Prädiktoren für ICD-Therapien bei Patienten mit ischämischer und nicht-ischämischer Kardiomyopathie

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1. Einleitung

1.1. Definition und Epidemiologie

In Deutschland sterben jährlich zwischen 100.000 und 200.000 Menschen am plötzlichen Herztod (Sudden Cardiac Death - SCD). Der plötzliche Herztod wird als unerwarteter, plötzlich eintretender natürlicher Tod mit kardialer Ursache definiert. Die Beschwerden dürfen nicht länger als eine Stunde anhaltend sein, obwohl der Beschwerdebeginn meistens schwierig festzulegen ist. {1} Etwa 50 % aller Fälle treten außerhalb des Krankenhauses auf. {2} Das Risiko für einen plötzlichen Herztod ist sechs- bis zehnfach höher, wenn eine klinisch relevante strukturelle Herzkrankheit vorliegt. Allerdings wurde in den letzten 50 Jahren eine 49 %ige Reduktion des SCD dokumentiert; {3} ursächlich dafür scheint die Optimierung der Behandlung des akuten Koronarsyndroms sowie die seit 1970 etablierte prophylaktische Implantation von Defibrillatoren zu sein. {4}

1.2 Strukturelle Herzkrankheit und SCD

In den ersten 48 Stunden nach einem akuten Koronarsyndrom besteht ein bis zu 15 % höheres Risiko für lebensbedrohliche Herzrhythmusstörungen. Die Mehrheit dieser Ereignisse tritt in den ersten 6 Stunden nach Schmerzbeginn auf. Insgesamt sind 50 % der Todesfälle bei koronarer Herzkrankheit auf den plötzlichen Herztod zurückzuführen. Die Prognose verschlechtert sich bei vorbestehenden Wandbewegungsstörungen oder bei Einschränkung der linksventrikulären Pumpfunktion, wobei eine Revaskularisierung primäre Kammertachykardien nicht ausschließt. Häufigste SCD-Ursachen sind alte Myokardinfarkte mit Narben- beziehungsweise Aneurysmabildung und nachfolgende ventrikuläre Tachykardien. Ein akutes Ereignis ist seltener die Ursache eines arrhythmogenen SCD. Ein Verschluss des RIVA (Ramus interventricularis anterior) oder des RCX (Ramus circumflexus) wird jedoch häufiger mit einem arrhythmogenen Ereignis assoziiert. {5} Darüber hinaus sind auslösende Faktoren wie Hypokaliämie, Hypomagnesiämie oder QT-Zeit-verlängernde Medikamente (z. B. Amiodaron) zu beachten.

Ein Drittel der Patienten mit dilatativer Kardiomyopathie stirbt am plötzlichen Herztod. Es ist paradox, dass die Patienten mit vergleichsweise besserer Pumpfunktion im Verlauf Kammertachykardien entwickeln, während die Patienten mit schlechterer linksventrikulärer Pumpfunktion an terminaler Herzinsuffizienz sterben. {6}

Bei circa 85 % der SCD-Fälle ist die vorliegende strukturelle Herzkrankheit eine ischämische oder dilatative Kardiomyopathie. Seltenere Genesen sind die hypertrophe Kardiomyopathie, die arrhythmogene Dysplasie des rechten Ventrikels, Ionenkanalerkrankungen (Long-QT, Brugada-Syndrom etc.), die Aortenstenose, die kardiale Sarkoidose, Speicherkrankheiten etc. {7-11}

1.3 Mechanismen der Arrythmien

Als häufigste SCD-Ursache ist Kammerflimmern zu dokumentieren; weniger häufig tritt eine polymorphe ventrikuläre Tachykardie auf (z. B. beim Long-QT-Syndrom oder ischämischen Ereignissen) und eher selten liegt eine monomorphe anhaltende ventrikuläre Tachykardie (mit oder ohne Degeneration ins Kammerflimmern) vor. {12} Bei circa 10-15 % der Patienten (vor allem DCM-Patienten) treten bradykarde Herzrhythmusstörungen oder Asystolien auf. Das Autreten einer Asystolie ist mit der Dauer des Herzstillstandes und dadurch mit einer schlechteren Prognose verbunden. Zudem ist primäres Kammerflimmern im Vergleich zur ventrikulären Tachykardie hämodynamisch ungünstiger, da es mit verminderter zerebraler Restperfusion und schlechterer ventrikulärer Pumpfunktion verbunden ist. {13-16}

1.4 Implantation von ICD – Klinische Studien

Die ICD-Implantation etablierte sich innerhalb der letzten Jahre als Goldstandard in der Behandlung von herzinsuffizienten Patienten. Die Implantationszahlen haben in den letzten 15 Jahren massiv zugenommen, sodass aktuell weltweit über 250.000 Implantationen pro Jahr durchgeführt werden. {17} Das perioperative Risiko bei transvenöser Implantation liegt in erfahrenen Zentren in

Deutschland bei 1-5 %, auch der stationäre Aufenthalt perioperativ hat sich deutlich verkürzt. {18; 19} Durch technische Entwicklungen im Bereich der ICD-Therapie konnten die meisten Episoden von ventrikulären Tachykardien (VT) oder Kammerflimmern (VF) erfolgreich terminiert werden, {20} zum Teil allein durch schmerzfreie ATP-Abgaben (antitachykardem Pacing). {21; 22} Auch der Einsatz von CRT-Systemen hat die linksventrikuläre Pumpfunktion und die Symptomatik der Patienten deutlich verbessert. {23}

Vier große Studien haben die ICD-Implantation in die alltägliche Praxis eingeführt. Laut den Ergebnissen der MADIT II-Studie (Second Multicenter Automatic Defibrillator Trial) {24} aus dem Jahr 2002 sowie der SCD-HeFT-Studie (Sudden Cardiac Death Heart Failure Trial) {25} aus 2005, zeigte die ICD-Implantation bei Patienten mit einer ischämischen Kardiomyopathie eine LV-EF (left ventricular ejection fraction) von 30-35 %, NYHA I-III eine deutliche Reduktion der Gesamtmortalität. Die DEFINITE-Studie (Defibrillators in Non-ischemic Cardiomyopathy Treatment Evaluation) {26} aus 2005 verwies darüber hinaus auf einen ähnlichen Benefit für Patienten mit dilatativer Kardiomyopathie und eingeschränkter Pumpfunktion. In der 2004 veröffentlichten COMPANION-Studie (Comparison of Medical Therapy, Pacing, and Defibrillation in Heart Failure) wurde die QRS-Dauer und die Rolle der Resynchronisationstherapie (CRT) bei ICM, LV-EF < 35 % und NYHA III-IV evaluiert. Hier zeigte sich eine deutliche Reduktion des stationären Aufenhaltes im Rahmen des Follow-up und der Gesamtmortalität. {27} Obwohl mehrere Studien den Profit der ICD-Therapie bewiesen haben, gestaltet sich die Risikostratifizierung für diese unterschiedliche Patientenpopulation aufgrund der Komplexität der Herzinsuffizienz, der unterschiedlichen Genese der Kardiomyopathien, der zugrundeliegenden Tachykardiemechanismen und der entsprechenden klinischen Ereignisse als schwierig.

1.5 ICD-Therapieabgaben

In der Literatur werden die Folgen einer ICD-Implantation hinsichtlich der Lebenqualität diffus beschrieben. {28; 24-26} Sicher ist, dass das Device bei der Mehrheit der ICD-Träger eine gewisse psychische Belastung mit sich bringt. Zum einen sind die Schocks möglicherweise schmerzhaft und

verursachen oder verschlechtern vorbestehenden Stress, Depressionen oder Todesangst. Zum anderen funktioniert der Defibrillator für viele Patienten wie ein Schutzmechanismus, der sie beruhigen und absichern kann. Ferner verspüren viele Patienten mit CRT-Systemen weniger Beschwerden, was einen deutlichen Unterschied in der Lebensqualität bedeuten kann. {23}

Etwa 30 % der Schockabgaben sind inadäquat {29} und werden am häufigsten durch supraventrikuläre Tachykardien (SVT) oder Sondendysfunktionen verursacht. Die Fortschritte in der ICD-Programmierung mit verschiedenen kombinierten Algorithmen (z. B. Verlagerung der Zähler in die Schock-Zone oder Programmieren von mehreren SVT/VT-Diskriminatoren) und die Entwicklung von ATP-schmerzfreien Therapien helfen, derartige Probleme im Alltag zu beheben. Es können jedoch bei Defibrillatoren auch technische Einschränkungen auftreten. {30-32} Sondendislokationen, Batterieerschöpfung, Aggregatdysfunktionen, Infektionen etc. stellen weiterhin ein alltägliches klinisches Problem dar. {33} Zudem sind die Kosten für die ICD-Implantation und für die damit verbundenen Komplikationen mit entsprechenden stationären Aufenhalten enorm. {34; 35} Aus diesen Gründen stellt die genaue Patientenselektion auch zukünftig eine dringliche Herausforderung dar.

1.6 Elektrischer Sturm

Es gibt eine direkte Assoziation zwischen Schockabgabe und Verschlechterung der Lebenqualität, sogar unabhängig von Schockanzahl oder Ätiologie des Schocks. {36; 24-25} Patienten mit elektrischem Sturm (über 3 VT/VF-Episoden innerhalb von 24 Stunden) haben ein fünffach höheres Mortalitätsrisiko, wobei auch inadäquate Schocks mit einem dreifach höheren Mortalitätsrisiko verbunden sind. {37} Der elektrische Sturm (ES) kommt in der ICD-Ära häufiger vor und ist als klinischer Ausdruck einer instabilen Situation mit hoher Mortalität und sofortigem Behandlungsbedarf zu interpritieren. In der Fachliteratur wird eine ES-Prävalence von 10-28 % beschrieben. {38-45} Patienten mit hochgradig eingeschränkter linksventrikulärer Pumpfunktion und bereits stattgefundenen VTs sind besonders gefährdet für ES. Mehrfache Schocks können zur myokardialen Verletzung, "electrical stunning" und elektromechanischer Entkopplung führen.

