Implantable cardioverter-defibrillators in patients with hypertrophic cardiomyopathy – dilemmas and difficulties

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Abstract

Introduction: The implantation of a cardioverter-defibrillator (ICD) is an established method of sudden cardiac death (SCD) prevention. The value of ICD therapy in secondary prevention of SCD is unquestionable. Precise identification of high-risk patients and ICD use for primary prevention of SCD, especially in patients with hypertrophic cardiomyopathy (HCM), remain controversial. Problems include the high prevalence of complications associated with ICD implantation and optimal selection of ICDs.

Aim: To estimate the frequency and type of complications after ICD implantations in HCM patients in a long-term follow-up.

Method: The efficacy and safety of ICD therapy were estimated in 46 HCM patients with devices implanted for a secondary (n-18) or primary prevention (n-28) of SCD.

Results: During the mean follow-up period of 28.2±26.1 months (from 2 to 68) appropriate ICD interventions occurred in 10 (55%) patients of the secondary prevention group and in 3 (10%) patients of the primary prevention group. Complications were documented in 15 (33%) patients. The most frequent were inappropriate ICD interventions recorded in 14 (30%) patients. The causes of these inappropriate ICD shocks were: T-wave oversensing (7 patients), atrial fibrillation with rapid ventricular rhythm (3 patients), lead failure (2 patients), and sinus tachycardia (2 patients). In two patients infections of the ICD pocket requiring removal of the system occurred. Displacement of the lead occurred in one patient. There were no significant differences in the prevalence of complications between the primary and secondary prevention groups or in the number of inappropriate interventions with respect to ICD type.

Conclusions: The high rate of appropriate ICD shocks provides proof of high ICD-based SCD prevention efficacy. There is a high rate of complications observed after ICD implantation with inappropriate interventions being the most frequent among them. This indicates that careful programming of the device as well as the use of a programme with T-wave oversensing prevention should be ensured.

Key words: implantable cardioverter-defibrillator, hypertrophic cardiomyopathy

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Introduction

Since the first implantation of a cardioverter-defibrillator (ICD) in man almost 25 years ago, this method has become the treatment of choice for prevention of sudden cardiac death (SCD) [1-3]. Technological development has been accompanied by an increase in the number of indications for ICD implantation. The use of ICD in secondary prevention of SCD is unquestionable, whereas precise identification of high-risk patients and ICD use for primary prevention are still controversial. In HCM patients the problem is particularly difficult for the following reasons:

1. The stratification of the SCD risk is not precisely defined and it is difficult to estimate the significance of a given clinical risk factor in an individual patient.

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2. The prognostic value of particular factors is low, especially when they are assessed individually.
3. HCM patients are young people, exposed to complications during long-term observation [4, 5].

The benefits of ICD implantation in primary and secondary prevention of SCD in HCM patients has been retrospectively documented in only a few studies [6, 7]. Maron et al. revealed that appropriate device interventions occurred at a rate of 11% per year for secondary prevention and at 5% per year for primary prevention [6]. A similar rate of appropriate device interventions was shown in another study [7]. It should be noted that this therapy is associated with a higher rate of complications compared with other groups of patients.

There are outstanding reports comparing single chamber ICD (VVI-ICD) with dual chamber ICD (DDD-ICD) [8, 9]. Theoretically, DDD-ICD, by providing additional information about the atrial rhythm, should reduce the rate of inappropriate shocks. However, the implantation procedure itself, the number of complications associated with the presence of two leads, and more frequent replacements due to limited durability of the battery are indicative of the superiority of VVI-ICD. The results of the prospective study [8] did not confirm the reduction of the number of inappropriate interventions in DDD-ICD patients.

The aim of the study was to estimate the frequency and type of complications after ICD implantations in HCM patients in long-term follow-up.

Methods

Patients

Forty-six HCM patients from the Institute of Cardiology in Warsaw, who underwent ICD implantation between 1996 and 2003, were enrolled into the study. The diagnosis of HCM was established based on clinical, electrocardiographic and echocardiographic criteria included in the ACC/ESC Expert consensus document [4]. Characteristics of the patients are shown in Table I.

