European Heart Journal (1996) **17**, 1565–1571

Impact of the implantable cardioverter-defibrillator on rehospitalizations

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Patients who survive out-of-hospital ventricular tachycardia or ventricular fibrillation are at risk of sudden cardiac death and often return to hospital after initial discharge. The frequency and duration of readmittance to hospital are not well known. Thus, the purpose of this study was to evaluate the impact of the implantable cardioverter defibrillator on frequency and duration of hospitalizations.

Methods Between 1989 and 1993, 38 consecutive patients who had drug-refractory ventricular tachyarrhythmias were selected for the study. A total of 38 patients were implanted with the implantable cardioverter-defibrillator in accordance with the guidelines of the European Society of Cardiology. This analysis includes 35 of the 38 patients (92%). All hospitalizations which occurred one year before and one year after were studied. Clinical information for all patients was obtained by consulting medical records and by interviewing personal general practitioners.

Results The annual number of hospitalizations before and after implantation of the implantable cardioverter-defibrillator was, respectively, $3{\cdot}28 \pm 2{\cdot}38$ hospitalizations/patient/year and $0{\cdot}88 \pm 1{\cdot}23$ hospitalizations/patient/year ($P<0{\cdot}05$). Before implantation of the implantable cardioverter-defibrillator, patients were hospitalized a mean of $32{\cdot}94 \pm 24{\cdot}18$ days/patient/year and after, $9{\cdot}31 \pm 32{\cdot}14$ days/patient/year ($P<0{\cdot}05$). The number of hospitalizations for cardiac reasons decreased by 90%. Before implantation, the most frequent cause was ventricular tachyarrhythmia (47 hospitalizations for ventricular tachycardia and eight for ventricular fibrillation), while after implantation, it was as a result of the shock from the implantable cardioverter-defibrillator (11 hospitalizations). The number of hospitalizations for non-cardiac reasons were similar in the two time periods. Of the 35 patients, 26 (74%) had at least one appropriate successful ventricular tachycardia interrupted by the implantable cardioverter-defibrillator, while 17 patients (49%) had their ventricular fibrillation terminated. There is a significant difference in the rate of hospitalizations to intensive care units (ICU) between the two periods. Before implantation, 30% of hospital days were spent in the ICU, with 3% after.

Conclusions This study documents that the implantable cardioverter-defibrillator not only reduces the frequency and duration of hospital stays, but reduces admissions to the more expensive units in hospital. Taking into account the reduction in hospitalizations, the payback period for the implantation of an implantable cardioverter-defibrillator is 19 months.
(Eur Heart J 1996; 17: 1565–1571)

Key Words: Hospitalizations, hospital stay, implantation, cost analysis.

Introduction

Out-of-hospital ventricular fibrillation or sustained symptomatic ventricular tachycardia in patients without an acute myocardial infarction is a life-threatening event with a high risk of recurrence[1–7]. They are also likely to have lengthy and expensive rehospitalizations for repeated ventricular arrhythmias after initial discharge. The frequency of and reasons for rehospitalization after such events are still undetermined.

A widely accepted treatment for life-threatening arrhythmias is the implantable cardioverter-defibrillator[8–12]. By implanting an implantable cardioverter-defibrillator in patients with cardiac arrhythmias, the frequency and duration of hospitalizations may decrease. This decrease may translate into cost savings for the health care provider.

The aim of this study was to evaluate the impact of implantable cardioverter-defibrillator therapy on the frequency and duration of hospitalizations. The study

Revision submitted 19 January 1996, and accepted 29 January 1996.

This study was supported by the Fondation de Cardiologie Lausanne.

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0195-668X/96/101565+07 $18.00/0

Table 1 Clinical characteristics

n	35
Male	34
Female	1
Age (years ± SD)	54 ± 14 (range 16–72)
Symptoms of arrhythmia	
Cardiac arrest	11
Syncope	6
Faintness–Dizziness	12
Palpitations	6
LV ejection fraction (% ± SD)	36 ± 13 (range 17–69)
Cardiac diagnosis	
Coronary disease	26
Idiopathic dilated cardiomyopathy	4
Arrhythmogenic right ventricular dysplasia	3
Other	2

LV=left ventricular.

consisted of tracking 38 consecutive patients 12 months before and 12 months after implantation.

Methods

Study population

All hospital documents of 38 consecutive patients with drug-refractory symptomatic ventricular tachyarrhythmias or ventricular fibrillation who had an implantable cardioverter-defibrillator implanted between 1989 and 1993 were retrospectively collected and studied. Two patients were excluded because of incomplete clinical information, a third patient was excluded because he died of heart failure before the end of the study period.