Darüber hinaus steigern das ventrikuläre Remodelling aufgrund der induzierten neurohormonellen Aktivierung bei der Schockabgabe sowie "adverse effects" nach aggressiver antiarrhythmischer Therapie die Mortalität dieser Patienten. Ob die Ursache der elektrische Sturm oder eher ein Epiphenomen einer bestehenden terminalen Herzinsuffizienz ist, wird kontrovers diskutiert. {48-52; 29} Die Folgen eines ES sind für die Patienten auf physischer und phychischer Ebene jedoch dramatisch. In älteren Studien sind verschiedene ES-Risikofaktoren wie zum Beispiel sekundärprophylaktische Implantation, Vorhofflimmern, linksventrikuläre Pumpfunktion und Niereninsuffizienz diskutiert worden, {42-47} eine genauere Identifizierung von unabhängigen reproduzierbaren Risikofaktoren ist noch nicht möglich. {40-41}

1.7 Risikostrafizierung

Nach den aktuellen Leitlinien ist die Implantation von Defibrillatoren eine Klasse IA Indikation für Patienten mit ischämischer oder dilatativer Kardiomypathie und deutlich eingeschränkter linksventrikulärer Pumpfunktion. Dementsprechend sind die Kosten für die Versorgung der herzinsuffizienten Patienten über die Jahre deutlich gestiegen. Obwohl alle Patienten das Risiko von inadäquaten Therapien, perioperativen Komplikationen und sekundären Arrhythmien eingehen müssen, bekommen nach aktueller Studienlage nur 30 % der Patienten im Verlauf adäquate Therapieabgaben. {52} Ältere Studien erwähnen mehrere Risikofaktoren für adäquate Therapien wie zum Beispiel Vorhofflimmern, {53-65} sekundärprophylaktische Indikation, {56-58} Niereninsuffizienz, {59-62} NYHA III-IV, {61; 62; 27} Alter {62} und Geschlecht. {27; 63} Allerdings ist die Patientenpolulation in diesen Studien so unterschiedlich, dass keine konkrete Schlussfolgerung für die tägliche Praxis getroffen werden kann. Das Ziel dieser Studie ist es daher, VT/VF-Risikofaktoren in einem "Real-World-Setting" zu identifizieren und den Einfluss der Grunderkrankung zu evaluieren.

2. Ziel

Das Ziel dieser Arbeit besteht darin, klinische Prädiktoren für Therapieabgaben bei Patienten mit ischämischer und nicht-ischämischer Kardiomyopathie zu identifizieren.

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CLINICAL RESEARCH

Differences in predictors of implantable cardioverter-defibrillator therapies in patients with ischaemic and non-ischaemic cardiomyopathies

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Aims Implantable cardioverter-defibrillators (ICDs) have been shown to reduce mortality in patients with both ischaemic and non-ischaemic cardiomyopathy by terminating life-threatening arrhythmias. However, such arrhythmic events are unequally distributed among different patient subgroups. We aimed to evaluate predictors of appropriate ICD therapies as a step towards risk stratification in a real-world cohort.

Methods and results The prevalence and predictors of appropriate ICD therapies were analysed in 330 consecutive patients (mean age 65 ± 11, 81% male) with implanted ICDs due to ischaemic ($n = 204$) or dilated ($n = 126$) cardiomyopathy. During a mean follow-up of 19 ± 9 months, 1545 appropriate ICD therapies (antitachycardia pacing and shocks) were detected in 94 patients (29%). In multivariate analysis applied on the whole cohort, the presence of atrial fibrillation [AF: odds ratio (OR) = 1.906, confidence interval (CI) = 1.143–3.177, $P = 0.013$] and secondary prevention indication (OR = 1.963, CI = 1.123–3.432, $P = 0.018$) was associated with ICD therapy. The presence of cardiac resynchronization therapy (CRT) had a protective value (OR = 0.563, CI = 0.327–0.968, $P = 0.038$). Moreover, the predictors were different depending on the aetiology of the cardiomyopathy: in the ischaemic group, only secondary prevention indication (OR = 2.0, CI = 1.029–3.891, $P = 0.041$) and the presence of a biventricular system (OR = 0.359, CI = 0.163–0.794, $P = 0.011$) remained significant, while in the non-ischaemic group, an association with AF was observed (OR = 4.281, CI = 1.632–11.231, $P = 0.003$).

Conclusion The aetiology of cardiomyopathy should be taken into consideration for the therapy of ICD patients. The protective role of CRT devices should be pointed out in ischaemic cardiomyopathy (ICM) and a more rigorous antiarrhythmic treatment should be considered for ICM patients with secondary prevention or for dilated cardiomyopathy patients with AF.

Keywords Cardiomyopathy • ICD • Antitachycardia pacing • Shocks • Predictors

Introduction

Heart failure due to ischaemic cardiomyopathy (ICM) or non-ischaemic dilated cardiomyopathy (DCM) is an important public health problem associated with an increased risk of sudden cardiac death (SCD). Implantable cardioverter-defibrillators (ICDs) have reduced mortality and become the standard of care for these patients.[1,2] As a result, ICD implantations and the concomitant costs have increased exponentially. However, pharmacological and invasive treatment of these patients has improved in the recent years. All ICD patients are at an increased risk of perioperative complications, inappropriate shocks, and secondary arrhythmias, but only about one-third of ICD patients receive appropriate ICD therapies.[2] Therefore, a further refinement of risk stratification is necessary to

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What's new?

- The modern era of cardiology has changed the population of ICD receivers.
- This study examines a contemporary cohort of 330 ICD patients for appropriate therapies according to the aetiology of their cardiomyopathy.
- We found that ischaemic patients today have a great benefit from a resynchronization therapy.
- Secondary prevention doubles the risk for arrhythmias, especially in ischaemic patients, whereas AF dramatically increases this risk, especially in non-ischaemic patients.
- Therefore, these patients warrant a more vigorous rhythm therapy.
- Trials are needed to examine the optimal method for rhythm control in these populations.

select clinical strategies for these patients today. Previous studies have tried to identify predictors of appropriate ICD therapies, including atrial fibrillation (AF),[3–5] secondary prevention,[6–8] renal dysfunction,[9–12] advanced New York Heart Association (NYHA) class,[11–13] age,[12] and gender.[13,14] Additionally, efforts were made to assess electrical instability or arrhythmic substrate,[15] but several limitations have hampered their implementation in daily clinical practice. However, all those trials included different patient populations, making it difficult to draw conclusions for clinical decision.

So far, it is still not well known which of these parameters apply in non-trial contemporary patients. Such real-world information is valuable for the translation of these studies into clinical practice. Moreover, data concerning predictors of appropriate ICD therapy with respect to the underlying cardiomyopathy are limited. Therefore, we aimed to identify risk factors for appropriate ICD therapies in patients with ICM and DCM in a real-world setting.

Methods

Patients

Consecutive patients ($n = 337$) undergoing an ICD implant in 2009–11 were included in our institutional registry. Patients with hypertrophic-obstructive cardiomyopathy ($n = 5$) and channelopathy ($n = 2$) were excluded, so that the final study population composed of 330 patients with ICM or DCM. Ischaemic cardiomyopathy was defined as a reduced left ventricular ejection fraction (LV-EF) associated with a significant coronary vessel obstruction (at least 75% narrowing of at least one major coronary artery), a history of myocardial infarction, or a history of coronary intervention. Dilated cardiomyopathy was defined as a reduced LV-EF in the absence of ischaemic, hypertrophic, valvular, or other clear aetiology of cardiomyopathy. All data were collected prospectively in accordance with institutional ethics guidelines and the Declaration of Helsinki.

Implantable cardioverter-defibrillator therapy

Device interrogations and rhythm adjudications were performed based on rate analyses, onset, stability, regularity, morphology, and atrioventricular dissociation by two experienced physicians (S.R. and M.D.). Outpatient follow-up was performed regularly at baseline, 3, 6, 12, 18, and 24 months, or after a symptomatic event or ICD shock as needed. Implantable cardioverter-defibrillators were programmed according to the current literature and manufacturer recommendations for optimal detection and therapy, including discrimination algorithms when available: Morphology Discrimination plus AV Rate Branch (St Jude Medical), PR logic and Wavelet (Medtronic), SMART (Biotronic), or Rhythm ID (Boston Scientific and Guidant). The ICD therapy was defined as either antitachycardia pacing (ATP) or ICD shock. The ventricular fibrillation (VF) zone was typically set to >200 b.p.m. with at least one train of ATP prior to shock while the ventricular tachycardia (VT) zone was typically >170 b.p.m. with at least three trains of ATP prior to shock. The monitor zone was set to >150 b.p.m. and atrial arrhythmia detection to >170 b.p.m. with supraventricular tachycardia discriminators enabled (according to the Pain-FREE trial) as previously described.[16] Device programming remained unchanged in all patients until therapies were delivered, at which point patient-specific programming changes were implemented. An ICD therapy delivered for VT or VF was defined as appropriate, and all other episodes were deemed as inappropriate.

Echocardiography

Transthoracic echocardiography data were acquired before the ICD implantation using a commercially available system (Vivid-7 and Vivid-9 General Electric Vingmed, Milwaukee, USA). Left ventricular end-diastolic and end-systolic volumes were assessed from the apical two- and four-chamber images, and LV-EF was calculated according to the monoplane or biplane Simpson method.

Statistics

Continuous variables are reported as mean $\pm$ standard deviation and categorical variables as frequencies. Continuous variables were compared using the Student's *t*-test, while categorical variables were compared using the χ^2 test. To determine the predictive factors of device therapy, univariate and multivariate analyses were performed. Variables with a *P*-value of ≤ 0.1 in univariate analysis were then included in the multivariate regression analysis for the determination of odds ratio (OR) and its 95% confidence interval (CI). A *P*-value of ≤ 0.05 was considered statistically significant. Positive predictive value and negative predictive value (NPV) were calculated for each dichotomous predictor. Survival and event-free rates from ICD intervention were calculated and depicted with the Kaplan–Meier method. All analyses were performed using SPSS v20.0 (SPSS Inc., Chicago, IL, USA).

Results

Patient population and implantable cardioverter-defibrillator therapies

Patient data are summarized in *Table 1*. Patients had a mean age of 65 ± 11, 81% male, with LV-EF of 29 ± 9%, congestive heart failure of NYHA $\geq$ II (88%) due to ICM (204, 62%) or DCM (126, 38%). There were 87 patients (26%) with ICD indications due to secondary prevention and a high prevalence of AF (150, 45%). There were 52 (16%) patients with secondary prevention and LV-EF $>$ 35% (44 ± 8%) that were similarly distributed between ICM and DCM (18 vs. 11%, $P = 0.09$). Implanted devices included 129 (39%) single-chamber, 48 (15%) dual-chamber, and 153 (46%) defibrillators with cardiac resynchronization therapy (CRT). Seven patients with ICM and three patients with DCM died after a median of 9 and 22

Table 1 Characteristics of patients with ICM or non-ischaemic DCM

	Total	ICM patients	DCM patients	*P*
Number of patients, *n*	330	204	126	
Age (years)	65 ± 10	67 ± 10	63 ± 12	0.01
Males, *n* (%)	268 (81)	180 (88)	88 (70)	0.001
Body mass index (kg/m^2)	29 ± 9	28 ± 9	29 ± 9	0.70
Diabetes mellitus, *n* (%)	136 (41)	117 (57)	76 (61)	0.57
Hypertension, *n* (%)	268 (81)	184 (90)	84 (67)	0.001
AF, *n* (%)	150 (45)	82 (40)	68 (54)	0.017
Persistent AF, *n* (%)	73 (22)	39 (19)	34 (27)	0.04
NYHA class I, *n* (%)	38 (12)	27 (13)	11 (9)	0.23
NYHA class II, *n* (%)	128 (39)	85 (41)	44 (35)	
NYHA class III, *n* (%)	146 (44)	82 (40)	64 (51)	
NYHA class IV, *n* (%)	17 (5)	10 (5)	7 (6)	
Amiodaron/sotalol, *n* (%)				
Baseline, *n* (%)	29 (9)	17 (8)	12 (10)	0.69
Temporary, *n* (%)	53 (16)	32 (16)	21 (17)	0.88
VT ablation				
Before implantation, *n* (%)	11 (3)	7 (3)	4 (3)	1.00
During follow-up, *n* (%)	12 (4)	9 (4)	3 (2)	0.55
Secondary prevention, *n* (%)	87 (26)	64 (31)	23 (18)	0.01
CRT, *n* (%)	153 (46)	69 (48)	84 (67)	0.001
LV-EF (%)	29 ± 9	31 ± 10	28 ± 8	0.01
LVEDD (mm)	61 ± 9	60 ± 9	64 ± 9	0.001
Heart rate (b.p.m.)	71 ± 17	71 ± 18	70 ± 18	0.72
QRS duration (ms)	123 ± 31	118 ± 32	132 ± 29	0.62
Creatinin (mmol/L)	108 ± 52	110 ± 58	106 ± 43	0.46

AF, atrial fibrillation; CRT, cardiac resynchronization therapy; LV-EF, left ventricular ejection fraction; LVEDD, left ventricular end-diastolic diameter; VT, ventricular tachycardia.

months, respectively ($P = 0.18$) and were censored at that time. Prior to implantation, VT ablation was performed in 11 patients with secondary prevention and sustained arrhythmias. Additionally, during follow-up there were 11 patients with secondary indication and electrical storm or sustained VT as well as an ICM patient with a slow VT (without ICD therapy) that also underwent a VT ablation.

