Novel Shock Configuration for Low-energy Transvenous Ventricular Defibrillation - A Case Report

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Summary

A novel shock configuration was tested intraoperatively in a 72-year-old male patient with a left-ventricular (LV) enddiastolic diameter of 8 cm, an LV aneurysm, and an LV ejection fraction of 30%. He had been resuscitated from sudden cardiac death, and his overall condition was assessed as NYHA class IV. The patient had two previous myocardial infarctions at the anterior and posterior LV and a three-vessel disease with occlusion of the left anterior descending artery, a 75% stenosis of the ramus circumflexus and two additional stenoses of 60 and 75%, respectively, at the right coronary artery. During electrophysiologic testing, three ventricular tachycardic rates of 220, 190, and 160 bpm could be induced, as well as an ectopic supraventricular tachycardia. The patient was admitted for ICD implantation. He had a first-degree AV block and a left bundle branch block. The new shock configuration uses three shock coils in the right ventricle (RV), the superior vena cava (SVC), and the coronary sinus (CS), respectively, in combination with an active ICD housing and a triphasic shock. Phase one with a maximum energy of 7 J is delivered between CS and RV; phases two and three are applied between the RV and SVC electrodes. Defibrillation energies of the triphasic configuration and a standard biphasic shock (RV vs. SVC and active housing) were compared. Using the triphasic configuration, total energies of 20 J, 10 J, 6 J and 5 J were successful. No attempt was made at energies below 5 J. Using the standard biphasic configuration, the first shock-delivered with 5 J was not successful. Sinus rhythm was restored with a second shock at 20 J. In the following, a polymorphic VT was induced and restored successfully with 10 and 8 J. This case report indicates that it may be feasible to further reduce the defibrillation energy of transvenous lead systems by using a CS shock coil for improving the energy transfer to the left ventricle. In our patient, no peri-operative complications due to the use of a CS shock coil were observed.

Key Words

Ventricular defibrillation, implantable cardioverter-defibrillator, defibrillation threshold, shock path

Introduction

Although the implantable cardioverter-defibrillator (ICD) has been highly effective in preventing sudden cardiac death since its inception [1-3], research has dedicated much effort to increasing the efficiency of ICD therapy in the past two decades. The two major goals were to reduce shock energy without losing defibrillation effectiveness [4] and increase detection specificity without losing sensitivity [5-7]. It is generally accepted that successful defibrillation requires the establishment of a minimum potential gradient across the entire fibrillating myocardium [8]. Although this rule would be optimally fulfilled by the application of epicardial patch electrodes, the use of a transvenous lead system is favored due to the lower peri-operative risk. The development has advanced from the right ventricle (RV) versus superior vena cava (SVC) shock path to the RV versus active device housing configuration [4]. As to be expected from the minimum potential gradient theory, the latter shock path facilitates defibrillation of the left ventricle due to the slightly improved field geometry. Yet, theory implies that the energy requirements may be reduced even further if the field penetration of the left ventricle is enhanced more. This may be achieved by using an additional shock coil in the coronary sinus (CS).

The first implantation of a lead in the coronary sinus was described by Moss and co-workers as early as 1970 [9]. New applications, such as multisite pacing or atrial defibrillation, have brought a renaissance to this site [6][10-12], which had been neglected because the right atrium was more easily accessible for atrial pacing. The experiences with the implantable atrial defibrillator and with catheter-based atrial defibrillation show that the use of a CS shock coil is safe and reduces the defibrillation threshold significantly when compared with right atrial configurations [6][12]. Consequently, it is expected that this method may also help to improve the efficiency of ventricular defibrillation. The following case report describes the first clinical investigation of a novel shock configuration that uses a CS shock coil for ventricular defibrillation.

Materials and Methods

The investigated configuration uses a triphasic shock applied between three shock coils as follows: Phase 1 is delivered between a RV electrode and a CS electrode (cf. Figure 1). During the investigation, the energy of this first phase was limited to a conservative maximum value of 7 J to avoid possible damage of the vessel through the shock release. Phases 2 and 3 were formed by a standard biphasic shock applied between a RV shock coil, a SVC shock coil and the ICD housing. The polarities of the electrodes used in the various phases are identified in Table 1. In order to set the energies of phase 1 and phases 2 and 3 separately for time-controlled shock delivery, the respective durations were calculated after having performed an impedance measurement. Figure 2 shows a typical shock waveform.