The study's final analysis included data from 35 patients implanted with an implantable cardioverter-defibrillator according to the guidelines of the European Society of Cardiology[13], which require that only patients with documented and reproducible ventricular arrhythmias are implanted. There were 34 men and one woman ranging in age from 16 to 72 years with a mean of 54 ± 14 years. All patients gave their written informed consent to the implantation. The presenting symptoms of arrhythmia, left ventricular ejection fraction and the cardiac diagnosis for each patient are summarised in Table 1. At time of the implantation 14 patients were on amiodarone treatment, five on sotalol, five on a class I antiarrhythmic drug, two on a beta-adrenoreceptor blocker and three on combined (class I+sotalol) treatment.

After implantation, patient data were gathered from regular evaluations in the pacemaker follow-up centre at the University Hospital (Centre Hospitalier Universitaire Vaudois) of Lausanne, Switzerland. Each patient was examined every 3 months for automatic tachycardia intervention, and results were reported and documented by implantable cardioverter-defibrillator-stored electrograms, if available.

Clinical information for all patients was continuously collected and obtained by consulting medical/hospital records and interviewing their personal general practitioners. This information included all documents concerning medical history, treatments and hospitalizations in the 12 months before and after implantable cardioverter-defibrillator implantation. Therefore we can provide data for the complete period of observation (12 months before and 12 months after implantation) for all patients. Special attention was given to the number of hospitalizations, the primary reason for each hospitalization, and the duration of hospital stay.

Patient hospitalizations before and after implantation were then classified as either cardiac or non-cardiac. Cardiac reasons included: (1) ventricular fibrillation or ventricular tachycardia; (2) cardiac procedure or cardiovascular surgery; (3) suspicion of inadequate functioning or shock from the implantable cardioverter-defibrillator; (4) angina pectoris or acute myocardial infarction; or (5) other. If a patient was hospitalized for a cardiac procedure or cardiovascular surgery, the reasons were further classified as: (a) percutaneous transluminal coronary angioplasty or coronary artery bypass grafting; (b) electrophysiological study; (c) prolonged monitoring of the implantable cardioverter-defibrillator functions; or (d) other.

The study's primary focus was on the frequency and duration of hospital stays before and after implantation. Hospitalization during implantation is considered a secondary focus and will be documented in a separate report.

The data are reported as mean values and standard deviation (± SD). The paired two-tailed Student's t-test was used for statistical analysis. A P value of <0.05 was considered statistically significant.

Results

Number of hospitalizations

The annual number of hospitalizations before implantation of the implantable cardioverter-defibrillators was 3·28 ± 2·38 range (range 0–10) hospitalizations/patient/year. After implantation, the number decreased to 0·88 ± 1·23 (range 0–5) hospitalizations/patients/year ($P<0.05$) (Table 2). In the year after implantation, the percentage of patients not readmitted to the hospital was significantly higher (48%) than in the year before implantation (8·6%).

The majority of hospitalizations before and after implantation were for cardiac reasons (Fig. 1), but the primary cardiac reasons differed significantly in the two periods studied (Fig. 2). Before implantation, there were 115 hospitalizations, with 108 (94%) for cardiac reasons. The most frequent cause for hospitalization in this case was ventricular arrhythmia, with 47 admissions for ventricular tachycardia and eight for ventricular fibrillation. In the time period after the first occurrence of ventricular tachycardia or ventricular fibrillation

Table 2 Main results

	Before ICD implantation	After ICD implantation
Number of patients	35	35
Yearly number of hospitalizations per patient	3·28 ± 2·38* Range (0–10)	0·88 ± 1·23* Range (0–5)
Yearly number of hospital days per patient	32·94 ± 23·86* Range (0–93)	9·31 ± 32·14* Range (0–188)
Total hospital days	1153	326
Number of hospital days for cardiac reason	1085	106
Number of hospitalizations for arrhythmic events	55 (8 VF, 47 VT)	2 (atrial fibrillation)
Number of patients treated with antiarrhythmic drugs	29	16

*$P<0·05$
ICD=implantable cardioverter-defibrillator; VT=ventricular tachycardia; VF=ventricular fibrillation.