In 18 (39%) patients ICDs were implanted for secondary prevention of SCD; 13 of them had ventricular fibrillation (VF), and two sustained ventricular tachycardia (sVT). The remaining three patients had both types of arrhythmia. Eight patients received amiodarone as a treatment for these arrhythmias.

In the remaining 28 (61%) patients prophylactic ICD implantation was performed. The indications for prophylactic ICD implantation included the presence of at least two of the following risk factors: non-sustained VT (nsVT) documented with routine ambulatory 24-hour ECG monitoring (Holter), left ventricular hypertrophy (LVH) with maximum wall thickness of 30 mm or more, family history of SCD or abnormal blood pressure response during exercise (Table I) [4, 9-11].

Single risk factors were present in three patients of the secondary prevention group and in none of the primary prevention group; two risk factors were observed in 7 and 14 patients and three risk factors in 8 and 14 patients, respectively.

Before the ICD implantation, in all patients family history was taken and ambulatory 24-hour ECG monitoring as well as echocardiography were performed. Thirty-three (72%) patients underwent the treadmill test by modified Bruce protocol. It should be stressed that in a subgroup of patients without classic (especially according to older guidelines) indications for ICD, episodes of VT/VF occurred during the follow-up. The following definitions were used:

- positive two-dimensional echocardiography result: wall thickness >15 mm, after exclusion of other causes of LVH;
- positive family history: HCM-related SCD of at least one first degree relative, aged <40 years [4];
- abnormal blood pressure (BP) response during exercise: BP increase of <20 mmHg or fall of >20 mmHg during the exercise test [4, 9];
- non-sustained VT: 3 beats or more and of at least 120 beats/min [11].

Implantation and programming of ICD

ICD systems used endocavitary leads and were implanted in the subclavian area under the pectoral muscle. Devices were equipped with the function of antibradycardia pacing, antitachycardia overdrive pacing (ATP), cardioversion with programmed energy and internal memory to store intracardiac electrograms during interventions. In 31 (67%) patients single-chamber systems were implanted. Except for the two youngest, except for the two youngest patients, all devices were programmed to both VF and VT detection and treatment zones.

Follow-up

Outpatient visits took place at three- or six-month intervals, whereas the ICD control took place one month after implantation, then at three-month intervals or when requested by patients (i.e./e.g. after shock delivery). Appropriateness of interventions was assessed based on device memory recorded electrocardiograms with clinical symptoms also taken into account.

Statistical analysis

Statistical analysis was carried out with the SAS 8e program using Fisher's exact test for comparing proportions and the unpaired Student's test for

continuous variables. A p value <0.05 was considered statistically significant.

Results

The mean follow-up period was 28.2±26.1 months (from 2 to 68). There was no significant difference between the primary and secondary prevention groups in demographic or clinical characteristics. One patient died (secondary prevention group) due to complications after heart transplantation. Another one (primary prevention group) underwent heart transplantation due to the worsening of heart failure (15 months after ICD implantation). Both of them had malignant tachyarrhythmias that were terminated with appropriate ICD shocks. In seven patients ICDs were replaced due to battery failure (4 cases) or damage of the device (3 cases).

Appropriate ICD interventions

Twenty-five correctly detected and terminated VT/VF occurred in 13 (28.7%) patients. Ten persons with appropriate ICD shocks (from 1 to 5) were among 18 patients who received ICD for secondary prevention (55 %). All the arrhythmias were detected in the VF zone and treated with defibrillation shocks. In three (10%) patients with prophylactic ICD implantation five episodes of malignant ventricular tachyarrhythmias occurred: VF was terminated with shocks in two persons and three episodes of VT were treated with antitachycardia pacing in the third one. Both, appropriate and inappropriate ICD interventions occurred in two persons.

Complications

ICD-related complications were observed in 15 (33%) patients (Table II). In two of them more than one complication occurred (inappropriate interventions and infection of the ICD pocket).

The rate of complications tended to be higher in the secondary prevention group (44% vs 25%), but the difference did not reach statistical significance (p=0.2).

