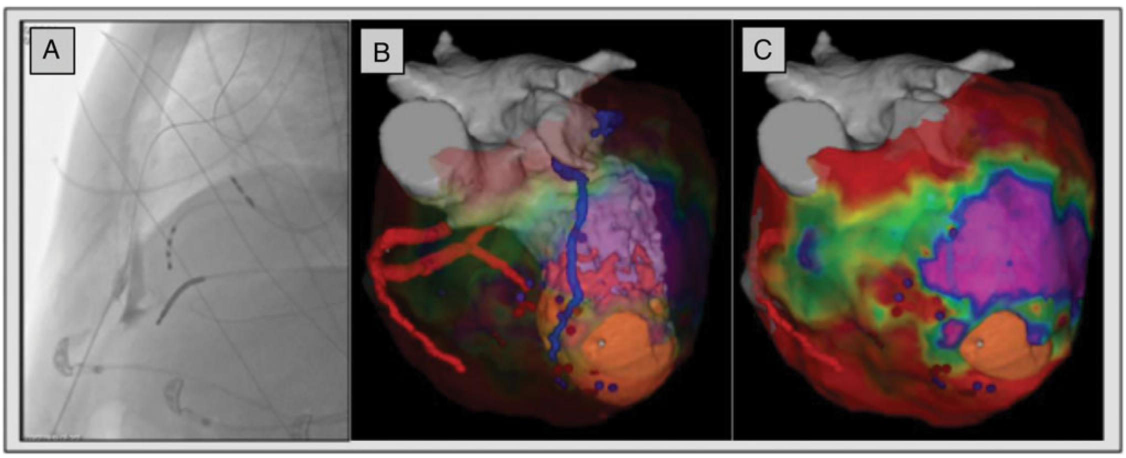

Figure 2 Patient 2 with ischaemic cardiomyopathy and an endocardial thrombus [anteroposterior (AP) view]. (*A*) Percutaneous anterior subxyphoidal epicardial puncture with Tuhoy needle using the left lateral fluoroscopic view. Contrast inside the pericardial space is seen and a guidewire freely moves within the pericardial space. A quadripolar catheter (Bard) inside the RV apex is used as anatomical landmark. Atrial and ventricular leads of intracardiac defibrillator are visible. (*B*) Merged image of transparant epicardial voltage map and three-dimensional mesh (derived from DE-MRI) made using Music® software with coronary artery system in red, coronary venous system in blue, and scar in orange. Local abnormal ventricular activity tagged in purple and ablation points are tagged in red. (*C*) Epicardial bipolar voltage map with merged image and EAM image, using the CARTO®3 system (Biosense Webster). Purple is normal voltage >1.5 mV, green is borderzone >0.5 to <1.5 mV, and red is dense scar or epicardial fat <0.5 mV. A hole is visible at the pericardial adhesions above the apical scar.

Epicardial access was obtained and the voltage map created showed an anterior scar. A coronary angiogram was performed and demonstrated no main coronary artery in the vicinity of the ablation site. A LAVA-based ablation was performed in sinus rhythm, based on substrate mapping, prolonged stimulus to QRS duration and pacemapping, and complete epicardial LAVA elimination was achieved. Therefore, it was decided to end amiodarone therapy after the procedure.

In patient 3, there was a large endocardial thrombus, with calcifications and severe wall thinning predominating at the basal and apical aspects of the myocardial infarction scar. In between these two areas, a relatively preserved wall thickness region suggested the possibility of an epicardial isthmus on the MDCT imaging. After obtaining epicardial access, difficulties were encountered to map in the direct surroundings of basal anterior aneurysm, because of pericardial adhesions. However, LAVAs were recorded in the borderzone of the low-voltage area and clustered in the pre-procedural identified isthmus. An induction protocol was not performed to avoid the risk for thrombus migration during a DC shock and pacemapping with long stimulation-to-QRS time was used to identify interesting sites. No coronary angiogram was performed since the image merge only revealed a small branch in the surroundings of the ablation site. Ablation was performed in sinus rhythm using substrate mapping, pacemapping, and prolonged stimulus to QRS duration. Endpoint reached was incomplete epicardial LAVA elimination but inducibility was not tested, because of the thrombus. Amiodarone and beta-blocker therapy were continued after the procedure.