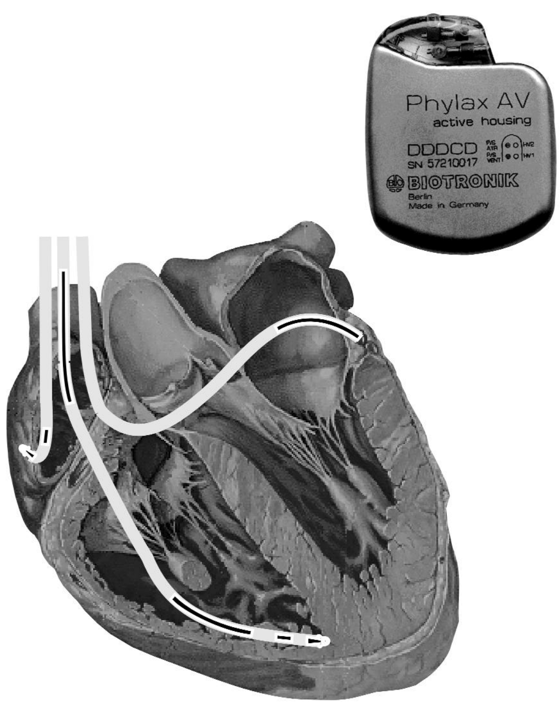

Figure 1. Schematic drawing of the investigated lead configuration.

The new shock configuration was investigated intraoperatively during ICD implantation in a 72-year-old male patient with a documented history of three sudden cardiac death episodes. Electrophysiologic testing revealed a first-degree AV block; a left bundle branch block; three separate ventricular tachycardias at rates of 220, 190, and 160 bpm; and an ectopic supraventricular tachycardia. The patient, therefore, was on a 200 mg per day Amiodarone therapy, which had not been effective. His overall condition was assessed as New York Heart Association class IV. The patient had two ten-year-old myocardial infarctions at the anterior and posterior left ventricle, as well as a three-vessel disease with an occlusion of the left anterior descending artery, a 75% stenosis of the ramus circumflexes, and two stenoses of the right coronary artery of 60 and 75%, respectively.

A KAINOX SL 75/16 lead (BIOTRONIK, Germany) with two shock coils in the right ventricle and superior vena cava was used in the investigation. The surface areas and length of the coils were 3.2 cm^2 / 40 mm and 6 cm^2 / 70 mm, respectively. In the coronary sinus, a custom-designed shock coil with a surface area of 3.2 cm^2 and a length of 50 mm was used. For control of the shock delivery, a special external slave shock box had been developed that was applied in combination with a PHYLAX AV (BIOTRONIK, Germany) ICD for dual-chamber sensing / pacing and shock triggering.

Results

For safety reasons, a function test was performed first using the standard biphasic wave form. Ventricular fibrillation with an approximate cycle length of 250 to 272 ms was induced by means of a T wave-synchronized shock. Applying 22 J between the RV and SVC shock coils and the active housing of the device immediately restored sinus rhythm. Then ventricular fibrilla-

	Coronary sinus (CS)	Right ventricle (RV)	Superior vena cava (SVC)	ICD housing
Phase 1	positive	negative	---	—
Phase 2	—	negative	positive	positive
Phase 3	—	positive	negativ	negative

Table 1. Polarities of the shock coils used in the three shock phases.

tion was initiated with 50 Hz burst pacing, and the triphasic configuration was used with a step-down testing protocol. The energy settings and the respective resulting rhythms are summarized in Table 2. Sinus rhythm was successfully restored with all triphasic shocks down to a minimum value of 5 J. The respective IEGM of this 5 J shock is shown in Figure 3. The step-down protocol was then aborted in order to limit the risk that is known to be associated with repeated induction of ventricular fibrillation. The 5 J shock was attempted with the standard biphasic configuration, but fibrillation could not be terminated. The resulting ventricular tachycardia, which intermittently degenerated into ventricular fibrillation, was finally successfully terminated with a 20 J shock. Subsequently, it was not possible to induce fibrillation but only polymorphic ventricular tachycardias. Sinus rhythm was restored using the biphasic configuration with energies of 10 and 8 J.