In comparison with DCM patients, the ICM group had an older age (67 ± 10 vs. 63 ± 12 years, $P = 0.01$), higher proportion of male patients (88 vs. 70%, $P = 0.001$), a higher incidence of hypertension (90 vs. 67%, $P = 0.001$), more secondary prevention indications (31 vs. 18%, $P = 0.01$), lower incidence of AF (40 vs. 54%, $P = 0.017$), narrower QRS (118 ± 32 vs. 132 ± 29 ms, $P = 0.001$), smaller left ventricular end-diastolic diameter (60 ± 9 vs. 64 ± 9 mm, $P = 0.001$), better LV-EF (31 ± 10 vs. 28 ± 8%, $P = 0.01$), and fewer use of CRT (48 vs. 67%, $P = 0.001$). Cardiac resynchronization therapy-biventricular pacing was similar between ICM and DCM patients (95 ± 6 vs. 92 ± 11%, $P = 0.23$). New York Heart Association status after CRT implantation improved in both ICM (2.8 ± 0.7 vs. 2.0 ± 0.7, $P < 0.001$) and DCM patients (2.7 ± 0.6 vs. 1.9 ± 0.6, $P < 0.001$) in a similar proportion ($P = 0.57$). No further significant differences were found between the ICM and DCM groups, including baseline drug treatment and previous VT ablation.

During a mean follow-up of 19 ± 9 months, 1545 appropriate ICD therapies were detected in 94 patients (29%). Ventricular tachycardia was the only causative arrhythmia in 723 events, whereas VF was the sole cause in 296 events. In 526 events, both arrhythmias were found. Most frequent form of arrhythmia termination was ATP (44 patients, 47%), followed by ICD shocks (32 patients, 34%), and a combination of both (18 patients, 19%). On an average, the first episode was detected after 14 ± 9 months and was followed by multiple therapies in 19% ($n = 63$) of all patients. In 23 cases (7%), an electrical storm was detected. The incidence of appropriate ICD intervention was similar in ICM and DCM patients (29 vs. 27%, $P = 0.7$) and between patients with LV-EF ≤35% and >35% (27 vs. 38%, $P = 0.1$).

Characteristics of patients with and without appropriate therapies are compared in *Table 2*. The therapy group had a higher incidence of AF (56 vs. 41%, $P = 0.01$) and a secondary prevention indication (38 vs. 22%, $P = 0.002$), narrower QRS duration (117 ± 33 vs. 126 ± 30 ms, $P = 0.01$), and fewer CRT implants (22 vs. 38%, $P = 0.002$) when compared with the no-therapy group. Patients with narrow QRS (≤120 ms) had more appropriate therapies (34 vs. 23%, $P = 0.03$), were younger patients (63 ± 10 vs. 68 ± 10 years, $P < 0.001$) with higher incidence of ICM (71 vs. 23%, $P = 0.001$) and secondary prevention (33 vs. 20%, $P = 0.008$) than those with wider QRS. There was a trend towards the male gender receiving appropriate therapies, but this did not reach statistical significance. Antiarrhythmic drugs and VT ablation during the follow-up were more common for the therapy group. There were no other significant differences between the therapy and therapy-free patients.

There were 22 patients with QRS of 120–140 ms and reduced LV-EF (26 ± 7%) that were expected to require a high percentage of ventricular pacing and received a CRT. These patients experienced a clinical benefit through CRT (NYHA 2.8 ± 0.7 vs. 2.1 ± 0.6, $P < 0.001$). The incidence of appropriate therapies in these patients was similar to the rest of the CRT patients (18 vs. 19%, $P =$ n.s.) and was tendentially lower than the rest of the ICD patients (18 vs. 35%, $P = 0.15$).

There were also 33 patients (10%) with a total of 558 inappropriate therapies: 19 (6%) due to AF, 11 (3%) due to atrial tachycardia, and 3 (1%) due to T wave oversensing. These patients had a higher incidence of AF (77 vs. 42%, $P = 0.002$) and secondary prevention (63 vs. 23%, $P < 0.01$) when compared with the rest of the cohort.

Predictors of implantable cardioverter-defibrillator therapies in the general population

In the overall population, the presence of AF, secondary prevention indication, CRT use, NYHA class, male gender, diabetes, and QRS duration were included in a forward, stepwise model. Multivariable analysis showed that patients receiving therapy were more likely to have a history of AF (OR = 1.906, CI = 1.143–3.177, $P = 0.013$) and an indication for secondary SCD prevention (OR = 1.963, CI = 1.123–3.432, $P = 0.018$). To the contrary, patients with CRT systems were less likely to experience an ICD therapy when

Table 2 Characteristics of patients with or without ICD therapy in the total population and according to the presence of ICM or non-ischaemic DCM

	All patients			ICM patients			DCM patients		
ICD therapies (patients)	**Yes (94)**	**No (236)**	***P***	**Yes (60)**	**No (144)**	***P***	**Yes (34)**	**No (92)**	***P***
Age (years)	65 ± 11	66 ± 11	0.60	65 ± 11	67 ± 9	0.06	65 ± 11	66 ± 11	0.24
Males, *n* (%)	82 (87)	186 (78)	0.09	56 (93)	124 (86)	0.16	26 (77)	32 (67)	0.26
Body mass index (kg/m^2)	28 ± 5	29 ± 10	0.55	28 ± 8	27 ± 9	0.50	28 ± 5	29 ± 10	0.55
Diabetes mellitus, *n* (%)	30 (32)	106 (45)	0.03	20 (33)	67 (46)	0.09	10 (29)	39 (43)	0.22
Hypertension, *n* (%)	79 (84)	189 (80)	0.53	79 (84)	189 (80)	0.53	23 (68)	61 (67)	1.00
AF, *n* (%)	53 (56)	97 (41)	0.01	26 (43)	56 (40)	0.64	27 (79)	41 (45)	0.001
Persistent AF, *n* (%)	23 (25)	50 (21)	0.52	11 (18)	28 (19)	0.68	12 (35)	22 (24)	0.001
NYHA class I, *n* (%)	13 (14)	25 (11)	0.35	26 (43)	16 (11)	0.08	2 (6)	9 (10)	0.40
NYHA class II, *n* (%)	38 (40)	91 (39)		26 (43)	59 (41)		12 (35)	32 (35)	
NYHA class III, *n* (%)	35 (37)	111 (46)		18 (30)	64 (44)		17 (50)	47 (51)	
NYHA class IV, *n* (%)	8 (9)	9 (4)		5 (8)	5 (4)		3 (9)	4 (4)	
Amiodaron/sotalol, *n* (%)									
Baseline, *n* (%)	12 (13)	17 (7)	0.11	7 (12)	10 (7)	0.28	5 (15)	7 (8)	0.31
Temporary, *n* (%)	24 (26)	29 (12)	0.01	14 (23)	18 (13)	0.05	10 (29)	11 (12)	0.03
VT ablation									
Before implantation, *n* (%)	4 (4)	7 (3)	0.52	4 (7)	3 (2)	0.19	4 (9)	–	0.57
During follow-up, *n* (%)	11 (12)	1 (0.4)	0.001	8 (13)	1 (0.7)	0.001	3 (9)	–	0.02
Secondary prevention, *n* (%)	36 (38)	51 (22)	0.002	27 (45)	37 (26)	0.008	9 (27)	14 (15)	0.10
CRT, *n* (%)	31 (33)	122 (52)	0.002	10 (17)	59 (41)	0.001	21 (62)	63 (69)	0.53
LV-EF (%)	31 ± 10	29 ± 9	0.14	33 ± 10	30 ± 9	0.13	31 ± 10	29 ± 9	0.77
LVEDD (mm)	61 ± 10	62 ± 9	0.64	60 ± 10	60 ± 8	0.93	61 ± 10	62 ± 9	0.53
Heart rate (b.p.m.)	72 ± 17	71 ± 18	0.61	72 ± 18	71 ± 19	0.74	72 ± 17	71 ± 18	0.72
QRS duration (ms)	117 ± 33	126 ± 30	0.01	109 ± 32	122 ± 31	0.01	117 ± 33	126 ± 30	0.59
Creatinin (mmol/mL)	108 ± 42	108 ± 57	0.89	106 ± 33	112 ± 65	0.53	108 ± 42	108 ± 57	0.26

AF, atrial fibrillation; CRT, cardiac resynchronization therapy; LV-EF, left ventricular ejection fraction; LVEDD, left ventricular end-diastolic diameter; VT, ventricular tachycardia.

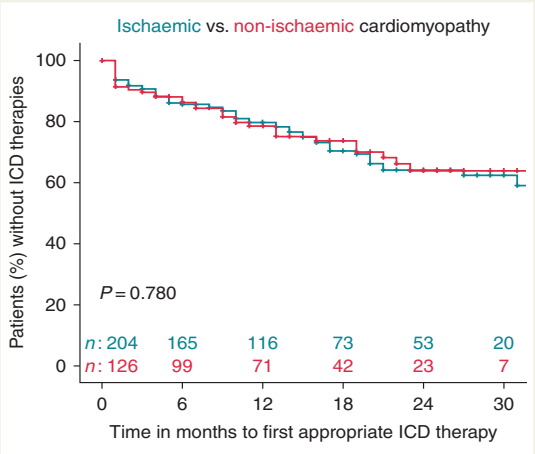

Figure 1 Kaplan–Meier curves for freedom from appropriate ICD therapies in patients with ischaemic (turquoise) and non-ischaemic (red) cardiomyopathy.

compared with patients with single- or dual-chamber devices (OR = 0.563, CI = 0.327–0.968, *P* = 0.038).

