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Predictors of Implantable Cardioverter-Defibrillator Implantation in Ischemic Heart Disease with Severe Left Ventricular Dysfunction. A Retrospective Analysis from a single Centre

Prédicteurs de l'implantation de défibrillateur automatique implantable dans la cardiopathie ischémique avec dysfonction ventriculaire gauche sévère. Une analyse rétrospective monocentrique

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Résumé

Contexte et objectif. Les patients atteints de cardiopathie ischémique avec une dysfonction ventriculaire gauche sévère (DVGS) présentent un risque élevé de mort subite cardiaque. Les défibrillateurs automatiques implantables (DAI) réduisent ce risque, mais leur indication repose habituellement sur la persistance d'une DVGS après trois mois. Cette étude visait à identifier les déterminants de l'implantation d'un DAI dans ce contexte. *Méthodes***.** Il s'agissait d'une étude de cohorte rétrospective incluant des patients adultes (≥18 ans) hospitalisés pour une cardiopathie ischémique avec une fraction d'éjection du ventricule gauche (FEVG) <35 %, entre janvier 2020 et août 2024, au Centre Hospitalier Sud Francilien (CHSF) en France. Tous ont été équipés d'un gilet défibrillateur puis réévalués à 3 mois. Une analyse multivariée par régression logistique a permis d'identifier les facteurs prédictifs d'implantation. *Résultats.* Sur 123 patients inclus dans l'étude, 51 (41,5 %) ont été implantés d'un DAI. Les facteurs associés de façon indépendante à l'implantation d'un DAI comprennent l'âge ≥60 ans (ORa: 1,99), l'hypertension artérielle (ORa : 2,52), la revascularisation précoce (ORa : 2,89), la tachycardie ventriculaire soutenue (ORa : 3,60), et une FEVG <20 % (ORa : 3,39). *Conclusion.* Chez les patients atteints de CI avec une DVGS, il y a des facteurs pouvant guider l'identification

Summary

Context and objective. Patients with ischemic heart disease (IHD) and severe left ventricular dysfunction (LVD) are at high risk of sudden cardiac death (SCD). Implantable cardioverter-defibrillators (ICDs) reduce this risk but are typically considered only after reassessing left ventricular ejection fraction (LVEF) three months post-discharge. The present study aimed to identify predictors of ICD implantation in patients with IHD and severe LVD. *Methods.* This was a retrospective cohort study including adult patients (≥ 18 years) with IHD and LVEF < 35%, hospitalized between January 2020 and August 2024 at the Centre Hospitalier Sud Francilien (CHSF). All were discharged with a wearable cardioverter defibrillator (WCD), and reassessed after 3 months. Multivariate logistic regression was used to identify factors associated with ICD implantation. *Results.* Among 123 patients, 51 (41.5%) underwent ICD implantation. Factors independently associated with ICD implantation included Age ≥ 60 years, hypertension (aOR 2.52; 95% CI: 1.57–5.99), early revascularization (aOR 2.89; 95% CI: 1.82–5.34), sustained ventricular tachycardia (aOR 3.60; 95% CI: 1.97–5.23), and LVEF ≤ 20% (aOR 3.39; 95% CI: 1.92–9.38). *Conclusion.* In IHD patients with severe LVD, several factors may guide early identification of candidates for ICD implantation.

Keywords: ischemic heart disease, sudden cardiac death, implantable cardioverter-defibrillators, predictors
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précoce des candidats à l'implantation d'un DAI.

Mots-clés : Cardiopathie ischémique, mort subite cardiaque, défibrillateurs automatiques implantables, déterminants
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Introduction