Patient with dilated cardiomyopathy with complicated epicardial puncture ($n = 1$)

Patient 4 received resynchronization therapy and prior His ablation because of persistent atrial fibrillation in a referral centre. Because of the disease substrate and surface ECG morphology of the VT, an epicardial approach was used from onset. The epicardial puncture was followed by a continuous bleeding finally limited to a total of 200 ml. After completion of the epicardial substrate map, it was decided not to obtain endocardial access, because of the disease substrate on imaging and mapping and to avoid further bleeding possibly associated with the heparin infusion needed for an endocardial

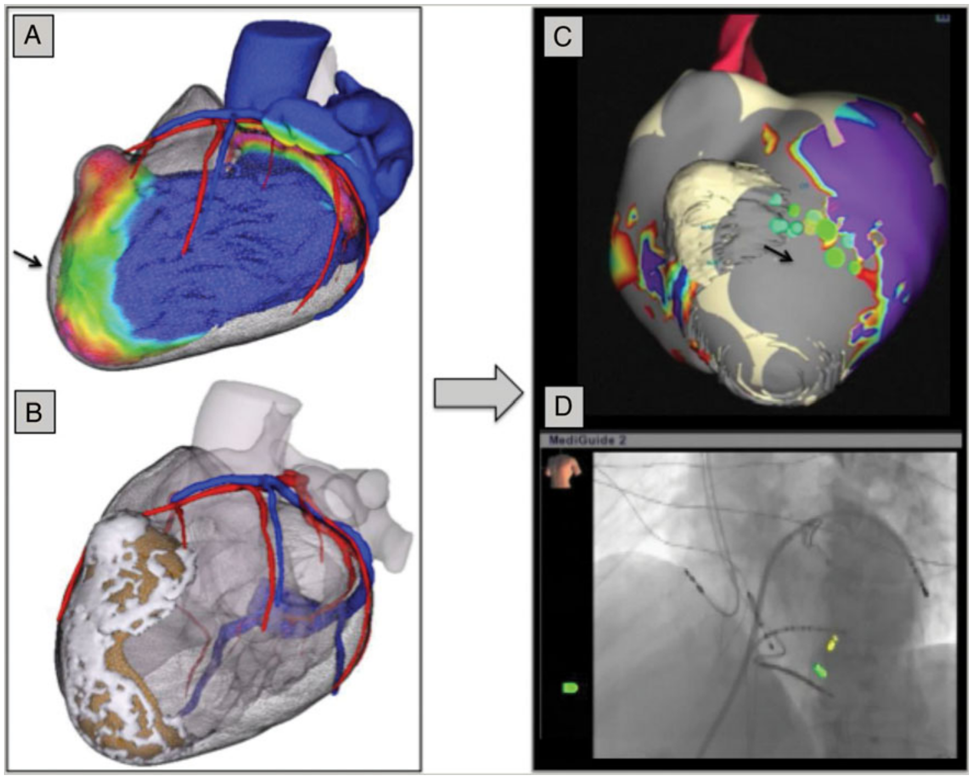

Figure 3 Patient 3 with ischaemic cardiomyopathy and an endocardial thrombus (lateral view). (*A*) Multidetector computed tomography color-coded wall thickness map showing an anterior left ventricular aneurysm with wall thinning (blue is normal thickness and red is <3 mm with intermediate thickness in green). An epicardial isthmus can be seen (black arrow). (*B*) Three-dimensional mesh (derived from MDCT) made using Music® software with coronary artery system in red, coronary venous system in blue, scar with calcification in white, and large mural thrombus in brown. (*C*) Epicardial bipolar voltage map with merged image and EAM image, using the EnSite™ Velocity™ system (St Jude Medical). Purple is normal voltage >1.5 mV, green is borderzone >0.5 to <1.5 mV, and grey is dense scar <0.5 mV. Green LAVA dots are manually tagged and seen besides the aneurysm inside the anatomical isthmus (black arrow). (*D*) Fluoroscopic anteroposterior (AP) image using the MediGuide™ system. Anterior epicardial access, using a steerable sheath (Agilis™, St Jude Medical). Magnetic sensors of MediGuide-compatible catheters (both St Jude Medical) show the tip of the ablation catheter (Saphire™ BLU™) in yellow and a decapolar catheter (LiveWire™) in green. Atrial and ventricular leads of intracardiac defibrillator are visible.

procedure. Epicardial LAVAs were found as well as sites of perfect pacemap matching the clinical VT. The area of interest was not in direct vicinity to a coronary artery or to the left phrenic nerve. The clinical VT was induced and entrainment manoeuvres confirmed the isthmus site. Ablation at that site was performed during VT and stopped the clinical VT. Complete epicardial LAVA elimination was not obtained due to a more intramural LAVA location, but VT was no longer inducible in the end. The pericardial bleeding stopped spontaneously 30 min after the procedure. It was then decided to extract the pigtail catheter after 3 h of monitoring using ultrasound monitoring. The patient did receive standard NSAID therapy during 5 days and did not present any clinical or electrocardiographic signs of pericarditis. No prolongation of his hospital stay was required. Prior anti-arrhythmic treatment (amiodarone and beta-blocker therapy) was continued.