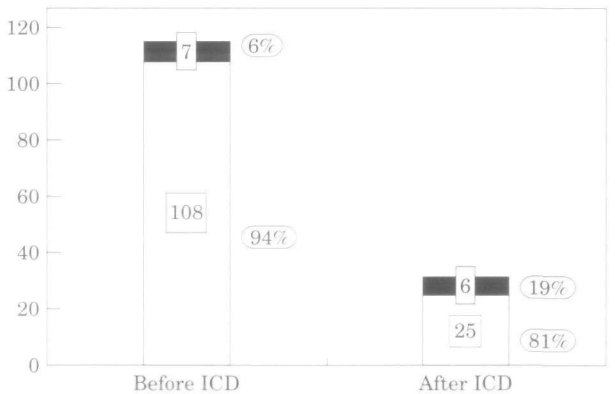

Figure 1 **Number of hospitalizations in the two time periods. Before ICD=hospitalizations in the year before implantable cardioverter defibrillator implantation; after ICD=hospitalizations in the year after implantable cardioverter defibrillator implantation; ■=hospitalizations for non-cardiac reasons; □=hospitalizations for cardiac reasons.**

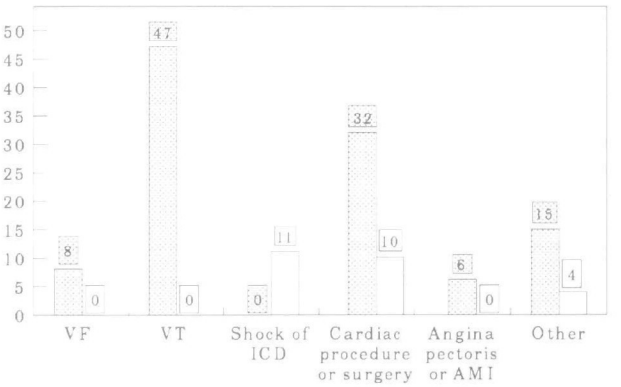

Figure 2 **Number of hospitalizations for cardiac reasons. VT=ventricular tachycardia; VF=ventricular fibrillation; AMI=acute myocardial infarction. ▨=Before (108 hospitalizations); □=After (25 hospitalizations).**

and before implantation, the average number of hospitalizations was 1·53 per patient (range 0–5).

After implantation, the number of hospitalizations dropped to 31, with 25 (81%) for cardiac reasons. In this case, however, the frequent cause was hospitalization for observation after a shock delivered by the implantable cardioverter-defibrillator (11 hospitalizations). Of the 35 patients, 26 (74%) had at least one appropriate successful ventricular tachycardia interrupted by the implantable cardioverter-defibrillator, while 17 patients (49%) had their ventricular fibrillation terminated, with some patients receiving up to 30 discharges.

Before and after implantation, another frequent cause for patient hospitalization was cardiac procedure or cardiovascular surgery. They caused 32 hospitalizations before implantation (28 for electrophysiological study) and 10 after (six for prolonged monitoring of the functions of the implantable cardioverter-defibrillator; two for pacemaker implantation; one for radiofrequency ablation of the atrioventricular junction; and one for surgery for an abdominal aortic aneurysm). Cardiac revascularization procedures were all carried out before implantation of the device (two percutaneous transluminal coronary angioplasty and two coronary artery bypass grafting)

The number of hospitalizations for non-cardiac reasons were similar in the two time periods, with seven hospitalizations before and six after implantation (Fig. 1).

Duration of hospital stay

Before implantation of the implantable cardioverter-defibrillator, patients were hospitalized a mean of 32·94 ± 23·86 (range 0–93) days/patient/year and after 9·31 ± 32·14 (range 0–188) days/patient/year.

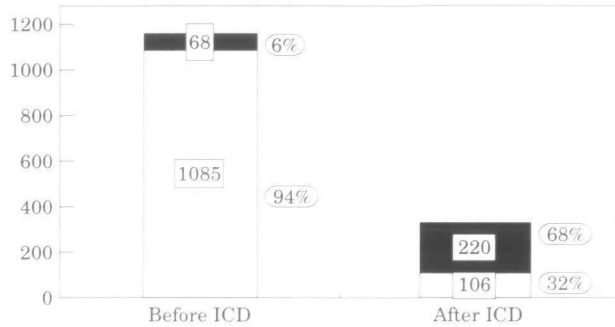

Figure 3 **Days of hospitalization in the two time periods. Before ICD=days of hospitalization in the year before implantable cardioverter defibrillator implantation; after ICD=days of hospitalization in the year after implantable cardioverter defibrillator implantation; ■=days of hospitalization for non-cardiac reasons; □=days of hospitalization for cardiac reasons.**