Ischemic heart failure (IHF) with severe left ventricular dysfunction (LVD) remains one of the leading causes of unplanned hospital admissions. It is associated with poor outcomes and imposes a significant financial burden on health systems. The total medical cost of annual median hospitalizations is estimated at USD 16,000 per patient (1, 2). The global burden of heart failure (HF) continues to rise, driven by an aging population and increasing rates of ischemic heart disease, hypertension, and diabetes (3). Severe LVD, defined as a left ventricular ejection fraction (LVEF) of 35% or less, is associated with a particularly high risk of adverse outcomes, including hospitalization, progression to end-stage heart failure, and sudden cardiac death (SCD). The latter, caused primarily by life-threatening arrhythmias such as ventricular tachycardia (VT) and ventricular fibrillation (VF), is a major contributor to mortality in these patients. The use of implantable cardioverter-defibrillators (ICDs) has been well-established in the prevention of SCD in high-risk patients with severe LVD, particularly those with a history of sustained ventricular arrhythmias or a significantly reduced LVEF. The efficacy of ICD therapy in preventing arrhythmic death has been demonstrated in numerous large clinical trials, and current guidelines recommend ICD implantation in patients with an LVEF of ≤35% who are at high risk for SCD (4). Although left ventricular ejection fraction (LVEF) remains a central criterion for guiding implantable cardioverter-defibrillator (ICD) implantation, its utility in predicting sudden cardiac death (SCD) is increasingly recognized as limited. Furthermore, adherence to this criterion often results in deferring the decision to implant an ICD until LVEF is reassessed three months after hospital discharge, a timeframe that may delay potentially life-saving intervention. Thus, researchers currently believe that the decision to implant an ICD may be multifaceted, involving a combination of clinical, electrophysiological,

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and therapeutic factors (5). Recent research has focused on identifying additional clinical and imaging markers to improve risk stratification and refine patient selection for ICD therapy beyond LVEF alone (6-13). Factors such as sociodemographic characteristics, cardiovascular risk factors, the timing of coronary revascularization, and findings from advanced imaging modalities, particularly cardiac magnetic resonance imaging, are emerging as potential determinants in the decision-making process, yet remain inadequately characterized. The purpose of this study was to identify the factors associated with ICD implantation in patients with IHD and severe LVD. Specifically, we aimed to compare the characteristics of patients who received an ICD with those who did not, focusing on identifying independent predictors of ICD implantation. Understanding these factors is crucial for refining risk stratification strategies and optimizing treatment decisions for this high-risk patient population. Given the clinical implications, this study provides valuable insights into the management of IHD with severe left ventricular dysfunction and its potential for improving outcomes through timely ICD intervention.

Methods

Study Design and Setting

This retrospective cohort study was conducted at the Centre Hospitalier Sud Francilien (CHSF), a tertiary care hospital located in the Essonne, France.

Population and Inclusion Criteria

The study included all men and women aged 18 years or older who were hospitalized for acute coronary syndrome (ACS) or revascularization for chronic coronary syndrome (CCS). Eligible patients had a LVEF of less than 35%, were discharged with a WCD, and were re-evaluated after a follow-up period of three months for potential ICD implantation. During the three-month follow-up period, patients underwent cardiac rehabilitation and the treatment optimization was performed.

Exclusion Criteria

Patients were excluded from the study if they had non-ischemic heart failure, were lost to follow-up, had died before the re-evaluation, or had received an ICD at another institution.

Primary Endpoint

The study' primary endpoint of was the implantation of an ICD at the three-month follow-up after discharge for IHD with severe LVD.

Data collection

The data collection for this study encompassed clinical characteristics, echocardiographic and angiographic findings, electrocardiographic monitoring data from the cardiological intensive care unit (ICU), relevant biological markers, and cardiac magnetic resonance imaging (MRI) results. All information was extracted from the hospital's electronic medical record system ("N.H Reference"). Data regarding external shocks delivered by the WCD were obtained from Zoll Medical. The final decision concerning ICD implantation was documented based on cardiology outpatient follow-up records.

Operational definitions

The following definitions were used in this study:

- IHD (also termed coronary artery disease or atherosclerotic disease) was identified based on documented medical diagnoses in patients' records. Specifically, patients were classified as having IHD if they had a recorded diagnosis of conditions such as angina pectoris, myocardial infarction**,** or history of coronary revascularization. Diagnosis of myocardial infraction was performed using standard criteria including stable angina and acute coronary syndrome, categorized as ST-T segment elevation myocardial infraction, non ST-T segment elevation myocardial infraction and unstable angina (6).
- Non-ischemic heart disease: refers to a myocardial disease that excludes coronary artery disease or ischemic injury (7).
- A standardized diagnosis of heart failure (HF) was established using the Framingham criteria and the guidelines of the European Society of Cardiology on the diagnosis and treatment of acute heart failure (AHF) (8). Both new-onset HF (AHF that occurs in patients without a history of HF) and acutely decompensated chronic heart failure (ADCHF) (AHF that occurs in patients with a history of chronic HF) were included.