Differences between ischaemic and non-ischaemic cardiomyopathy

The incidence of appropriate ICD intervention was similar in ischaemic and non-ischaemic patients with comparable ratios for ATP (14 vs. 12%, *P* = 0.68), shock (5 vs. 6%, *P* = 0.71), or a combination (9 vs. 10%, *P* = 0.7). Kaplan–Meier curves depicting freedom from appropriate ICD therapy for both ICM and DCM patients are shown in *Figure 1*.

Results from an individual univariate and a multivariate analysis separately for each cardiomyopathy type are shown in *Table 2* and *Figure 2*, investigating the importance of baseline differences between ICM and DCM patients. Multivariate analysis revealed that in ischaemic patients, only the secondary prevention indication (OR = 2.000, CI = 1.029–3.891, *P* = 0.041) and the presence of a CRT (OR = 0.359, CI = 0.163–0.794, *P* = 0.011) remained as significant independent predictor. Positive predictive value and NPV were 45 and 74% for secondary prevention, and 62 and 58% for CRT, respectively. In the DCM group, multivariate analysis revealed

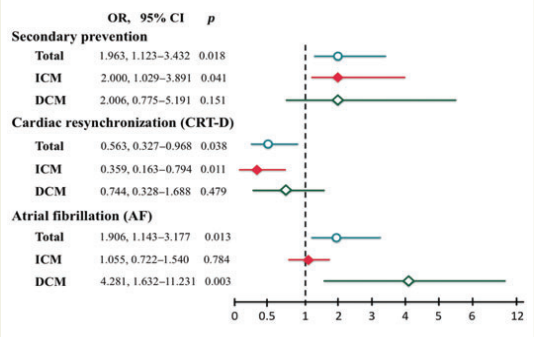

Figure 2 Multivariable logistic regression for the predictors of appropriate therapies in ICM and non-ischaemic DCM. The figure presents graphically the OR for appropriate therapies with the corresponding 95% CIs and *P* values.

the presence of AF as the only predictor showing an association with appropriate therapies (OR = 4.281, CI = 1.632–11.231, $P = 0.003$). Positive predictive value and NPV for AF were 79 and 55%, respectively.

Kaplan–Meier curves illustrate that in patients with ICM, freedom from therapy was significantly higher if the initial indication was not for secondary prevention (*Figure 3A*), or if a biventricular system was present (*Figure 3B*). In the DCM group, freedom from therapy was significantly higher in patients without AF (*Figure 3C*), whereas indication or CRT use did not have a relevant effect on the appropriate therapies applied.

A sub-analysis for shock therapies revealed AF (OR = 2.941, CI = 1.541–5.635, $P = 0.001$) and secondary prevention (OR = 2.542, CI = 1.341–5.664, $P = 0.004$) as independent predictors and a tendency for a protective CRT effect (OR = 0.545, CI = 0.290–1.024, $P = 0.059$). In ICM patients, both AF (OR = 2.767, CI = 1.248–6.133, $P = 0.012$) and secondary indication (OR = 2.375, CI = 1.074–5.250, $P = 0.033$) remained significant, whereas in DCM patients AF (OR = 3821, CI = 1.192–12.265, $P = 0.024$) was the only independent factor associated with shock therapies.

Discussion

Main findings

This study demonstrates that baseline characteristics of ICD recipients can be useful for identifying patients at high risk for appropriate therapies and that these parameters are different according to their type of cardiomyopathy. In this cohort of real-world patients, appropriate therapies occurred in 29% over a mean follow-up of 19 $\pm$ 9 months. In this setting, secondary prevention indication and AF were associated with an ICD therapy, while the presence of a CRT showed a protective effect. However, in the ICM population, only secondary prevention indication and the presence of a CRT proved independently predictive, whereas in the DCM population, only AF remained significant. These findings reveal the most important predictors of ICD therapies in a real-world experience and are valuable for their ease of use in clinical practice.

Implantable cardioverter-defibrillator therapies

The incidence of appropriate ICD therapy in our study population was 29% over almost 2-year follow-up and is higher when compared with results from MADIT-II trial (ICD shock rate of 23% over a follow-up of 17 months)[2] and of SCD-HeFT trial (21% over a 5-year follow-up).[1] Moreover, in contrast to the previous studies, 25% of our patients received an ICD with secondary prevention indications. This could be explained by the changing characteristics of heart failure patients in the recent years. Since advanced medical treatment and improved revascularization technics are now widely available, more patients survive an SCD and more heart failure patients live longer, tending to have a higher risk for arrhythmias. This reflects the importance of our findings that apply better on contemporary patients.

Predictors of implantable cardioverter-defibrillator therapies

Previous studies examining ICD-therapy predictors were mostly older clinical trials with different patient populations, mostly from the 1990s, that focused on specific risk factors, such as AF, secondary prevention, renal function, without regarding the underlying cardiomyopathy.[3–7,10,14] Recent data added some practical insights, such as the presence of non-sustained VT or lack of β-blockers,[17–19] but the application of so many different predictors in a changing population of heart failure patients still remains a hurdle. Therefore, more practical data are needed in order to put this knowledge into a real-world perspective.

The results of our study support that patients surviving SCD and receiving ICDs are two times as likely to receive appropriate therapies, especially in ICM patients.[6–8,15] Secondary prevention though is less prevalent and does not reach statistical significance for DCM patients. A possible explanation for this may be the improved survival of ischaemic patients after an aborted SCD. Additionally, the presence of local scar makes ICM patients more vulnerable to arrhythmias, whereas in DCM electrical disturbances tend to have a more diffuse distribution. Nevertheless, secondary prevention represents the presence of an arrhythmogenic substrate and tends to be significant ($P = 0.07$) for DCM patients too. Since ICD patients with secondary prevention are more common today, closer follow-up and timely treatment of arrhythmias should be more vigorous in these patients.

The appropriate application of CRT is a well-known preventive factor that has changed the disease course of heart failure patients. When compared with ICM, DCM patients have been found to have a greater response to CRT but without any effect on the incidence of ICD shocks.[20] The present findings suggest that in the long-term, although all patients improve in NYHA class, ICM patients could benefit more from a proper CRT use. The increased benefit from CRT in ICM patients nowadays may be a result of reduced scar burden. Contrary to previous randomized landmark trials, patients today benefit more from an improved medical and revascularization therapy. As such, efforts should focus into carefully applying and improving resynchronization in ICM patients, e.g. by improving methods to assess the optimal LV-lead position.

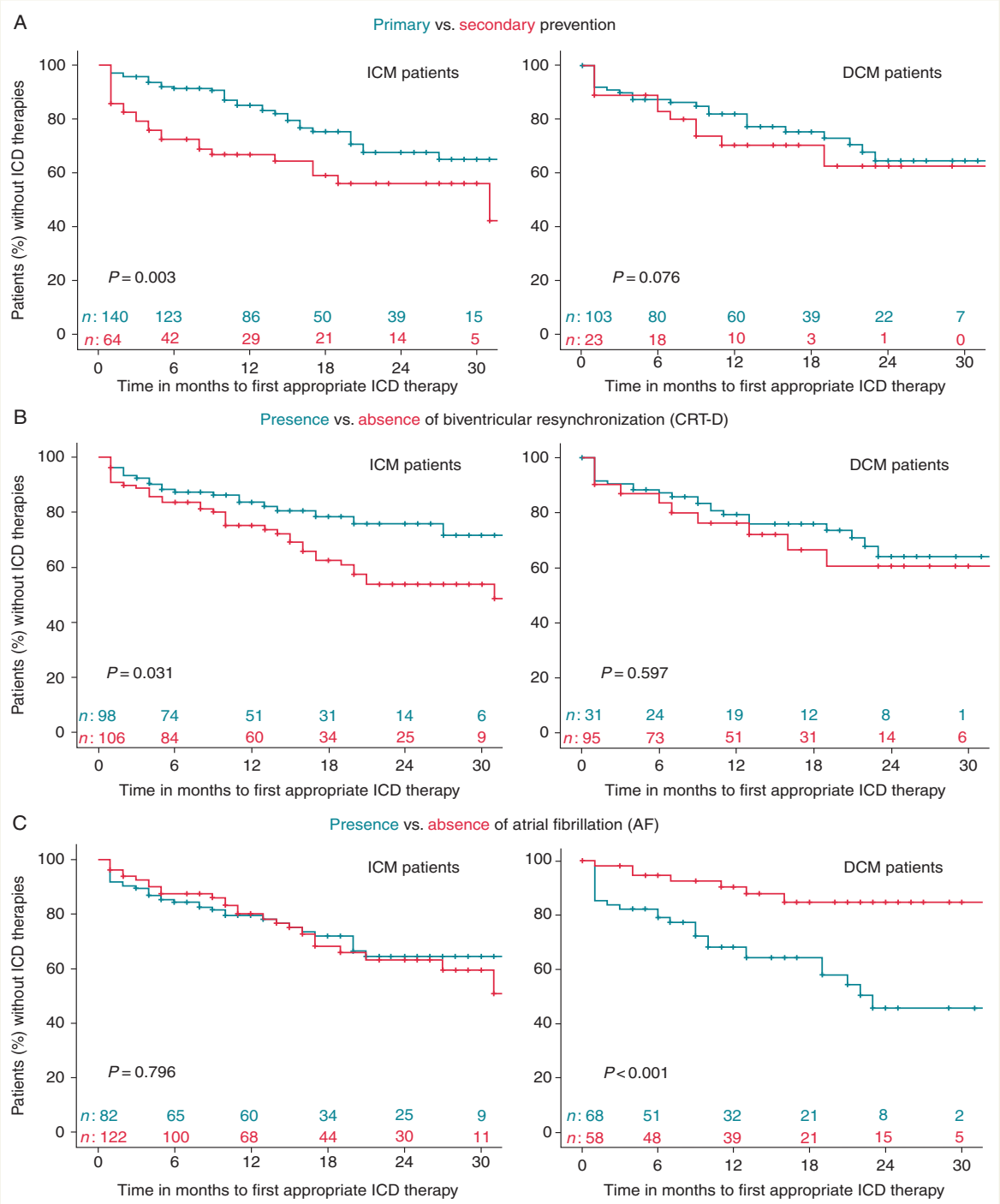

Figure 3 Kaplan–Meier curves for freedom from appropriate ICD therapies in ICM and non-ischaemic DCM patients according to (*A*) indication of implantation, (*B*) the presence of a biventricular resynchronization system, and (*C*) the presence of AF.