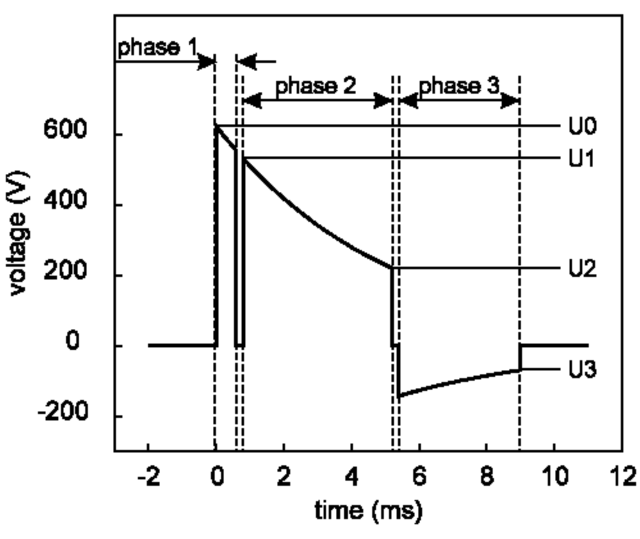

Figure 2. Example of the shock waveform. The energy for phase 1 is set to 5 J, and the energy of phases 2 and 3 is set to 15 J. Phase 1 is applied between the CS shock coil and the RV shock coil, whereas phases 2 and 3 are applied between RV and SVC shock coils.

Discussion

This case report indicates that it may be feasible to further reduce the defibrillation energy of transvenous lead systems by using a CS shock coil. This is attributed to the more favorable field geometry the investigated triphasic configuration (as compared with biphasic standard configurations) provides for defibrillation of the left ventricle. Note, that in our patient, no perioperative complications due to the use of a CS shock coil were observed, which confirms experiences obtained with the implantable atrial defibrillator on a chronic basis. The author is well aware that the presented results have to be interpreted qualitatively rather than quantitatively, because the defibrillation threshold test protocol has not been completed in either configuration. Therefore, the new method will be explored systematically in order to obtain quantitative results. These investigations are also needed as a basis for the discussion whether the advantage of reduced energy consumption compensates for the efforts and risks associated with the implantation of an additional lead in the coronary sinus. This question, however, is also put up for discussion by other new techniques, like biatrial or biventricular pacing. Considering the positive overall experiences in these fields, it is expected that success or failure of the novel configuration will

Induction method	Arrhythmia induced	Shock type	Energy (J)				Resulting rhythm
			total	phase 1	phase 2	phase 3	
shock on T	**VF** (250272 ms)	biphasic	22	---	19.1	2.5	sinus
50-Hz burst	**VF** (226258 ms)	triphasic	20	4.4	13.0	2.0	sinus
50-Hz burst	**VF** (228304 ms)	triphasic	10	2.2	6.5	1.0	sinus
50-Hz burst	**VF** (226398 ms)	triphasic	6	1.3	3.9	0.6	sinus *
50-Hz burst	**VF** (210258 ms)	triphasic	5	1.1	3.3	0.5	sinus
50-Hz burst	**VF** (218304 ms)	biphasic	5	---	4.4	0.6	VT

*Table 2. Results from intraoperative defibrillation using tri- and biphasic shock configurations. *) The 6 J dual pathway triphasic shock led to a Type II termination with 2 short RR intervals prior to a return to sinus rhythm. All other successful shocks exhibited Type I immediate termination.*

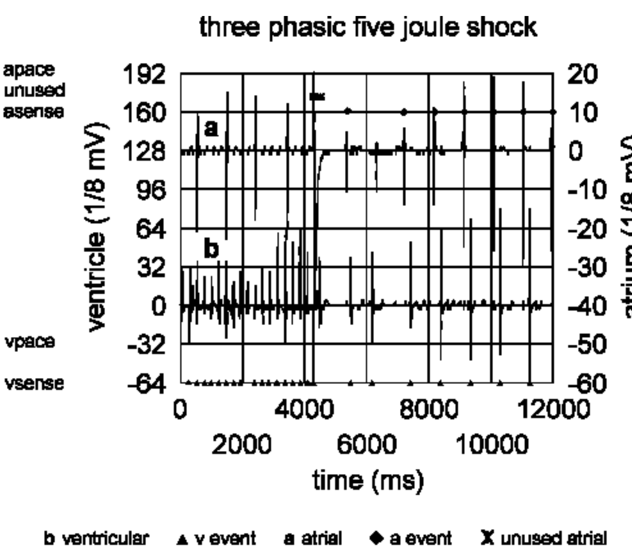

Figure 3. Atrial and ventricular signals during defibrillation with the triphasic configuration. Ventricular fibrillation is terminated with a 5 J shock.

be determined predominantly by its efficiency: A further reduction in the size of the implantable cardioverter-defibrillator is still highly desirable.

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