Hospital readmission after transvenous cardioverter/defibrillator implantation

A single centre study

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Aims Hospital readmission after implantation of cardioverter/defibrillators has a major impact on quality of life and cost-effectiveness in defibrillator patients. Rehospitalization has not been studied in large patient populations with modern transvenous defibrillation systems.

Methods and Results We report on incidence, reasons, time in follow-up, duration and predictors of hospital readmission in 180 patients after transvenous implantation of a cardioverter/defibrillator during a follow-up period of 25 ± 18 months. There were 156 readmissions in 79 patients with a 0.87 readmission rate per patient during the time followed, a 0.46 readmission rate per patient-year of follow-up and a 0.38 readmission rate per patient-year of follow-up for cardiac reasons. The majority of readmissions was caused by multiple appropriate shock interventions (26%), battery depletion (19%) and lead- and device-related complications (14%). The time to first hospital readmission was 12 ± 9 months for arrhythmia-related and 20 ± 16 months for other cardiac-related reasons (P < 0.05), and could not be predicted by clinical variables, respectively. The duration of rehospitalization was 14 ± 15 days for cardiac-related reasons and 12 ± 17 days for arrhythmia-related reasons. Age > 60 years was an independent predictor of rehospitalization time per patient-year of follow-up for both cardiac-related (P < 0.005) and arrhythmia-related reasons (P < 0.05).

Conclusion The rate of hospital readmission per patient-year of follow-up is as high as 0.46 after implantation of a modern cardioverter/defibrillator. Rehospitalization time in such patients is significantly longer in the patient cohort > 60 years. The majority of readmissions is caused by multiple appropriate shock treatments. Further studies are needed to systematically investigate strategies for the prevention of rehospitalization in modern ICD therapy.

Key Words: Implantable cardioverter defibrillator, hospital readmission, rehospitalization time.

Introduction

The implantable cardioverter/defibrillator has been shown to be remarkably effective in preventing sudden cardiac death and total mortality in patients with life threatening ventricular tachyarrhythmia¹⁻². Recent studies show favourable results for defibrillators implanted in high risk patients with a prophylactic indication³⁻⁴. Since changes in the socioeconomic climate force justification of the use of expensive medical interventions³, potential benefits of defibrillator therapy have to be characterized focusing on softer end-points such as cardiac morbidity, quality of life and cost-effectiveness. Recent studies addressed hospital readmission as a severe adverse event of defibrillator therapy⁵ and as a major factor of cost-effectiveness analysis⁶. ICD implantation might decrease the frequency and duration of hospitalization in high risk patients and translate into cost savings for the health care provider.

This is the first single centre study to systematically and prospectively analyse incidence, reasons, time in follow-up, duration and predictors of hospital
Patient population and follow-up

The study population consisted of 180 patients who underwent successful implantation of a transvenous defibrillation system with stored electrogams or RR interval recordings. All devices were implanted as single chamber systems: 105 devices (58%) were placed in a left ventricle, and two devices (1%) in a right subpectoral pocket, 73 chamber systems: 105 devices (58%) were placed in a left ventricle, and two devices (1%) in a right subpectoral pocket, 73 devices (41%) were placed in an abdominal pocket. Access to lead placement was obtained by cephalic vein cutdown. All leads were fixed by double anchoring sleeves with non-resorbable strings. Of the devices implanted 139 were manufactured by Medtronic (Minneapolis, Minn.), 24 by CPI (St. Paul, Minn.), nine by Sulzer Intermedics (Angleton, Tex.), six by Telectronics (Englewood, Denver), and two by Ventritex (Sunnyvale, Calif.).

Clinical characteristics of the patients are depicted in Table 1. At the time of hospital discharge 11 patients (6%) were on amiodarone, 65 (36%) on d/l-sotalol, 25 (14%) on class I antiarrhythmic drugs, 12 (7%) on beta-blocker and 10 (6%) on combined (class I+sotalol) treatment. Of the patients with coronary artery disease 77 (68%) were either on beta-blocker or on d/l-sotalol, 11 patients (10%) were on amiodarone.

Antitachycardia pacing was programmed in patients with documented or suspected monomorphic ventricular tachycardia with a cut-off rate of 10 beats . min$^{-1}$ below the rate of the clinical ventricular tachycardia. In patients with only a history of ventricular fibrillation a cut-off rate of 190 beats . min$^{-1}$ for shock treatment was programmed. Enhanced detection criteria were not available in all devices and not programmed at first hospital discharge.

Follow-up of this prospective study began on the day of hospital discharge after first ICD implantation. Hospital readmission was defined as readmission to the first or any other hospital for more than 12 h. The patients were also routinely seen in the outpatient clinic of the implanting centre every 3 months. Pertinent information was obtained by reviewing patients’ hospital records and by telephone contact with patients, their families, or private physicians. No patient was lost to follow-up.