Atrial fibrillation is another known risk-factor[3–5] that increased appropriate ICD therapies by almost two times in this study population and by four times in patients with DCM. This association may be explained through different mechanisms: (i) a direct causation due to a pro-arrhythmic effect of short–long–short sequences and reduced ventricular refractoriness; (ii) an indirect causation due to haemodynamic changes (e.g. decreased diastolic filling and cardiac output) and reflex increase in the sympathetic tone; and (iii) a tachycardia-induced ischaemia with secondary activation disorders, especially in patients with ICM. However, as shown in the current study, AF was mostly associated with appropriate shocks in DCM patients and therefore the contribution of an ischaemic mechanism is probably trivial. Finally, since AF and ventricular arrhythmias can share common risk factors, AF may be interpreted as an epiphenomenon or as a surrogate of advanced heart failure that leads to more ICD therapies. This association is further supported by recent evidence that an effective rhythm control such as AF catheter ablation could reduce ICD therapies (both appropriate and inappropriate) and improve LV-EF in ICD patients.[16] In this sense, prompt initiation of aggressive antiarrhythmic therapy should be considered for DCM patients with AF.

Other previously described predictors for ICD therapies[9–14] were not confirmed by our findings. This could be explained by the fact that we included a homogenous population and optimal medical therapy prior to reference in our tertiary centre. Renal dysfunction, obesity, and advanced age or heart failure were not as prevalent in our study population as in other studies[9–13] and thus failed to reach a significant predictive value. Prior VT ablation in this cohort was limited and statistically did not affect future ICD therapies. Interestingly, in this study more patients with narrow QRS had appropriate therapies than those with a wider QRS. These were younger patients with higher incidence of ICM and secondary prevention. This could represent a higher substrate burden in these patients that in combination with proper CRT use (high biventricular pacing) in patients with wide QRS may have eliminated the predictive value of QRS duration.[15] Nevertheless, this cohort of patients represents the typical constellation of current clinical presentations, where heart failure is diagnosed early and ICD therapy is applied before co-morbidities develop.

Clinical implications

The observations of this study add to our understanding of the differences between ICM and non-ischaemic DCM. Earlier primary prevention ICD studies did not differentiate with respect to the aetiology of heart failure. Our data supplement previous studies and suggest that the type of cardiomyopathy should be taken into consideration at the time of ICD implantation. In ischaemic patients, the benefit of CRT devices should be emphasized and appropriate application should be pursued, including patients with expected pacemaker-dependency. Ischaemic patients with secondary prevention and non-ischaemic patients with AF should undergo a rigorous rhythm-stabilising treatment, in order to avoid the high risk of appropriate therapies, especially the shock therapies. Simple clinical criteria such as these are easy to implement in the clinical routine and maybe helpful for therapy planning according to the aetiology of the cardiomyopathy in ICD patients.

Limitations

This is a single-centre study with the limitations of a *post hoc* analysis. However, we included consecutive patients with regular and thorough device interrogations to obtain a comprehensive dataset. In addition, the use of both shock and appropriate ATP, led to the inclusion of slower and relatively stable VTs that are not necessarily life-threatening. However, given the adverse effects of a slow VT (syncope, de-compensation, and secondary arrhythmias) prediction of stable VTs may be as equally important. Inclusion and programming of different devices could have had an effect on our findings, but guideline-guided programming did not change throughout the study, except in case of an ICD therapy. Therefore, the Kaplan–Meier curves remain unaffected and still depict the differences in terms of freedom from therapies. Finally, reduced co-morbidities and clinical characteristics of the local population may have had an effect. On the other hand, this may also represent a trend towards earlier diagnosis and intervention in heart failure patients. Further studies are needed to clarify the importance of the clinical parameters studied here and their association with complementary diagnostics in order to examine the effect of an optimal CRT use or of a strict rhythm therapy in ICD patients, in terms of mortality and quality of life. The optimal method of rhythm control in such patients remains to be proved in prospective trials.

Conclusions

The aetiology of cardiomyopathy should be taken into consideration for the therapy of ICD patients. Proper CRT use was shown to be important for ischaemic patients, whereas secondary prevention in ischaemic patients or the presence of AF in non-ischaemic patients is critical and warrants an aggressive rhythm control in these patients.

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Electrical storm in patients with implantable cardioverter-defibrillator in the era of catheter ablation: Implications for better rhythm control

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BACKGROUND The modern era of cardiology has changed the population of implantable cardioverter-defibrillator (ICD) recipients. Identifying predictors of electrical storm (ES) in contemporary ICD patients could improve risk stratification, therapeutic strategies, and mortality.

OBJECTIVE The purpose of this study was to address these points in a real-world setting.

METHODS In 330 consecutive patients (65 ± 11 years, 81% male, left ventricular ejection fraction 29% ± 9%) with ICD implanted because of ischemic (n, 204) or nonischemic dilated cardiomyopathy (n, 126), we analyzed the prevalence, predictors, and outcome of ES (≥3 separate VT/VF episodes within 24 hours) therapy.

RESULTS During a median of 21 months (range 17–36 months), 23 patients (7%) had ES. Secondary prevention (61% vs 24%, $P < .01$), single-chamber devices (57% vs 38%, $P = .02$), and prior appropriate (96% vs 24%, $P < .001$) and inappropriate (30% vs 9%, $P = .004$) therapies were more prevalent in these patients. In ES patients, first appropriate therapy occurred more often in the first year after implantation than in the rest of the cohort (85% vs 45%, $P = .008$), and mortality was significantly higher (22% vs 2%, $P < .001$). Multivariate Cox regression analysis showed that secondary prevention (hazard ratio [HR] 2.83, 95% confidence interval [CI] 1.21–6.61, $P = .016$) and prior appropriate (HR 88.99, 95% CI 11.73–675, $P < .001$) and inappropriate (HR 2.83, 95% CI 1.14–7.0, P = .04) therapies were independent predictors of ES.

CONCLUSION ES is not uncommon in ICD recipients. A secondary prevention indication and the occurrence of both appropriate and inappropriate ICD therapies increase the risk for ES. Prompt initiation of aggressive treatment, especially catheter ablation, should be considered for these patients.

KEYWORDS Catheter ablation; Electrical storm; Implantable cardioverter-defibrillator; Shocks; Predictors

ABBREVIATIONS **AAD** = antiarrhythmic drug; **AF** = atrial fibrillation; **ATP** = antitachycardia pacing; **CI** = confidence interval; **CRT** = cardiac resynchronization therapy; **DCM** = nonischemic dilated cardiomyopathy; **ES** = electrical storm; **HR** = hazard ratio; **ICD** = implantable cardioverter-defibrillator; **ICM** = ischemic dilated cardiomyopathy; **LVEF** = left ventricular ejection fraction; **VF** = ventricular fibrillation; **VT** = ventricular tachycardia

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Introduction

Electrical storm (ES) is a devastating, life-threatening event that has become more commonly seen in today's clinical practice. Characterized by multiple episodes of ventricular tachycardia (VT) or ventricular fibrillation (VF), ES represents an unstable condition that remains challenging in terms of management and prevention. As a result of the wide use of implantable cardioverter-defibrillator (ICD) and modern therapy improvements, ICD recipients now survive longer and run a higher risk for recurrent arrhythmias.[1–3]

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ICD recipients with impaired systolic function or a previous history of arrhythmias are at increased risk for ES and cardiac death.[4] Whether ES is a causal factor or just an epiphenomenon is still unclear, although it is undisputable that repetitive shocks may provoke myocardial damage and contribute to further deterioration of the underlying disease. Nevertheless, ES exposes patients to great physical and psychological stress, whose impact on clinical outcome should not be underestimated.[1–3] Therefore, identifying ES predictors in a real-world setting would facilitate risk stratification and clinical therapy of these patients.

Previous studies have attempted to identify ES predictors, including secondary prevention, atrial fibrillation (AF), ejection fraction, renal insufficiency, and other potential triggering factors such as worsening of heart failure, emotional stress,

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alcohol excess, electrolyte abnormalities, and myocardial ischemia.[5–10] However, no independent predictors have been reproducibly identified, and the role of prior ICD therapies has not yet been sufficiently addressed.[3,4]

Therefore, we aimed to identify ES predictors in ICD recipients in a real-world setting, with a focus on prior ICD therapies and their impact on outcome and prognosis in the era of VT catheter ablation.

Methods

Patients

Consecutive patients (n, 337) undergoing an ICD implant in 2009–2011 were included in our institutional registry. Patients with hypertrophic obstructive cardiomyopathy (n, 5) and channelopathy (n, 2) were excluded, so the final study population comprised 330 patients with ischemic dilated cardiomyopathy (ICM, n, 204 [62%]) or non-ischemic dilated cardiomyopathy (DCM, n, 126 [38%]). ICM was defined as reduced left ventricular ejection fraction (LVEF) associated with significant coronary vessel obstruction, a history of myocardial infarction, or a history of coronary intervention. DCM was defined as reduced LVEF in the absence of ischemic, hypertrophic, or other clear etiology of cardiomyopathy. All data were collected in accordance with the Declaration of Helsinki, and the study was approved by the institutional research committee.

Echocardiography

Transthoracic echocardiography data were acquired before ICD implantation using a commercially available system (Vivid-9 General Electric Vingmed, Milwaukee, WI). Left ventricular end-diastolic and end-systolic volumes were assessed from the apical 2- and 4-chamber images, and LVEF was calculated according to the Simpson method.

ICD programming

Device interrogation was performed regularly (every 4–6 months) or on demand after ICD shocks or after a symptomatic event in an outpatient clinic. Rhythm adjudications were performed based on rate analyses, onset, stability, regularity, morphology, and atrioventricular disassociation by 2 experienced physicians (SR, MD). ICDs were programmed according to the current manufacturer recommendations for the optimal arrhythmia detection and therapy, including discrimination algorithms when available: Morphology Discrimination plus AV Rate Branch (St. Jude Medical), PR logic and Wavelet (Medtronic), SMART (Biotronik), or Rhythm ID (Boston Scientific and Guidant). The ICD therapy was defined as either antitachycardia pacing (ATP) or ICD shock. The ventricular fibrillation (VF) zone was typically set to >200 bpm with at least 1 train of ATP before shock whereas the ventricular tachycardia (VT) zone typically was >170 bpm with at least 3 trains of ATP before shock. The monitor zone was set to >150 bpm and atrial arrhythmia detection to >170 bpm with tachycardia discriminators enabled (according to the Pain-FREE trial) as previously described.[11] An ICD therapy delivered for VT or VF was defined as appropriate, and all other episodes were deemed as inappropriate. Device programming remained unchanged in all patients until therapies were delivered or an ablation procedure was preformed, at which point patient-specific programming changes were implemented.

ES Definition and Therapy

ES was defined as ≥ 3 separate episodes of VT/VF within 24 hours, separated by bouts of normal rhythm after a successful therapy, either ATP or shock.[1] To qualify as ES, the 3 episodes could not be continuous VT/VF in which device therapy was unsuccessful or VT below detection that is untreated.

ES treatment was based on physician's preference and when possible on the treatment of reversible causes. Conservative treatment included admission to the intensive care unit, electrolyte substitution, recompensation, revascularization, and beta-blocker and antiarrhythmic drugs (AADs) as necessary. Amiodarone or lidocaine were the first-choice in the acute phase and oral amiodarone or sotalol were preferred for chronic management. Hypokalemia was preferably treated by substitution, whereas premature ventricular contractions were rather ablated.

