Radiofrequency catheter ablation of ventricular tachycardia guided by intracardiac echocardiography


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Abstract Aims Ventricular tachycardia (VT) frequently has an anatomical substrate. Identification of areas prone to arrhythmogenicity facilitates radiofrequency catheter ablation (RFCA). Furthermore, direct monitoring of complications potentially increases safety of RFCA. The aim of this study was to evaluate the feasibility of guiding RFCA of VT with intracardiac echocardiography (ICE), in order to improve outcome and procedural safety.

Methods and Results Eleven patients (age 59 ± 15 years) with drug-refractory VT of various etiologies were studied. VT mapping and ablation were performed using standard techniques. ICE was performed with a multifrequency (5–10 MHz) phased-array transducer positioned in the right ventricle. Twenty different VTs were treated (CL 352 ± 120 ms, 2.0 ± 0.9 VT per patient). LV a- or dyskinesia was identified in all post-infarct patients. In patients with arrhythmogenic right ventricular dysplasia, right ventricular aneurysms and dyskinesia could be identified. In all patients catheter position and tip-tissue contact could easily be monitored with ICE. Procedural success (non-inducibility of hemodynamically stable VT) was achieved in all patients. Complications did not occur.

Conclusion ICE is feasible in guiding RFCA of VT of different etiologies. The use of ICE in conjunction with fluoroscopy and mapping procedures will facilitate treatment of VT and may contribute to the safety of the procedure.

Keywords intracardiac echocardiography; ventricular tachycardia; radiofrequency catheter ablation.

Introduction

Intracardiac echocardiography (ICE) has been used to guide radiofrequency catheter ablation (RFCA) procedures. Thus far, ICE was mainly used for...
guiding the treatment of supra-ventricular arrhythmias, while experience with use of ICE in guiding ventricular procedures was only limited.\(^1\)

The majority of ventricular tachycardia (VT) is secondary to ischemic heart disease.\(^2\) Surviving subendocardial cell layers play a key role in the induction and perpetuation of reentry after myocardial infarction. Identification of these areas is mandatory to predict the expected area of arrhythmogenicity in post-infarct patients. These areas can usually easily be recognized by echocardiography, since a- or dyskinesia of the infarcted part of the myocardial wall is frequently present.\(^3\) Also, areas with aneurysm formation give rise to VT, and these areas can also easily be identified by echocardiography.\(^4\) Other causes of VT with an anatomical substrate include arrhythmogenic right ventricular dysplasia (ARVD)\(^5\) or other cardiomyopathies. Focal aneurysms in the free wall of the right ventricle, as frequently present in ARVD, can be identified by echocardiography.\(^6\)

RFCA of VT is the treatment of choice in selected patients with hemodynamically stable VT.\(^7\) RFCA procedures, however, are associated with an increased risk of serious procedure-related complications,\(^7,8\) such as thrombo-embolic events or perforation with subsequent pericardial effusion (tamponade) due to catheter manipulation or—less often—the application of RF-current. The ability to monitor the occurrence of complications directly will potentially have beneficial effects on outcome.

The aim of this study is to assess the feasibility of the use of ICE in guiding RFCA treatment of VT with different etiologies. ICE was used to examine the substrate of ablation for structural abnormalities, to guide catheter positioning, to evaluate catheter tip-tissue contact and to monitor the occurrence of complications.

**Patients and methods**

Eleven patients were included in the study. Trans-thoracic echocardiography, coronary arteriography, biplane left ventriculography and/or myocardial perfusion scintigraphy were performed prior to the ablation procedure to exclude ischemia as the etiology underlying VT.

**Intracardiac echocardiography**

ICE was performed with a 10 Fr Acunav\(^{TM}\) diagnostic ultrasound catheter (Acuson Corp., Mountain View, CA, USA), which was introduced in the left femoral vein and connected to an ultrasound system (Acuson, Sequoia, CA, USA). A 64-element phased-array multifrequency transducer (5–10 MHz) is incorporated in the single use ultrasound catheter. The transducer has full Doppler capability for hemodynamic and functional cardiac evaluation. A mechanism on the handle of the catheter allows rotation in two different planes. Fluoroscopy was used to guide the ultrasound catheter into the right atrium. Imaging of anatomical structures and catheter position was performed with the ultrasound catheter positioned in either the right atrium or right ventricle.

**Mapping and ablation procedure**

Two diagnostic catheters were positioned in the heart via a right transfemoral approach. One catheter was positioned in the right atrium, the other catheter was placed in the right ventricular apex. A mapping/ablation catheter was positioned in the right ventricle via the right femoral vein, or in the left ventricle via a retrograde aortic approach. Mapping was performed using a 48-channel acquisition system (Cardio-lab 4.1, Prucka Engineering, Houston, TX, USA). RFCA was performed with a maximum output of 50 W and a maximum temperature of 70 °C for ablation procedures in the right ventricle (non-cooled). Radiofrequency ablation in the left ventricle was performed with cooled ablation with a maximum output of 45 W and a maximum temperature of 50 °C. Heparin was administered intravenously during the procedure (ACT two to three times normal value).