Classification of hospital readmissions

Hospital readmissions were classified as cardiac or non-cardiac by consensus between two investigators (T.K., W.J.). Cardiac readmissions were subclassified in arrhythmia-related and non-arrhythmia-related. Arrhythmia-related readmissions were subdivided into those caused by ventricular tachyarrhythmia with and without appropriate shock, supraventricular tachyarrhythmia with and without inappropriate shock, device- and lead-related complications and battery depletion. Non-arrhythmia-related cardiac readmissions were congestive heart failure and ischaemia (i.e. acute myocardial infarction, unstable angina). When patients were admitted for a combination of the above reasons, the dominant problem was considered to be the reason for readmission.

Statistical analysis

Rates of readmission were determined by dividing the number of hospitalizations experienced by the total number of person-years of follow-up for both individual patients and for groups. The data are reported as mean, maximum and minimum values and as standard deviation (± SD). The probabilities of freedom from cardiac- and arrhythmia-related readmission were estimated by the method of Kaplan and Meier, and the Mann–Whitney test was used for statistical comparison. As predictors of the time to first cardiac- or arrhythmia-related readmission and rehospitalization time per patient-year of follow-up age, gender, NYHA classification, coronary heart disease and left ventricular ejection fraction were analysed. For this purpose age was dichotomized at 60 and left ventricular ejection fraction at 30%. The Mann–Whitney test was used for predictor analysis. A P-value of <0.05 was considered statistically significant for all tests.

Results

There were 156 readmissions in 79 patients (44%) after a mean follow-up period of 25 ± 18 months [1–71]. The rate of hospital readmission was 0.87 per patient during the time followed and 0.46 per patient-year of follow-up. One hundred and thirty readmissions (83%) in 72

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**Table 1 Patient characteristics**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value</th>
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<tbody>
<tr>
<td>Patients [n]</td>
<td>180 (m:149; f:31)</td>
</tr>
<tr>
<td>Age [y]</td>
<td>57 ± 12 [15–79]</td>
</tr>
<tr>
<td>Diagnosis:</td>
<td></td>
</tr>
<tr>
<td>CAD [n]</td>
<td>114 (63%)</td>
</tr>
<tr>
<td>IDC [n]</td>
<td>38 (21%)</td>
</tr>
<tr>
<td>Idiopathic VF [n]</td>
<td>21 (12%)</td>
</tr>
<tr>
<td>ARVD [n]</td>
<td>6 (3%)</td>
</tr>
<tr>
<td>Myocarditis [n]</td>
<td>1 (0.6%)</td>
</tr>
<tr>
<td>VF [n]</td>
<td>71 (39%)</td>
</tr>
<tr>
<td>VT [n]</td>
<td>66 (37%)</td>
</tr>
<tr>
<td>VT/VF [n]</td>
<td>43 (24%)</td>
</tr>
<tr>
<td>LVEF [%]</td>
<td>43 ± 17</td>
</tr>
<tr>
<td>Follow-up [months]</td>
<td>25 ± 18 [1–71]</td>
</tr>
</tbody>
</table>

CAD=coronary artery disease, IDC=idiopathic dilated cardiomyopathy, ARVD=arrhythmogenic right ventricular dysplasia, VF=ventricular fibrillation, VT=ventricular tachycardia, LVEF=left ventricular ejection fraction.
patients (40%) were cardiac-related with a cardiac readmission rate of 0.38 per patient-year of follow-up. One hundred and ten readmissions (71%) in 34 patients (19%) were arrhythmia-related. The mean time to first hospital readmission was 12 ± 9 months for arrhythmia-related and 20 ± 16 months for other cardiac-related reasons (P<0.05, Mann–Whitney test) (Fig. 1). The duration of readmission was 14 ± 15 days [1–118] for cardiac reasons and 12 ± 17 days [1–118] for arrhythmia-related reasons (P>0.05). The reasons for hospital readmission are summarized in Fig. 2.

Twenty patients (11%) died during follow-up. Reasons were congestive heart failure in 10 patients (6%), myocardial infarction in two patients (1%), sudden cardiac death in three patients (2%), cerebral or gastrointestinal bleeding in three patients (2%), sepsis in one patient (0.6%) and unknown in one patient (0.6%).