The most frequent complications were inappropriate ICD interventions, recorded in 14 (30%) patients; in this group 129 unnecessary shocks were delivered (from 1 to 53 in individual cases). Only three inappropriate interventions in two patients were detected in the VT zone (sinus tachycardia, Figure 1); the remaining interventions were detected as a VF.

The type of ICD (VVI-ICD or DDD-ICD) did not influence the incidence of inappropriate interventions or their number in individual patients (in group VVI-ICD 9.6±5.1 versus in group DDD-ICD 14.7±12.7, NS).

Solutions in the case of inappropriate ICD interventions were the following:

Table I. Characteristics of HCM patients with implanted ICD

Male gender – number [%]	19 (41%)
Age at the time of implantation (years)	32 (±15.6)
≤20	15 (33%)
≤40	30 (66%)
-age range	6-71
Symptoms	
VT/VF	18 (39%)
Syncope	29 (63%)
Family history	23 (50%)
Echocardiographic findings	
LV wall thickness (mm)	22.2±6.7
≥30 mm	8 (17%)
LV posterior wall thickness (mm)	12.2 (±3.2)
LV outflow tract peak gradient (mm Hg)	14.7±32.5
≥30 mm Hg	8 (17%)
<30 mm Hg	16 (35%)
Holter monitoring	
nsVT	25 (54%)
chronic AF	5 (10%)
Paroxysmal AF or SVT	22 (48%)
Inappropriate blood pressure response (n-33)	23 (69.7%)

Abbreviations:
AF – atrial fibrillation
LV – left ventricle
HCM – hypertrophic cardiomyopathy
ICD – implantable cardioverter-defibrillator
nsVT – non-sustained ventricular tachycardia
SVT – supraventricular tachycardia
VF – ventricular fibrillation
VT – ventricular tachycardia

1. T-wave oversensing: in all patients the problem was solved by changing the ICD sensitivity. In Biotronik devices the option *Enhanced T-wave suppression* was switched on. In the case of St Jude Medical devices the parameters of automatic sensitivity control *Decay delay* and *Threshold start* were changed. The change of programming in all cases solved the problem.
2. Atrial fibrillation (AF) with rapid ventricular response: all inappropriate interventions were detected in the VF zone. The management was to change the limits of the VF detection zone to enable use of the rhythm stability criterion. The alternative solution was to modify pharmacotherapy in order to induce atrioventricular conduction block or to prevent AF. Also in these cases we managed to eliminate inappropriate interventions.

Table II. Complications associated with ICD implantation

Total number of patients with complications	15 (33%)	
Inappropriate interventions*		
Number of patients [%]	14 (30%)	
Number of interventions	129 (from 1-53 in 1 patient)	
Reasons for inappropriate interventions		
T-wave oversensing	7 patients (15%)	62 interventions
Atrial fibrillation	2 patients (6.5%)	41 interventions
Lead dysfunction	3 patients (6.5%)	23 interventions
Sinus tachycardia	2 patients	3 interventions
-Infection of ICD pocket	2 patients (4%)	
-Lead displacement	1 patient	

**In both patients with an infection of the ICD pocket inappropriate ICD shocks occurred*

3. Sinus tachycardia: incorrect detections were all captured in the VT zone, so it was possible to reprogramme the sudden onset criterion (Sudden Onset) and increase the dose of β-blockers.
4. Dysfunction of leads: damaged leads were removed and replaced with new ones.

Procedures in the case of other complications

Lead displacement in the early postoperative period was an indication for lead replacement. In one case of infection of the ICD pocket in the early postoperative period, the whole system was removed.