On initiation of the procedure, ventricular anatomy and function were evaluated with ICE and the presence of intracardiac thrombus was investigated. Mapping was performed first at sites with a- or dyskinesia or with aneurysmatic dilatation, as determined with ICE. Target sites for ablation were sought by identification of areas with fragmented electrograms. Arrhythmia induction was performed with programmed electrical stimulation. During VT, selection of target sites for RFCA was based on localization of early fragmented signals, concealed entrainment and recordings of middiastolic potentials.

**Results**

ICE was used in 11 patients with drug-refractory VT. In one patient, an intracardiac thrombus was detected with ICE. This patient was excluded from RFCA. In the other 10 patients, ICE was used to guide the RFCA procedures. Patient characteristics are summarized in Table 1.
The underlying cause of VT was coronary artery disease with a previous myocardial infarction in five patients (including one patient with left ventricular thrombus), ARVD in two patients and hypertrophic obstructive cardiomyopathy (HOCM) in one patient. VT was idiopathic (right ventricular outflow tract origin) in three patients.

ICE was used to identify a- or dyskinetic regions in the patients with coronary artery disease and previous myocardial infarction. In all cases, ICE identified a- or dyskinetic regions in the infarcted zones. VT could be induced in these areas and was subsequently treated by RFCA.

In the patients with ARVD, regions with focal aneurysms were identified. Intravenous contrast (Levovist, Schering SA, Berlin, Germany) was injected to improve delineation of the endocardial borders to facilitate detection of focal aneurysms. Electrophysiological testing confirmed inducibility of VT in these regions and RFCA was performed.

In the patients with HOCM and idiopathic VT, ICE was used to confirm adequate catheter tip-tissue contact during RFCA. Thrombus formation during RFCA was excluded. Procedural success, defined as non-inducibility of hemodynamically stable VT after RFCA, was achieved in all patients. Pericardial effusion post-ablation was excluded in all patients, except for the patient with HOCM who had already minimal pericardial effusion prior to the procedure. Procedure-related complications did not occur.

Three representative case examples are reported in detail in the next paragraphs.

**Case example 1**

A 77-year-old man was referred for evaluation/treatment of VT. He had a history of inferior myocardial infarction, and underwent coronary artery bypass grafting (CABG) in 1997. In 1999, the patient was admitted with VT based on ischemia (evidenced by Table 1).
by myocardial perfusion scintigraphy and subsequent coronary angiography), followed by re-CABG. Following uneventful recovery, the patient was re-admitted with chest pain and palpitations (no collapse). ECG monitoring during hospitalization showed sustained VT. Pharmacological anti-arrhythmic therapy (Amiodarone) resulted in conversion to sinus rhythm. Despite medical therapy, recurrences of non-sustained, monomorphic VT were observed frequently. Myocardial perfusion scintigraphy excluded ischemia, and coronary angiography confirmed pgraft patency. Accordingly, electrophysiological testing with RFCA therapy was planned. On initiation of the procedure, the patient was in sinus rhythm. Prior to arrhythmia induction, cardiac anatomy (in particular left ventricular morphology) was evaluated with ICE. ICE was able to obtain high quality images of the left ventricle and mitral valve (Fig. 2, left panel). Global left ventricular function was moderately reduced, with akinesia of the inferior wall (compatible with previous inferior infarction). In addition, a circumscript region of the posterolateral wall was aneurysmatic showing dyskinesia (Fig. 2, right panel). No thrombus could be detected. Mapping of the posterolateral/inferior wall showed fragmented signals.

Two slow VTs could be induced, originating from the aneurysm of the posterolateral wall. RFCA was performed. ICE was used to confirm catheter position in the left ventricle and aneurysm and to monitor the occurrence of complications. After ablation, no slow VT could be induced. However, programmed electrical stimulation induced a fast VT (CL 270 ms), with hemodynamic instability. The patient was electrically cardioverted to sinus rhythm, and an implantable cardioverter defibrillator (ICD) was implanted. The procedure time was 235 min and fluoroscopy time was 38 min. ICE excluded pericardial effusion at the end of the procedure.

Case example 2

A 49-year-old man was admitted for recurrent VT. Cardiac catheterization revealed normal coronary arteries with preserved left ventricular ejection fraction (60%). Transthoracic echocardiography demonstrated an enlarged right ventricle with pronounced trabecularization. Magnetic resonance imaging showed high signal intensity of the right ventricular myocardial wall, suspicious for ARVD. Twenty-four hour Holter monitoring revealed multiple episodes of non-sustained VT. Anti-arrhythmic medication was not successful. Because of persistent VT (without collapse), the patient was scheduled for RFCA. Cardiac function and anatomy were evaluated with ICE. Visualization of the right ventricle was directed predominantly at the right ventricular apex, the outflow tract and the infundibulum (the so-called triangle of dysplasia) (Fig. 3, left panel). Intravenous contrast (Leovist, Schering SA, Berlin, Germany) was administered to achieve more detailed visualization of the right ventricular myocardial wall. However, no abnormalities were observed in these regions. In the inferior wall, however, a dyskinetic region was detected (Fig. 3, right panel).