Follow-up

After a mean follow-up of 21 ± 12 months, recurrence of the clinical VT was seen in one patient (25%) and no mortality was observed.

Discussion

This is the first case series reporting on epicardial only mapping and ablation in a limited subset of patients. The main findings of this study were:

(1) An epicardial only VT ablation procedure is feasible.
(2) This purely epicardial approach seems to be associated with acceptable short-term success.
(3) Endpoints are more difficult to verify since LAVA elimination is only evaluated epicardially, and VT inducibility was not performed in the presence of endocardial thrombus.

This approach seems especially useful for the patients referred for VT ablations with an endocardial thrombus, a clear contra-indication for an endocardial approach. We do believe that in this context, this approach compares favourably with surgery which would be associated with a significantly higher risk in these fragile patients. We further presume that this approach can potentially shorten procedure time (compared with a combined procedure) in unstable selected patients since no endocardial access is obtained and no endocardial mapping is used. The complication that occurred is related to the epicardial access and not to the strategy in itself. We expect a similar complication rate of any epicardial procedure but these case series are too small to draw any conclusions about safety.

In patients with secondary wall thinning (ICM and arrhythmogenic right ventricular cardiomyopathy), there is a reasonable chance that epicardial ablation can eliminate endocardial LAVA. We have previously demonstrated that the opposite approach, eliminating epicardial LAVA using endocardial ablation, works if the wall thickness does not exceed 5 mm.[20]

The first patient did undergo prior endocardial mapping. We did not exclude this patient, since myocarditis patients with subepicardial only scar on imaging could in fact benefit from purely epicardial mapping and ablation procedures. We have observed in a previous series that in these patients with preserved LV wall thickness and using the current ablation tools, the likelihood for eliminating epicardial LAVA using endocardial RF delivery was null.[10] This case series illustrates the feasibility. In this subset, an epicardial only approach could be effective, since no LAVAs were found endocardially in all patients.[11]

Limitations

This is a single centre heterogeneous and small cohort retrospective study. The follow-up period is relatively short. A larger population and longer follow-up is needed prospectively to validate this approach.

Conclusion

An epicardial only VT ablation procedure is feasible and demonstrates good outcome at short-term follow-up. This approach should however only be used in experienced centres in a very selective patient population.

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