**Arrhythmia-related readmissions**

Forty readmissions (26%) in 20 patients (11%) were caused by multiple appropriate shock interventions due to recurrent ventricular tachyarrhythmia. In 12 patients antiarrhythmic treatment was changed, four patients were put on amiodarone. In one patient defibrillator reprogramming was performed with modified antitachycardia pacing for avoidance of shock interventions. One patient with coronary artery disease and a left ventricular ejection fraction below 30% had to stay in the hospital for 118 days and suppression of recurrent slow ventricular tachycardia could only be achieved by additional dual chamber pacing and combined class III and class I antiarrhythmic drug treatment.

The occurrence of atrial fibrillation or atrial flutter with rapid ventricular response caused 19 readmissions (12%) in 18 patients (10%). In five readmissions (3%) in five patients (3%) rapid atrial fibrillation was the cause of inappropriate shock intervention. In two patients a successful internal cardioversion with the ICD defibrillation system was performed, in five patients antiarrhythmic treatment was changed, three patients were put on amiodarone. In two patients defibrillator reprogramming was performed with use of rate stability as an enhanced detection criterion for atrial fibrillation in one patient and an altered zone of detection for ventricular tachyarrhythmias in the other patient. In one patient ablation of atrial flutter was successfully performed.

**Lead- and device-related readmissions**

Lead-related complications caused 13 readmissions (8%) in 13 patients (7%). There were six lead fractures, four dislodgements, and three insulation defects. All insulation defects were diagnosed after inappropriate ICD intervention, all fractures and lead dislodgements were diagnosed with biplane chest X-ray during routine follow-up. Lead fractures and dislodgements were diagnosed at 13.7 ± 12.7 [2–31] months. Of the six fractured leads three were right ventricular leads and three were...
subcutaneous patch leads. Of the four dislodged leads three were right ventricular leads with passive fixation and one was a superior vena cava lead. Insulation defects were diagnosed 8 ± 6.6 [1–14] months after implantation. Three of these leads had a silicone rubber and one lead polyurethane insulation. All lead-related complications had to be surgically revised.

Device-related complications caused nine readmissions (6%) in nine patients (5%). The cause was generator pocket infection in three patients and pocket haematoma or seroma in four patients. All infections occurred in patients with an abdominal generator pocket. Of the four haematoma and seroma three occurred after left subpectoral and one after abdominal implantation. One patient was readmitted for abdominal device dislodgement causing an ileus and one patient for inappropriate antibradycardia pacing. Device-related complications occurred 20.1 ± 18.3 [1–52] months after first hospital discharge, all pocket infections led to a complete system revision with a hospital stay of 48.3 ± 11.8 days.

Table 2  Predictors of the time to first hospital readmission and rehospitalization time per patient-year of follow-up for cardiac- and arrhythmia-related reasons

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Time to first hospital readmission</th>
<th>Rehospitalization time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cardiac-related</td>
<td>Arrhythmia-related</td>
</tr>
<tr>
<td>Age &gt;60 years</td>
<td>0.48</td>
<td>0.23</td>
</tr>
<tr>
<td>Gender</td>
<td>0.27</td>
<td>0.32</td>
</tr>
<tr>
<td>NYHA III–IV</td>
<td>0.56</td>
<td>0.23</td>
</tr>
<tr>
<td>CAD</td>
<td>0.51</td>
<td>0.65</td>
</tr>
<tr>
<td>LVEF &lt;30%</td>
<td>0.5</td>
<td>0.51</td>
</tr>
</tbody>
</table>

CAD=coronary artery disease, LVEF=left ventricular ejection fraction.

Predictors of readmission

The P-values of the analysed predictors for the time to first cardiac- and arrhythmia-related readmission and rehospitalization time per patient-year of follow-up are summarized in Table 2. None of the tested clinical variables, i.e. age, gender, NYHA classification, coronary artery disease and left ventricular ejection fraction, were able to predict the time to first hospital readmission for cardiac- and arrhythmia-related reasons. Age >60 years was identified as an independent predictor for rehospitalization time per patient-year of follow-up for both cardiac-related (P<0.005) and arrhythmia-related reasons (P<0.05).

Discussion

Incidence and duration of readmission

This first single centre study of hospital readmission in patients with modern, transvenous ICD systems demonstrates an overall readmission rate of 0.46 per patient-year of follow-up. The time to first hospitalization was 12 ± 9 months for arrhythmia-related and 20 ± 16 months for other cardiac-related reasons. The MADIT investigators[7] reported 360 hospitalizations during 2254 person-months of observation in 89 ICD patients (47% of patients with epicardial ICD system). Fahy et al.[8] reported a 0.72 readmission rate per year of follow-up in a series of 34 patients with 48% epicardial systems and a short medium follow-up of 19 [10–27] months. The significantly higher number of readmissions (both studies did not include rehospitalizations for battery depletion) in these two series might, in part, be explained by the lower mean ejection fraction of 27% and 34%, and a higher mean age of 62 years and 67 years, respectively.