Catheter Ablation Procedure

VT ablation was performed for patients not responding to AAD or as a first-choice for recurrent or incessant arrhythmias, as previously described.[12,13] After providing signed informed consent, patients were studied while under deep propofol sedation with continuous invasive monitoring of arterial blood pressure and oxygen saturation. The left ventricle was accessed through a transseptal approach using a steerable introducer (Agilis, St. Jude Medical, St. Paul, MN). Electroanatomic maps were obtained while patients were in sinus rhythm (CARTO 3, Biosense Webster Inc, Diamond Bar, CA; or EnSite, St. Jude Medical, Minneapolis, MN). Ablation was performed using 3.5-mm saline-irrigated catheters (Navistar ThermoCool, Biosense Webster; or Celsius ThermoCool, Biosense Webster, 40–50 W, 30 mL/min) and a multichannel recording system (Prucka Cardiolab, GE, Milwaukee, WI). Isovoltage maps were constructed, and areas with healthy tissue (>1.5 mV), dense scar (<0.5 mV), or fragmented, late potentials were annotated. If not incessant, VT was induced with programmed stimulation and activation or entrainment mapping was performed to locate exit sites and critical isthmuses. For hemodynamically unstable VTs, activation and pace-mapping were used and substrate modification was based on local potentials. Epicardial approach was used in 1 case after an unsuccessful prior endocardial ablation. Ablation end-points were elimination of the clinical (partial acute success) or any induced VT (complete acute success).

In order to calculate the impact of ES therapy on ICD therapies, total follow-up time (3.4 $\pm$ 1.1 years) was

divided into a period from ICD implantation until ES therapy (0.8 ± 0.7 years) and into a period from thereon (2.5 ± 1.3 years) to the most recent follow-up, the next ES, an additional AAD, or AF ablation. In order to mitigate the bias of a reduced AF burden on the incidence of appropriate therapies after an AF ablation, patients were censored at the time of the procedure (in 2 cases after 0.8 ± 0.7 years). These patients had previously received both appropriate and inappropriate (due to AF) ICD therapies.

Statistical Analysis

Continuous variables are reported as mean ± SD if normally distributed (Kolmogorov–Smirnov test) and as proportions for categorical variables. Continuous variables were compared using the Student *t* test, whereas categorical variables were compared using the χ^2 test. To determine the predictive factors of device therapy, univariate and multivariate analyses were performed. Variables with $P \leq .1$ in univariate analysis were then included in the multivariate Cox regression analysis for determination of the hazard ratio (HR) and its 95% confidence interval (CI). $P \leq .05$ was considered significant. Positive predictive value and negative predictive value were calculated for each dichotomous predictor. Survival and event-free rates from ES were calculated and depicted with the Kaplan–Meier method. All analyses were performed using SPSS (version 20.0, SPSS Inc, Chicago, IL).

Results

Patient Population and ICD Therapies

Patient data are summarized in Table 1. Devices included 129 (39%) single-chamber, 48 (15%) dual-chamber, and 153 (46%) defibrillators with cardiac resynchronization (CRT-D). During follow-up, 33 patients (10%) had inappropriate therapies due to AF (n, 19 [6%]), supraventricular tachycardia (n, 11 [3%]), or T-wave oversensing (n, 3 [1%]). Some patients with ICM (n, 7) or DCM (n, 3) died after a median of 9 and 22 months ($P = .18$), respectively, and were censored at that time.

ES Predictors

After a median of 21 months (range 17–36 months, 23 patients (7%) had ES. Secondary prevention indication (61% vs 24%, $P < .01$), single-chamber devices (57% vs 38%, $P = .02$), and prior appropriate (96% vs 24%, $P < .001$) and prior inappropriate (30% vs 9%, $P = .004$) therapies were more prevalent in these patients. In patients with ES, first appropriate therapy occurred more often in the first year after implantation than in the rest of the cohort (85% vs 45%, $P = .008$). Mortality of ES patients was significantly increased (22% vs 2%, $P < .001$).

Multivariate Cox regression analysis showed that secondary prevention indication (HR 2.83, 95% CI 1.21–6.61, $P = .016$), appropriate (HR 88.99, 95% CI 11.73–675.00, $P < .001$), and inappropriate (HR 2.83, 95% CI 1.14–7.00, $P = .04$) therapies before the ES episode were independent predictors of ES (Figure 1). Kaplan–Meier curves illustrate that freedom from ES in ICD patients was significantly lower for patients with secondary prevention, or appropriate or inappropriate therapies (Figure 2).

In patients with CRT-D (see Online Supplementary Table 1), those with ES (n, 5) during follow-up had a higher incidence of secondary indication (60% vs 14%, $P = .03$) and more often appropriate therapies (100% vs 18%, $P < .001$), especially in the first year after implantation (60% vs 16%, $P = .04$), despite frequent use of AADs

Table 1 Characteristics of ICD patients with and without electrical storm

	Total	Electrical storm		*P* value
No. of patients	330	No (307)	Yes (23)	
Age (years)	65 ± 10	65 ± 10	68 ± 12	.14
Males	268 (81)	248 (81)	20 (87)	.34
Body mass index (kg/m^2)	29 ± 9	28 ± 9	29 ± 9	.72
Diabetes mellitus	136 (41)	129 (42)	7 (30)	.38
Hypertension	268 (81)	248 (81)	20 (87)	.59
AF	150 (50)	137 (45)	13 (57)	.29
Persistent AF	73 (22)	67 (22)	6 (26)	.53
NYHA class I	38 (12)	35 (11)	3 (13)	.21
NYHA class II	128 (39)	120 (39)	9 (39)	1.00
NYHA class III	146 (44)	135 (44)	11 (48)	1.00
NYHA class IV	17 (5)	17 (6)	—	.38
Amiodarone/sotalol	29 (9)	25 (8)	4 (7)	.13
Secondary prevention	87 (26)	73 (24)	14 (61)	<.001
Ischemic cardiomyopathy	203 (62)	189 (62)	14 (61)	.55
Single-chamber device	129 (39)	116 (38)	13 (57)	.02
CRT-D	153 (46)	148 (48)	5 (22)	.06
Appropriate therapies	94 (24)	72 (24)	22 (96)	<.001
Single	32 (10)	31 (10)	1 (4)	<.001
Multiple	63 (14)	42 (14)	21 (92)	<.001
During first year	158 (48%)	138 (45)	20 (85)	.008
Inappropriate therapies	33 (10)	26 (9)	7 (30)	.004
Mortality	10 (3)	5 (2)	5 (22)	<.001
LVEF	29 ± 9	28 ± 9	28 ± 8	.98
LVEDD (mm)	61 ± 9	62 ± 9	60 ± 9	.52
Heart rate (bpm)	71 ± 17	71 ± 18	70 ± 18	.38
QRS duration (ms)	123 ± 31	124 ± 31	114 ± 41	.14
Creatinine (mmol/L)	108 ± 52	108 ± 54	111 ± 36	.81

Values are given as mean ± SD or no. (%).

AF, atrial fibrillation; CRT-D, cardiac resynchronization therapy–defibrillator; ICD, implantable cardioverter-defibrillator; LVEF, left ventricular ejection fraction; LVEDD, left ventricular end-diastolic diameter; NYHA, New York Heart Association.

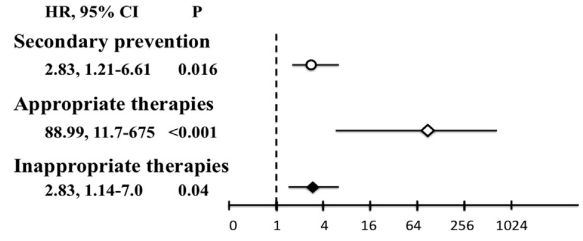

Figure 1 Multivariable Cox regression analysis for predictors of electrical storm (ES) in implantable cardioverter-defibrillator patients. Graphic representation of hazard ratios (HR) for ES with corresponding 95% confidence intervals (CI) and *P* values.

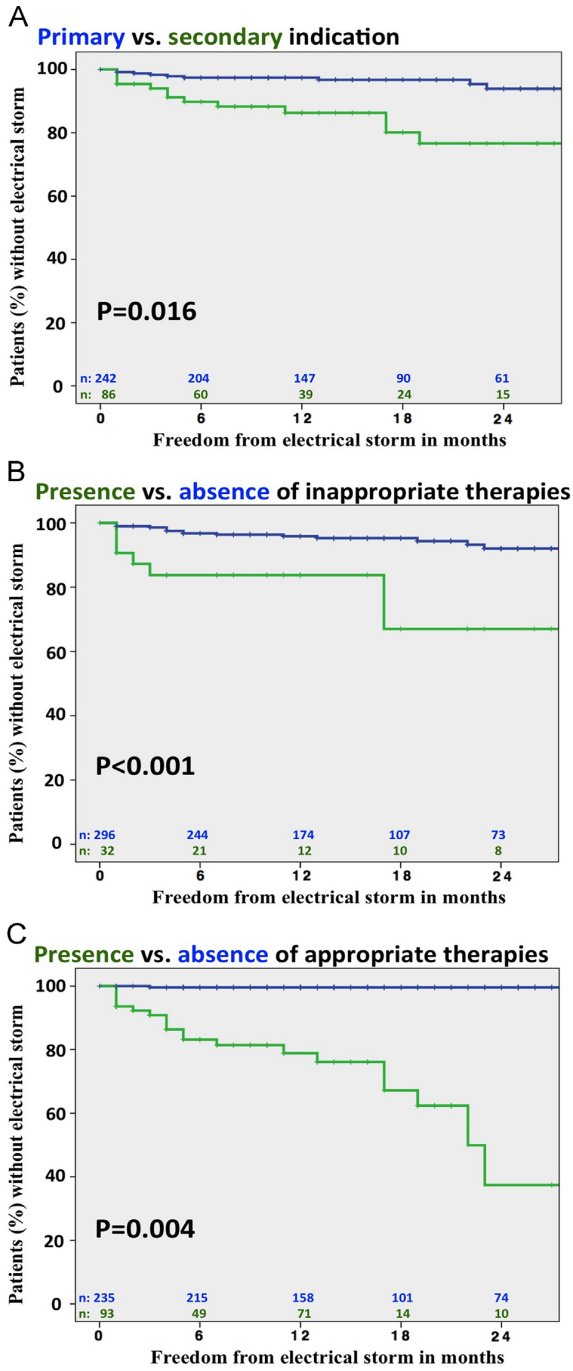

Figure 2 Kaplan–Meier curves for freedom from electrical storm in implantable cardioverter-defibrillator patients according to indication for implantation **(A)** and occurrence of inappropriate **(B)** or appropriate **(C)** therapy.

(60% vs 10%, $P = .01$). However, the low number of ES cases prohibited regression analysis from revealing statistically significant predictors.