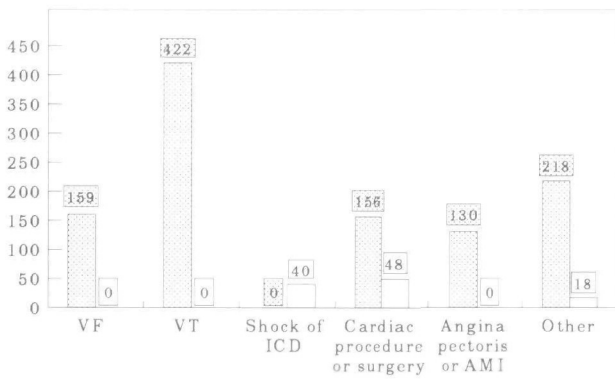

Figure 4 **Days of hospitalization for cardiac reasons. VT=ventricular tachycardia; VF=ventricular fibrillation; AMI=acute myocardial infarction; ▨=Before (1085 hospitalization days); □=After (106 hospitalization days).**

The total number of hospital days for cardiac reasons decreased by 90% after implantation. Ninety-four percent of patients' time spent in hospital (1085 days) before implantation was due to a cardiac problem, in contrast to 32% (106 days) in the year following (Figs 3 and 4). A major reason for hospitalization before implantation of the device was for arrhythmic events (581 days or 50% of the pre-implantable cardioverter-defibrillator total hospital days) and 13 hospitalizations were for antiarrhythmic drug testing (184 days or 16% of the pre-implantable cardioverter-defibrillator total hospital days). These included 16 cardiac arrests (all occurred before implantation); 50% happened outside the hospital and 50% during the hospital stay. Of the 35 patients analysed in our study, 25 (71·4%) were cardioverted or defibrillated at least once during the year before implantation (52 external shocks, range per patient 1–5). After implantation, only one patient was externally cardioverted for atrial fibrillation during hospitalization and no additional drug testing was required.

After implantation, the major reason for hospitalization was related to the implantable cardioverter-defibrillator (69 days), including prolonged monitoring of the functions of the device or patients' low tolerance to shocks. Each stay was brief (average 4·05 days, range 1–12), and generally patients were discharged after interrogation of the implantable cardioverter-defibrillator. There were no hospitalizations for inappropriate functioning of the implantable cardioverter-defibrillator or infection.

The total number of hospital days for non-cardiac reasons is higher after implantation (220 days after and 68 days before), but this is primarily due to one patient who stayed in hospital for 165 days. The patient suffered from a vascular complication of diabetes mellitus requiring leg amputation and subsequent physiotherapy.

Implantation of the implantable cardioverter-defibrillator

The average length of hospitalization for implantable cardioverter-defibrillator implantation was 17 days ± 8, with a minimum of 9 and a maximum of 43 days. For the 29 patients who had at least one episode of ventricular tachycardia or ventricular fibrillation, the implantable cardioverter-defibrillator was implanted an average of 116 days (range 16–304) after the first occurrence of ventricular tachyarrhythmias. The remaining six patients in the study did not suffer from spontaneous ventricular tachycardias during the year before implantation. In these patients, however, it was possible, despite drug treatment, to induce rapid (>150) ventricular tachycardia during an electrophysiological study.

Cost analysis

Between the two periods, we observed a significant difference in the number of ICU hospitalizations for the 36 patients in the study (including the man who died from heart failure). Before implantation, 360 out of 1172 hospitalization days (30·7%) were spent in intensive care unit. After implantation, ICU stays decreased to 3% or 11 days.

According to a cost-accounting analysis using 1991 cost estimates, one day spent in our centre's intensive care unit costs an average of 2546 Swiss francs, as compared to 954 Swiss francs in a general ward. Because we noted a decrease of 9·69 days per patient spent in ICU and 12·42 in general wards, we calculated a cost reduction of 36 519 Swiss francs per patient. To determine the cost effectiveness of the implantable cardioverter-defibrillators, we considered the average cost of the device and hospitalization during implantation (Table 3). Using a cost of 58 061 Swiss francs per implantable cardioverter-defibrillator implantation, we calculated that the payback period for an implantable cardioverter-defibrillator investment is 19 months.

Table 3 Cost analysis

	Before implantation	After implantation	Implantation of the ICD
Number of patients	36	36	36
Days spent in ICU per patient	10	0·31	1·11
Average cost for hospitalization in ICU per patient (=2546 Fr./day)	Fr. 25 460	Fr. 789	Fr. 2826
Days spent in general ward per patient	22 56	10·14	15·97
Average cost for hospitalization in general ward per patient (=954 Fr./day)	Fr. 21 522	Fr. 9674	Fr. 15 235
Cost for device per patient			Fr. 40 000
Total cost per patient	Fr. 46 982	Fr. 10 463	Fr. 58 061

ICD=implantable cardioverter-defibrillator.
Fr.=Swiss Francs.