The AVID investigators[9] compared the probability of rehospitalization in the ICD group (93% transvenous systems) with a 59.57/84.883% probability in the first, second and third year after ICD implantation as compared to 55.6/64.77/5% in the conventional arm.
high risk patients with and without de
su
tation and the performed comparison might thus not
signi
te ventricular and supraventricular arrhythmia are often
significantly different before and after device implant-
tion and the performed comparison might thus not suf-
ciently compare significance of rehospitalization in
high risk patients with and without defibrillator.

Our results confirm Fahy et al.[8] documenting an 83%
rate of cardiac readmissions as arrhythmia-related and
an earlier occurrence of arrhythmia-related as compared
to overall cardiac-related readmissions. Since former
studies[4,11] have shown an accumulation of arrhythmia
occurrence in the first few months after implantation the
rate of hospital readmission might still go down in
future studies with a still longer follow-up period.

Reasons for readmission and prevent
strategies

The main reasons for readmissions were multiple appro-
priate shock treatments (26%) and the occurrence of
atrial fibrillation or atrial flutter with or without in-
appropriate shock (12%). Fahy et al.[8] found 24% ventricu-
lar arrhythmias and 24% supraventricular arrhythmias as the
cause for hospital readmission. These findings confirm the data of Nunain et al.[12] with recurrent arrhythmias as a significant source of mor-
bidity in defibrillator patients. The majority of 68% of
patients with coronary artery disease in our study had
either been on beta-blocker or on d,l-sotalol, 42% of
patients were on a class III antiarrhythmic drug, similar
to the drug regimen of former studies[12]. Antitachy-
cardia pacing had been programmed in all patients with
documented or suspected ventricular tachycardia, since
it dramatically reduces the delivery of high energy
shocks in patients with ventricular tachycardia[13]. Treat-
ment of patients with readmissions for arrhythmia
recurrence was, in most patients, a change of the anti-
arrhythmic drug regimen with a change to amiodarone
in 23% of cases and a combination of two antiarrhyth-
mic drugs in 23.5% of cases. Encouraging results of
advanced detection algorithms with single- or dual-
chamber defibrillators for avoidance of inappropriate
shocks have been published[14,15] but have not been
systematically studied as a preventive strategy for avoid-
ance of hospital readmission of patients due to inap-
propriate intervention. In case of drug-refractory recurrence of
ventricular and supraventricular tachycardia as a
cause of readmission ablation techniques might gain
more importance in the future[16–18]. The possibility of
dual-chamber, rate-responsive pacing in dual-chamber
systems may also decrease the incidence of readmission
in patients requiring chronic pacing.

Hardware-related problems caused 14% of all hospital
readmissions with 8% lead-related and 6% device-related
readmissions. These data confirm results of large
follow-up studies[12,19]. In our small series these compli-
cations could not be explained by specific hardware used
or implantation technique. Future studies will have to
show if advanced lead technology, reduced generator
size and pectoral device implantation will help reduce
the still high rate of hardware problems and thus
hospital readmission.

The impact of battery depletion which makes up for
19% of all hospital readmissions in this study was not
analysed in other studies[7,8,10]. Batteries had a longevity
of 38 ± 8.9 [15–54] months and readmission for device
change and thus overall readmission rate should signifi-
cantly drop with future devices offering an advanced
battery technology. The long mean duration of hospital
stay for battery depletion in this series was due to the
long hospital stay in single patients with system infection
and an indicated two step procedure with explantation
of the whole system, antibiotic treatment and
consecutive implantation of a new system.

Predictors of hospital readmission

In this series no independent predictor could be ident-
ified for the time to first cardiac- and arrhythmia-related
readmission. Age >60 years was found as a significant
predictor of rehospitalization time for both cardiac- and
arrhythmia-related reasons. Fahy et al.[8] found a New
York Heart association class III and IV to significantly
predict a shorter time to first cardiac-related readmission
using a cox regression analysis. Predictors such as
underlying heart disease and ejection fraction should be
reanalysed in future studies with larger patient cohorts.

Study limitations

Hospital readmissions not only to the implanting centre
were analysed and the indication for patient admission
might vary between different institutions. Since treat-
ment of a large ICD patient cohort cannot exclusively be
performed by the implanting centre realistic numbers of
hospital readmission have to include admissions to
smaller, more unexperienced institutions with a possibly
different admission policy.

Conclusions

Hospital readmission decreases significantly in recipients
of modern transvenous ICD systems, and rehospitaliz-
tion time is significantly longer in the patient cohort
>60 years. Further studies are needed to systematically
investigate prevent strategies for further reduction of
rehospitalization in modern ICD therapy.

References

with the automatic implantable cardioverter-defibrillator.