ES Therapy

Conservative therapy was chosen in 11 patients, 5 of whom were treated with amiodarone and 5 stabilized after electrolyte substitution, beta-blocker dose increase, and cardiac recompensation. One patient rapidly deteriorated because of hemodynamically ongoing VTs despite AADs and died before VT ablation was performed.

VT ablation was performed in 12 patients (52%), 2 with ongoing VT, 2 with noninducible VT, and 8 with inducible VT. In 2 patients, ventricular premature beats initially were targeted as presumptive triggers for the clinical VTs, and further ablation of inducible VTs was pursued. Noninducibility of any VT (acute complete success) was achieved in 8 patients (67%), whereas elimination of the clinical tachycardia only (acute partial success) was achieved in 4 (33%). At discharge, all patients were prescribed beta-blockers, and 5 (42%) had an additional AAD (4 on amiodarone, 1 on sotalol). One patient (8%) experienced a second ES after 40 months and was prescribed amiodarone at that point. Additionally, 4 patients underwent a second ablation because of sustained VT (n, 3) or symptomatic premature ventricular contraction (PVC, n, 1).

Patients with polymorphic VT or primary VF (n, 6) often had hypokalemia as a primary cause and could be effectively treated conservatively rather than undergo an ablation (83% vs 16%, $P = .069$). Patients with monomorphic VT (n, 15) were distributed similarly to both treatments (40% vs 60%, $P = .4$) whereas patients with primary initiating premature ventricular contractions (n, 3) were selected for ablation ($P = .48$). The difference in indications for ES treatment though between ablated and non-ablated patients did not reach statistical significance ($p > 0.05$).

Considering the total number of appropriate device therapies applied, a significant reduction was observed. During follow-up, 119.4 ± 175.9 appropriate therapies per patient-year were administered before ES as opposed to 5.2 ± 7.1 during 2.5 ± 1.3 years after ES therapy ($P = .009$). There was no significant reduction of inappropriate therapies (Figure 3).

Patients who received conservative treatment had a tendency for reduction of appropriate therapies per patient-year (18 ± 11 vs 5 ± 8, $P = .05$), whereas patients who underwent VT ablation experienced a significant reduction (202 ± 205 vs 5 ± 7, $P = .01$). Ablated patients had initially more appropriate therapies ($P = .016$) and experienced a higher reduction (197 ± 205 vs 13 ± 17 therapies per patient-year, $P = .014$). However, other clinical characteristics and follow-up time (before and after ES) were similar between the 2 groups. Mortality was 8% (1/12) in the ablated patients and 18% (2/11) in the conservative treatment group ($P = .09$).

Discussion

Main Findings

This study demonstrates that secondary prevention and previous ICD therapies, both appropriate and inappropriate, signify a higher risk for ES in the future. In this cohort of

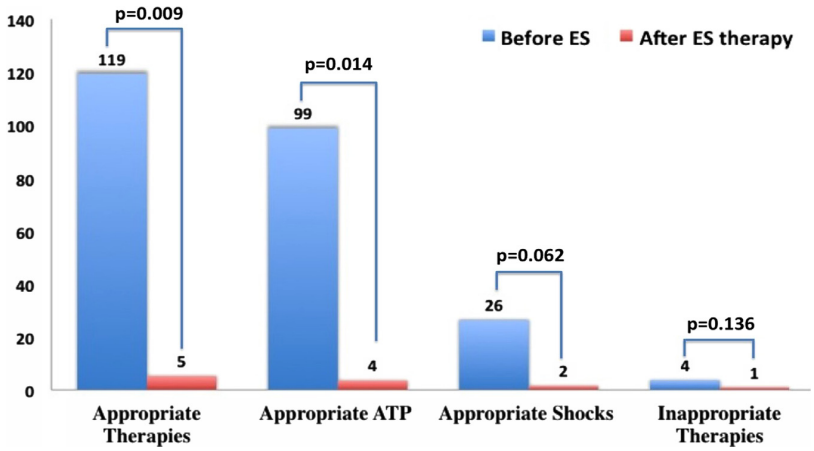

Figure 3 Number of implantable cardioverter-defibrillator therapies per patient-year before electrical storm (ES, *blue*) in comparison to the period after appropriate ES therapy *(red)*. Therapies for ES were excluded from the analysis. ATP, antitachycardia pacing.

real-world patients, appropriate therapies occurred in 7% over median follow-up of 21 months. Appropriate treatment of the cause of ES can reduce the number of appropriate ICD therapies, and VT ablation is an effective rhythm therapy, especially for patients with high VT burden. Because ES is associated with higher mortality, catheter ablation could carry a survival benefit that deserves further investigation in comparison to pharmacologic treatment.

ES prevalence and Mortality

The occurrence of ES is a life-threatening event that is not rare in everyday clinical practice. Initial studies have shown that ES occurs in 10% to 28% of ICD recipients and is associated with increased mortality.[1–8] This could be explained by different factors: (1) myocardial injury and ventricular remodeling due to neurohormonal activation, caused directly by the shocks[14]; (2) adverse effects of a heavy pharmacologic regimen; or (3) ES could just be a relatively "innocent bystander" in a rapidly deteriorating cardiac condition.

Our study confirms the association between ES and mortality despite the lower incidence of ES in the era of VT ablation.[15] This could be attributed to the changing characteristics of ICD recipients in recent years. Because advanced medical treatment and improved revascularization and ablation techniques are now widely available, the number of patients who experience recurrent arrhythmias has declined. Only the very sick suffer an ES, and their prognosis remains poor. Therefore, our findings apply better to today's patient population and could have important implications for reduction of mortality rates.

ES Predictors

The clinical factors and mechanisms predisposing to ES initiation remain incompletely understood. In the SHIELD trial, a precipitating cause could be identified in 13% of the cases and mostly consisted of worsening HF and electrolyte disturbances.[4] This could be identified in 21% of our study patients who were effectively treated with conservative therapy. Although some studies have reported similar data[3,5–7] or other clinical predictors (eg, ejection fraction, QRS duration),[8] in the vast majority of patients there is no clear ES trigger, and the potential role of appropriate and inappropriate therapies has not yet been adequately studied.

Our findings revealed that secondary prevention and prior ICD therapies remain the most significant predisposing factors. An increased susceptibility to ventricular arrhythmias as well as the ICD therapies *per se* represent a proarrhythmic burden. Similarly, Bänsch et al[5] showed that VT inducibility is an independent predictor of ES in DCM patients. Therefore, ES is a result of interplay between (1) preexisting pathologic conditions creating a vulnerable substrate, (2) patient-specific initiating factors, and finally maybe (3) the ICD therapy itself. As such, the tendency to develop sustained ventricular arrhythmias before or soon after implantation should lead to strict follow-up and possibly the introduction of an adequate prophylactic antiarrhythmic therapy in order to avoid not only VT burden but ICD therapies as well.

Our study showed that inappropriate ICD therapies, delivered mostly during high-rate episodes of AF or supraventricular tachycardia, also are independent ES predictors. There is a known association between AF and VT occurrence,[16,17] as well as between AF history before ICD implantation and ES occurrence in DCM patients.[18] AF might have a negative impact on the ventricles through rapid ventricular rate, short–long–short sequences, decreased cardiac output, or increased cardiac filling.[16–18] To date, however, no study has evaluated the role of inappropriate therapies in ES. Interestingly, AF or supraventricular tachycardia alone in our study was not directly associated with the occurrence of ES. According to our findings, inappropriate ICD shocks have *per se* a detrimental effect on the prognosis because they carry the same problems associated with appropriate therapies, especially when shocks are concerned.

Consequently, special attention should be paid to ICD recipients with recurrent therapies, and aggressive rhythm control should be initiated in a timely matter.

Impact of Catheter Ablation

Choosing the right therapy (conservative or invasive) and the proper time to treat an ES could have an important impact on clinical outcome. Successful ES ablation has been recently associated with reduced ES recurrence and mortality. Sra et al[19] reported on catheter ablation of 19 ES patients with only 11% ES recurrence and no death over 26-week follow-up. A prospective study with ablation of 95 ES patients also showed a cumulative success of 92% over 22 months.[20] Similarly, Deneke et al[21] reported 94% acute success and 9% mortality during 15 months of follow-up of 32 ES patients. Two other cohort studies of catheter ablation for ES also showed a high acute success rate and significant survival benefit.[22,23] In agreement with these data, we found that ES ablation has an acute and long-term success of 92%. Moreover, despite the fact that mortality of ES patients is increased, there is a tendency for reduced mortality when ablated patients are compared to those who have undergone conservative therapy.

Considering the impact of appropriate and inappropriate therapies on ES, one could also advocate prophylactic ablation. Although data are scarce, there is some encouraging evidence of ICD therapy reduction in patients with prior myocardial infarction. The SMASH-VT trial showed that prophylactic ablation (without AADs) could reduce ICD shocks from 31% to 9% over mean follow-up of 23 $\pm$ 5 months.[24] The VTACH trial randomized patients with prior myocardial infarction and stable VT to either ablation or conservative treatment and also found a higher reduction of appropriate therapies in the ablation group.[25] Because most trials reported on ICM, it is not clear whether the outcome would be similar for nonischemic patients. Dinov et al[13] showed that in patients with DCM and recurrent sustained VTs, catheter ablation with complete VT noninducibility is associated with better long-term success and reduced mortality. In our study, ablated patients (50% with DCM) experienced a significant reduction of appropriate therapies and a trend for lower mortality despite carrying a higher VT burden in comparison to those treated conservatively. Prophylactic ablation at an earlier stage of multiple appropriate therapies might have drawn a different picture. Therefore, the merits and the optimal timing of catheter ablation in comparison to pharmacologic management of ES remain to be proven by a randomized controlled trial.

Study limitations

This is a single-center study with the limitations of a retrospective analysis. However, we included consecutive patients with regular and thorough interrogations to obtain a comprehensive dataset. ES treatment was not randomized, but the indications for ES therapy were similar between ablated and nonablated patients. However, a selection bias cannot be excluded because ablated patients had a higher VT burden that could explain the greater subsequent reduction. Because VT or PVC ablation today is a more common treatment option, it may have prevented the occurrence of ES and thus resulted in a limited number of ES patients, which in our opinion reflects a trend toward earlier diagnosis and intervention in contemporary ICD patients. Moreover, in order to exclude bias and simplify statistical analysis, the follow-up time was abridged with strict criteria, including ES recurrence and AF/VT ablation, leading to a reduced follow-up period and to high standard variation. Finally, the wide variety of manufacturers, devices, and discriminating algorithms hampered a direct comparison of programming within the cohort. However, the fact that every individual patient served as his or her own control may have minimized that kind of bias. Because of the low number of events, mortality difference (1/12 vs 2/11) between the 2 treatments showed a trend but did not reach statistical significance. Certainly, the significance of these findings requires further evaluation in larger prospective cohorts with longer follow-up periods and randomized comparison of different therapy strategies.