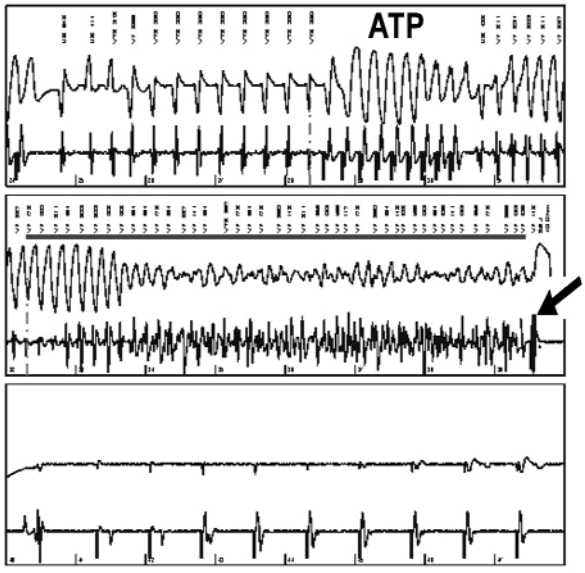

Figure 1. Inappropriate ICD intervention. Antitachycardia pacing during sinus rhythm leads to ventricular fibrillation which in turn is terminated by cardioversion (arrow)

After antimicrobial therapy guided by cultures and complete healing of the wound, the new ICD was implanted on the opposite side. Infection of the ICD pocket also occurred in a 19-year-old woman from the secondary prevention group five years after initial implantation and two years after reimplantation. The device was removed without the intravascular part of the lead, and after complete healing of the wound a new ICD was implanted on the opposite side.

Discussion

There are only two [6, 7] reports on ICD therapy in HCM patients with a relatively high number of patients included in the analysis (128 and 132, respectively). These retrospective studies investigated mainly the effect of ICD on mortality in such patients. Our study was designed to analyse the incidence of complications in such patients; it is an extremely important field of investigation because currently primary prevention indications for ICD implantation predominate, and patients are young and are expected to live long lives.

It was not the purpose of the authors to estimate the risk of SCD or to establish the indications for ICD implantation in HCM patients. However, one must realise that of three patients after cardiac arrest in the secondary prevention group, only one invasive risk factor was found. Thus, using a conservative strategy, i.e. the presence of at least two risk factors as an indication for implantation of ICD in the primary prevention of SCD, none of these three patients would comply with these criteria. A similar case was described by Maron et al. [12].

On the other hand, it should be emphasised that a positive prognostic value of a single risk factor is low, and thus the decision for ICD implantation might result in device implantation in many patients with an apparently low risk of SCD [4, 5]. The modified electrophysiological

testing proposed by Saumerez et al. is very promising; its positive prognostic value is 0.3 [13]. The limitation of the method is that it is invasive in nature.

In all studies on ICD in HCM patients a high incidence of complications is noticeable. In the study with the greatest number of patients [7] the rate of complications was 30%, which is comparable with the results of our study. It is particularly important as the role of ICDs in SCD prevention is constantly growing. The number of complications results in part from the young age of the patients and their activity (lead dysfunction, sinus tachycardia or T-wave oversensing). The most common complications are inappropriate ICD shocks, with the leading role of T-wave oversensing and atrial fibrillation with rapid ventricular rate. T-wave oversensing in all cases caused inappropriate interventions in the VF detection zone.

In the VT detection zone the use of additional differential criteria prevent inappropriate ICD interventions caused by T-wave oversensing. The critical criterion is the assessment of rhythm stability (the RT interval usually is not equal to the TR interval in the electrocardiogram). It must be emphasised that the presence of relatively rapid sinus tachycardia is required to be falsely interpreted as VF. In the case of T-wave oversensing, it is recommended to adjust ICD sensing characteristics without changing the maximum sensitivity value; otherwise there is a risk of losing VF detection. It is very important to remember that reprogramming of sensing parameters must be very careful.

Atrial fibrillation with rapid ventricular rate requires not only changes of pharmacotherapy to slow down the atrioventricular conduction but also reprogramming of the ICD. In some HCM patients AF can lead to VF [4, 5]. Programming of a fast VT detection zone with cardioversion as an initial therapy is a safe method of treatment. With this approach it is possible to use the stability criterion without delaying the therapy. Incorrect detections of sinus tachycardia were not a significant problem in our group, which suggests that the sudden onset criterion may has been effective. As evidenced by our results we concluded that the type of ICD did not influence the rate of inappropriate interventions. These findings are consistent with the results of a randomised controlled study [8].