Discussion

First used in 1980[14], the automatic implantable defibrillator has been the subject of extensive studies, but most used historical controls or non-randomized concurrent patients to compare with the implantable cardioverter-defibrillator-implanted patients[15–19]. In spite of that, the implantable cardioverter-defibrillator has become the treatment of choice in patients resuscitated from cardiac arrest[10,20]. Using this device, there has been a significant reduction in sudden cardiac death rates when compared to historical controls[9,21–28].

In this study we compared the use of hospital services in a 12 month period before and after implantable cardioverter-defibrillator implantation. As all arrhythmias were refractory to drug treatment including amiodarone, the defibrillator had to be considered as a last treatment choice and therefore ethical considerations prohibited randomization.

Reduction of hospitalizations after implantation of this device is a topic which has been discussed by many authors[8]. However, in-depth cost-effectiveness studies and quality-of-life assessments of implantable cardioverter-defibrillator therapy have never been performed before.

The present study reveals that the implantable cardioverter-defibrillator reduces days of hospitalization for cardiac reasons by 90%. Before implantation of the implantable cardioverter-defibrillator, a major reason for patient hospitalization was tachyarrhythmias. The individuals had to endure long and costly stays in the ICU and frequently required external shocks.

The effectiveness of the implantable cardioverter-defibrillator in the treatment of ventricular tachyarrhythmias is demonstrated in our study because hospitalization decrease was primarily due to a reduction of tachyarrhythmia-related hospital admissions. To further prove this point, study results show that of the 35 patients, 74% had at least one appropriate successful ventricular tachycardia interrupted by the implantable cardioverter-defibrillator and 49% had their ventricular fibrillation terminated. The study shows a relatively high rate of spontaneous ventricular arrhythmias after implantation, but this may be explained by our restrictive patient selection criteria detailed earlier in this report. In particular, a significant difference in the rate of admissions to intensive care unit was noted between the two time periods. Therefore, this study also reveals that the implantable cardioverter-defibrillator not only reduces the number and days of hospitalizations, but reduces admissions to the more expensive units in hospital.

Antiarrhythmic drug therapy vs implantable cardioverter-defibrillator

It has been reported that implantable cardioverter-defibrillator therapy as early intervention does not necessitate excessive costs and may be as cost effective as antiarrhythmic drug therapy[29–32]. In the present study, it is interesting to observe that, before implantation, 13 (11·3%) hospitalizations and 184 (15·9%) hospital days were due to testing of antiarrhythmic drugs. After implantation no further drug testing was performed. Furthermore, before hospitalization for implantation of the implantable cardioverter-defibrillator, 83% of patients were treated with at least one antiarrhythmic drug, but only 45% were discharged on antiarrhythmic drugs after implantation (see Table 2).

Our study shows that the conventional therapeutic strategy, which reserves the implantable cardioverter-defibrillator for patients failing to respond to classical antiarrhythmic treatment and to many diagnostic and therapeutic procedures, significantly contributes to prolonged hospitalization stays which always translate into high health care costs.

As a tertiary centre we have to deal mostly with complex cases. Earlier referral might have given even more favourable results.

Hospitalizations due to classic manifestations of ischaemic heart disease (myocardial infarction or angina) were also reduced. This reduction was probably due to the benefit of myocardial revascularization in some patients (two coronary artery bypass grafting and two percutaneous transluminal coronary angioplasty) before the implantable cardioverter-defibrillator was

implanted. However, it is known that these procedures do not reduce cardiac arrhythmias[33,34].

Another area which must be considered when evaluating the cost-effectiveness of the implantable cardioverter-defibrillator is the increase in patients' productive hours. In general, patient acceptance of the device is very high[35–37], with more than 50% of the patients resuming work during the year after implantation[37,38].

Because the study was designed with a follow-up of 12 months after implantation, a valid survival analysis was not the aim of this study. Nevertheless, the overall survival rate at one year for our group is 97·2%, which corresponds to current medical literature[9,21–28].

Conclusions

In 35 patients who received the implantable cardioverter-defibrillator for drug-refractory ventricular tachyarrhythmias, the number and duration of hospitalizations were significantly reduced.

By reducing hospitalization, the study also shows that implantable cardioverter-defibrillator therapy can be cost effective when compared to other medical interventions. The study suggests a payback period for the implantable cardioverter-defibrillator of 1·5 years.

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