Conclusion

ES is not uncommon in patients with an ICD. A secondary prevention indication and the occurrence of both appropriate and inappropriate ICD therapies increase the probability for ES. Prompt initiation of aggressive antiarrhythmic treatment, especially catheter ablation, should be considered to reduce the incidence of ES in this patient population.

Appendix

Supplementary data

Supplementary material cited in this article is available online at http://dx.doi.org/10.1016/j.hrthm.2015.07.034.

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4. Diskussion

Die ICD-Implantation bei herzinsuffizienten Patienten hat zu einer deutlichen Mortalitätsreduktion geführt. Allerdings müssen im Verlauf nur bei etwa einem Drittel der implantierten ICDs adäquate Therapien abgegeben werden. Die Risikostratifizierung für diese Patienten scheint daher weiterhin

eine große Herausforderung zu sein. In unserer Patientenkohorte sahen wir adäquate Therapien bei 29 % der Patienten in einem Follow-up von 19 ± 9 Monaten. Diese Rate ist im Vergleich zur MADIT-II-Studie (23 %) oder SCD-HeFT-Studie (21 %) {53; 63} leicht erhöht. Zudem haben 25 % der Patienten aus unserer Datenbank sekundärprophylaktisch einen Defibrillator erhalten. Dies lässt sich durch die etwas veränderte Patientenpopulation erklären. Die medizinischen Fortschritte im Bereich des akuten Koronarsyndroms sowie Verbesserungen in der Behandlung von herzinsuffizienten Patienten haben wahrscheinlich die Lebenserwartung der Population erhöht. Damit stieg jedoch auch das Risiko, im Verlauf lebensbedrohliche Arrhythmien zu entwickeln. In unserer Patientenpopulation entwickelten 7 % (23 Patienten) innerhalb von 21 Monaten einen elektrischen Sturm. Dementsprechend war die Mortalität für diese Patienten deutlich höher (22 % vs. 2 %, P 0.001). Eine Rate von 7 % der Population mit ES erscheint im Vergleich zu den zuvor beschriebenen Zahlen aus älteren Studien eher gering, man muss jedoch die modernen Revaskularisationsmöglichkeiten und Ablationstechniken miteinbeziehen. Heutzutage sind es nur die sehr kranken Patienten, die einen ES erleiden werden und für sie bleibt die Prognose weiterhin schlecht.

In älteren Studien der 1990er-Jahre wurde das Vorhofflimmern, die sekundärprophylaktische Implantation, eine eingeschränkte Nierenfunktion {53-67; 61; 66} sowie nicht-anhaltende ventrikuläre Tachykardien oder eine fehlende Betablockertherapie {65-67} als Risikofaktoren für Kammertachykardien identifiziert. Die vorliegende Grunderkrankung wurde jedoch weniger untersucht und die klinische Schlussfolgerung dieser Studien blieb problematisch. Unsere Daten zeigen, dass die sekundärprophylaktische Implantation einen großen Einfluss bei ICM-Patienten mit fast zweifach erhöhtem Risiko für adäquate Therapien hat. Dies ist am ehesten durch myokardiale Narben bedingt. Bei DCM-Patienten zeigte sich statistisch dagegen kein signifikant erhöhtes Risiko. Allerdings spricht eine sekundärprophylaktische Implantation bei DCM-Patienten für eine arrhythmogene Disposition und tendiert dazu, signifikant zu werden (P=0.07). Insgesamt erscheint die sekundärprophylaktische Implantation ein wichtiger Prädiktor zu sein, sodass bei diesen Patienten ein engmaschiges Follow-up und eine Rhythmusstabilisierung empfehlenswert sind.

Ein anderes wichtiges Ergebnis unserer Studie ist die Rolle der Resynchronisationstherapie. Obwohl beide Patientenpopulationen (ICM- und DCM-Patienten) eine klinische Verbesserung unter der Resynchronisationstherapie beschrieben, zeigte sich statistisch nur bei den ICM-Patienten eine Rhythmusstabilität unter CRT; diese Patientenpopulation erlitt auch weniger Schocks im Laufe des Follow-up. Die zügige Revaskularisierung und das Remodelling durch die Resynchronisationstherapie scheint durch dieses Phänomen zu erklären. Der Einfluss der CRT-Systeme wurde in den letzten Jahren immer signifikanter und wird in Zukunft eine noch größere Rolle bei der Behandlung dieser Patienten spielen.

In unserer Studie stellte das Vorhofflimmern einen unterschätzten klinischen Risikofaktor für das Auftreten von Kammertachykardien dar. Das Risiko für adäquate Therapien erhöhte sich bei unserem Patientenkollektiv mit Vorhofflimmern um ein Zweifaches, bei DCM-Patienten sogar um ein Vierfaches. Verschiedene VT/VF-Pathomechanismen durch das Vorhofflimmern (z. B. proarrhythmogener Effekt durch „short-long-short sequences“ oder tachykardie-bedingte Kardiomyopathie) können diskutiert werden, letztlich bleibt aber unklar, ob das Vorhofflimmern die Ursache an sich oder eher das Zeichen einer fortgeschrittenen Kardiomyopathie ist. Jedenfalls scheint die Rhythmusstabilisierung für diese Patienten die Schockanzahl (adäquat oder inadäquat) zu verringern, {68} sodass eine aggressivere Therapie (medikamentös oder interventionell mittels Ablationsbehandlung) vor allem bei DCM-Patienten sinnvoll erscheint.

In weiteren statistischen Analysen zu den Risikofaktoren für ES sahen wir die sekundärprophylaktische ICD-Implantation sowie das Vorhandensein von adäquaten oder inadäquaten Therapien als unabhängige Risikoparameter an. In der Fachliteratur wird die Induzierbarkeit von VTs während einer elektrophysiologischen Untersuchung ebenfalls als unabhängiger Risikofaktor beschrieben. {42} ES scheint das Resultat eines vulnerablen Myokardsubstrats, Patienten-assoziierter Eigenschaften und der ICD-Therapieabgabe selbst zu sein. Darüber hinaus zeigen unsere Ergebnisse, dass inadäquate Schockabgaben, auch in Bezug auf ES, per se einen negativen prognostischen Effekt haben, genau wie die adäquaten Therapien.

Die Auswahl der richtigen Behandlungsstrategie bei ES bleibt problematisch. In der Fachliteratur {74-81} wird ein aggressives Verfahren mittels VT-Ablation mit der Verringerung des ES-Rezidives und der Mortalität verbunden. Im selben Kontext wird bei Hochrisikopatienten eine prophylaktische VT-Ablation favorisiert. {79-80} Bei unseren Patienten führte die VT-Ablation (50 % bei DCM-Patienten) zu einer signifikanten Reduktion von adäquaten Therapien und Mortalität, obwohl dasselbe Patientenkollektiv im Vergleich zu den restlichen Patienten, die mit AAD behandelt worden sind, eine hohe VT-Last hatte. Größere randomisierte prospektive Studien zur Beurteilung von besseren Rhythmus-Strategien für ES sind aber weiterhin notwendig.

Das Ziel dieser Studie war es, individuelle Risikofaktoren in Abhängigkeit zur Grunderkrankung zu identifizieren. Bei ICM-Patienten erscheinen die CRT-Systeme einen deutlichen Benefit zu bringen, was sowohl die Klinik als auch die Rhythmusstabilität betrifft. Die Therapie von Vorhofflimmern ist in beiden Gruppen (besonders bei Patienten mit dilatativer Kardiomyopathie) wichtiger als bisher gedacht und führt möglicherweise zur Verringerung der Schockanzahl (adäquat und inadäquat). Des weiteren sind Patienten mit sekundärprophylaktischer Indikation stärker gefährdet und sollten klinisch engmaschiger kontrolliert werden. Diese einfachen klinischen Parameter können in der alltäglichen Praxis hilfreich sein.

5. Limitationen

Die vorliegende Studie weist gewisse Limitationen auf. Es handelt sich bei der vorliegenden Arbeit um eine „Single-center/Post-hoc“-Analyse. Allerdings wurden konsekutive Patienten mit regelmäßigem Follow-up eingeschlossen. Die ICD-Programmierung erfolgte leitliniengemäß und wurde, mit Ausnahme eines Patienten, während des Follow-ups nicht geändert, sodass die statistischen Daten unbeeinflusst blieben. In die Studie wurden auch Patienten mit langsamen ventrikulären Tachykardien aufgenommen. Diese Rhythmusstörungen waren möglicherweise nicht lebensbedrohlich, können aufgrund sekundärer Folgen (Synkope, Degeneration ins

Kammerflimmern, kardiale Dekompensation) klinisch jedoch genauso relevant sein. Zudem handelt sich es um Patientendaten aus dem Berufsalltag, mit weniger Komorbiditäten als in älteren Studien beschrieben, was eventuell einen Einfluss auf die Endergebnisse haben kann. Allerdings wird dadurch eine in den letzten Jahren auftretende Tendenz zur früheren Diagnose und Behandlung von herzinsuffizienten Patienten demonstriert. Weitere größere randomisierte Studien sind notwendig, um die Rolle der Resynchronisationstherapie und der Rhythmusstabilität bei diesem Patientenkollektiv zu überprüfen.

6. Schlussfolgerungen

Die ICD-Implantation ist ein wichtiges Tool in der Behandlung von herzinsuffizienten Patienten, jedoch werden nur circa 30 % dieser Patienten im Verlauf adäquate Episoden bekommen. Für die Risikostrafizierung solcher Patienten sollte die vorliegende Grunderkrankung berücksichtigt werden. Als besonderer Risikofaktor ist die sekundärprophylaktische Indikation bei ICM-Patienten zu beachten. Dahingegen kann ein CRT-System für die gleiche Patientenpopulation prophylaktisch wirken. Vorhofflimmern scheint vor allem für DCM-Patienten ein wichtiger, unterschätzter Risikofaktor für Kammertachykardien zu sein und sollte aggressiver behandelt werden, um eine Rhythmusstabilität zu erhalten.

7. Zusammenfassung

Dissertation zur Erlangung des akademischen Grades Dr. med.

Prädiktoren für ICD-Therapien bei Patienten mit ischämischer und nicht-ischämischer Kardiomyopathie

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Der implantierbare Kardioverter-Defibrillator gehört zu der Behandlung von herzinsuffizienten Patienten. In dieser Arbeit wird eine Risikostratifizierung anhand der vorliegenden Grunderkrankung analysiert.

Untersucht wurden 330 konsekutive Patienten mit ischämischer oder nicht-ischämischer dilatativer Kardiomyopathie, die zwischen 2009 und 2011 einen ICD erhalten haben. Im Rahmen des Follow-up von 19 ± 9 Monaten erlitten 29 % der Patienten adäquate ICD-Therapien. Als signifikante Risikofaktoren für adäquate Therapien waren die sekundärprophylaktische Implantation bei ICM-Patienten und die Präsenz von Vorhofflimmern bei DCM-Patienten zu beobachten. Die leitliniengerechte CRT-Implantation zeigte eine prophylaktische Wirkung bei ICM-Patienten.

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9. Erklärung

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Datum Unterschrift

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