Infectious complications are particularly dangerous for patients with an implanted ICD. In the analysed group, the two cases of infectious complications were restricted only to the ICD pocket. The case of suppuration of the wound five years after initial implantation and two years after reimplantation of the device seems to be particularly interesting. There were neither clinical symptoms nor specific findings in additional tests, including transoesophageal echocardiography, to support the diagnosis of infectious endocarditis. Thus, no attempt was made to remove the old lead.

Extreme LVH may cause a high defibrillation threshold [14], and consequently inability to provide effective ICD therapy (in theory, even termination of VF induced during the procedure may be impossible). A case of high defibrillation threshold preventing us from ICD implantation took place in our Department after the database for this study had been closed. It was a woman with extreme LVH and indications for prophylactic ICD implantation. The patient underwent second procedure with the implantation of the ICD providing the highest currently available energy of cardioversion (ATLAS DR SJM).

Limitations of the study

The retrospective character of the study is the most important limitation. Because of the limited number of patients, any general statements cannot be valid. Still, it has to be emphasised that there are only two reports in world medical literature devoted to ICD therapy in HCM patients involving a greater numbers of patients. Another limitation is the fact that classification of ICD intervention was based on device memory recorded electrocardiograms. These are known to be difficult to interpret unanimously.

Conclusions

1. A high rate of appropriate ICD shocks is proof of high efficacy of ICD therapy in the primary and secondary prevention of SCD in HCM patients.
2. A high rate of complications is observed after ICD implantation with inappropriate interventions being the most frequent among them. This indicates that careful device programming as well as use of a program with T-wave oversensing prevention should be ensured.

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Kardiowertery-defibrylatory u chorych z kardiomiopatią przerostową – dylematy i trudności

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Streszczenie

Wstęp: Wszczepienie kardiowertera – defibrylatora (ICD) jest uznaną metodą zapobiegania nagłym zgonom sercowym (SCD). Wartość tej formy terapii w prewencji wtórnej SCD jest bezsporna. Kontrowersje budzą jednak pewne aspekty prewencji pierwotnej, zwłaszcza u chorych z kardiomiopatią przerostową (HCM). Problemem jest duża liczba powikłań oraz wybór optymalnego typu ICD.

Cel: Ocena liczby i rodzaju powikłań po wszczepieniu ICD u chorych z HCM w obserwacji odległej.

Metodyka: Analiza skuteczności i bezpieczeństwa stosowania ICD u 46 chorych z HCM, u których wszczepiono ICD jako wtórną (n-18) lub pierwotną (n-28) profilaktykę SCD.

Wyniki: W trakcie obserwacji trwającej średnio 28±26,1 miesięcy (od 2 do 68 mies.), adekwatne interwencje ICD wystąpiły u 10 (55%) pacjentów z grupy profilaktyki wtórnej i 3 (11%) z grupy profilaktyki pierwotnej. Powikłania wystąpiły u 15 (33%) chorych. Najczęstszym powikłaniem były nieadekwatne interwencje ICD, które wystąpiły u 14 (30%) osób. Ich przyczyną było: sterowanie załamkiem T (7 chorych), migotanie przedsionków z szybką czynnością komór (3), uszkodzenie elektrody (2) oraz tachykardia zatokowa (2). U 2 chorych konieczne było usunięcie układu z powodu zakażenia loży. U jednej osoby wystąpiła dyslokacja elektrody. Nie stwierdzono różnic dotyczących liczby powikłań pomiędzy grupą profilaktyki pierwotnej i wtórnej. Przedstawiono metody postępowania mające na celu redukcję liczby nieadekwatnych interwencji oraz dyskusję na temat roli ICD u chorych z HCM na podstawie doświadczeń własnych i piśmiennictwa.

Wnioski: Wysoki odsetek adekwatnych interwencji ICD świadczy o wysokiej skuteczności tej formy terapii w zapobieganiu SCD. Wszczepienie ICD obarczone jest dużym odsetkiem powikłań, z których najczęstsze są nieadekwatne interwencje. Nakazuje to szczególnie uważne programowanie i zastosowanie programów zapobiegających sterowaniem załamkami T.

Słowa kluczowe: wszczepialne kardiowertery defibrylatory, kardiomiopatia przerostowa

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