Arrhythmia induction was performed and a monomorphic VT (CL 420 ms) could be induced. Fig. 4 shows the surface ECG of this patient in sinus rhythm and during VT. Mapping of the right ventricle showed earliest activation and fragmented signals in the dyskinetic part of the inferior wall. RFCA was performed at this site. ICE was used to

![Figure 2](https://academic.oup.com/ehjcimaging/article-abstract/5/1/34/2397615/15)
monitor the position of the ablation catheter and to confirm catheter tip-tissue contact. After RFCA, aggressive stimulation was not able to re-induce the VT. Procedure time was 275 min and fluoroscopy time 34 min; no complications occurred.

Case example 3

A 52-year-old man was diagnosed with HOCM in 1984. Medical therapy (beta-blockers, calcium antagonists) adequately suppressed the gradient in the left ventricular outflow tract. The patient received an ICD for recurrent VT; in addition Amiodarone was added to prevent VT with frequent ICD discharges. Until recently, the patient was asymptomatic and VT was adequately suppressed. Recently, however, Amiodarone-associated hyperthyroidism was discovered and thyreostatic therapy (Strumazol) was initiated. Termination of Amiodarone resulted in frequent ICD discharges (for VT) again. Accordingly, the patient was scheduled for RFCA. High resolution imaging of the marked septal hypertrophy could be achieved with ICE. The thickness of the interventricular septum, as measured with ICE, was 3.2 cm. Minimal pericardial effusion was noticed near the posterolateral wall before initiation of the ablation procedure (Fig. 5). Two different morphologies were inducible. Mapping showed early fragmented signals in the basal septal regions of the right and left ventricles. RFCA was performed at these sites, and catheter positions and tissue contact were monitored with ICE. Both morphologies terminated during RFCA. Following RFCA, VT was no longer inducible. Procedure time was 245 min and fluoroscopy time 27 min. There was no increase in pericardial effusion after the procedure.

Discussion

The use of ICE in guiding the treatment of supra-VTs with RFCA has been described. The

Figure 3  Left panel: right ventricular outflow tract (RVOT). Long axis views of the aortic root (AO) and pulmonary artery (AP) can be observed. Right panel: imaging of the right ventricular inferior wall revealed a circumscribed area of dyskinesia. RV, right ventricle.

Figure 4  Twelve lead body surface ECG during sinus rhythm (left panel) of the patient admitted with VT under suspicion of ARVD and the body surface ECG (right panel) after induction of sustained monomorphic VT (CL 420 ms) with right bundle branch morphology, left axis deviation and negative QRS in the inferior leads.
availability of low-frequency ultrasound transducers has made accurate imaging of both left and right atrial anatomical structures possible with an ultrasound catheter positioned in the right atrium. Transseptal puncture has been successfully performed guided by ICE.12

In the current report we reported on our experience with ICE in guiding RFCA of VT with different cardiac substrates. Morphologically altered myocardium (scar tissue following infarction, focal aneurysms in ARVD) is prone to formation of reentry circuits. To localize these regions (in order to apply RFCA therapy) fluoroscopy is not sufficient and there is need for additional visualization of intracardiac anatomy. In particular, identification of the a- and dyskinetic regions that give rise to VT is difficult. As mentioned, ICE using low-frequency transducers has made accurate visualization of right and left cardiac structures possible.13 As indicated in the current study, adequate visualization of the a- and dyskinetic regions was feasible, enabling guidance of catheter positioning and identifying potential target areas for RFCA therapy. Exact visualization of aneurysms was possible both in the left and right ventricles. The use of intravenous contrast was useful to facilitate visualization of the substrate in patients in whom ventricular aneurysms can be expected, such as patients suspected of ARVD or post-infarct patients.

Exact localization of catheters using fluoroscopy is difficult and time-consuming, in particular when small localized aneurysms as observed in ARVD, are the targets of ablation. Besides guiding catheter positioning, the use of ICE will allow substantial reduction of fluoroscopy time and radiation for both patients and physicians.

Moreover, monitoring of catheter tip-tissue contact was feasible and direct assessment of potential complications was illustrated. In particular, visualization of thrombus formation during the RFCA procedures as has been reported previously14 can be monitored and pericardial effusion (as a result of perforation, particularly in patients with thinned scar tissue) can be evaluated continuously during the procedures.

In conclusion, ICE may provide a useful technique to facilitate RFCA procedures of patients presenting with VT of different etiologies. Moreover, the use of ICE in conjunction with fluoroscopy and mapping procedures will optimize treatment of VT and contribute to the safety of the procedure by monitoring the occurrence of acute complications.

References