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- Cardiogenic shock was diagnosed when AHF was accompanied by low systolic blood pressure (SBP <90 mmHg) for at least 30 minutes, or if support is needed to maintain SBP ≤ 90 mm Hg and oliguria (<0.5 mL/kg/h for minimum of 6 hours), or low cardiac index (<2.2 L/min/m^2) (9).
- Acute coronary syndrome was defined as per the 2023 recommendations of the ESC (10)
- Chronic coronary syndrome was defined as the presence of a clinical history of chest pain or discomfort along with a coronary artery stenosis (≥50%) on coronary angiography (11)

Patients were stratified into four groups following clinical criteria according to the Killip and Kimball classification in their original paper(12), as follows: KC-I: no signs of congestion, KC-II: S3 heart sound and basal rales on auscultation, KC-III: acute pulmonary edema and KC-IV: cardiogenic shock

- Cigarette smoking was defined as use of any type of smoked tobacco product on a daily or occasional basis (13).
- Alcohol abuse was defined as >14 standard drinks/week for men or >7 for women (14),
- Diabetes was defined as history of diabetes, regardless of duration of disease, need for antidiabetic agents, or a fasting blood glucose level ≥ 10 mmol/L and HbA1c > 7% (15).
- The diagnosis of high blood pressure was based on a history of hypertension and/or the use of antihypertensive medications (16).
- Coronary heredity has been defined as a family history of coronary artery disease, wherein which one or more first-degree relatives (parents, siblings) have been diagnosed with coronary artery disease, including conditions such as myocardial infarction, angina, or coronary artery bypass grafting, typically occurring before the age of 55 in males and 65 in females.
- Dyslipidemia was defined as an LDL-cholesterol level ≥ 1.6 g/L and/or an HDL-cholesterol level ≤ 0.40 g/L in men and ≤ 0.50 g/L in women and/or a total cholesterol level ≥ 2 g/L and/or a triglyceride level ≥ 1.5 g/L (17). LDL-cholesterol was calculated using the Friedewald method as LDL-cholesterol (g/L) = CT (g/L) − HDL-cholesterol (g/L) − triglyceride (g/L)/5 (if the triglyceride level was ≤ 3.4 g/L) (17). It was directly dosed using the dextran sulfate filtration technique if the triglyceride level was > 3.4 g/L (17).
- Obesity was defined as a BMI greater than or equal to 30 kg/m^2 (18).
- The diagnostic process for acute kidney injury (AKI) involved evaluating daily serum creatinine (sCr) levels and urine output using the Kidney Disease: Improving Global Outcomes (KDIGO) (19) criteria, which includes daily measurements of urine output. The KDIGO AKI definition, which considers a mobile window for the diagnosis, strictly followed. The reference SCr for diagnosis was the level observed 48 hours or seven days prior to the observed elevation of 0.3 mg/dl or 50%. For patients admitted with sCr levels of 4 mg/dL or higher, the creatinine criterion considered was an increase in sCr of at least 1.5 times during follow-up.
- Delayed cardiac MRI enhancement was defined as hyperintense areas on late gadolinium enhancement images, indicating myocardial injury or fibrosis, typically appearing 10–15 minutes after contrast administration to identify myocardial infarction or damage (20).

Statistical analyses

The data was compiled into an Excel 2016 database and subsequently exported to SPSS version 24 for analysis. Descriptive statistics were presented as an average (plus or minus standard deviation) for continuous variables with a normal distribution and as a median (with interquartile range) for continuous data with non-Gaussian distribution. The normality test (Kolmogorov-Smirnov or Shapiro-Wilk) allowed us to differentiate between normally distributed and non-normally distributed quantitative variables. Absolute (n) and relative (%) frequencies were expressed for the categorical variables. The Student t-test, Mann-Whitney U-test, and Pearson's chi square or exact Fisher test were performed to compare means, medians and proportions in both groups, respectively. Logistic regression analysis was used to identify ICD implantation associated factors in both univariate and multivariate analysis. The adjusted odds ratio calculated allowed for estimating the degree of association between the implanted ICD and independent

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variables. For all tests used, a p-value < 0.05 was considered the threshold for statistical significance. To assess ascertainment bias in high-risk patients with implanted ICDs, we compared traditional cardiovascular risk factors between patients who were implanted with an ICD and those who were not.

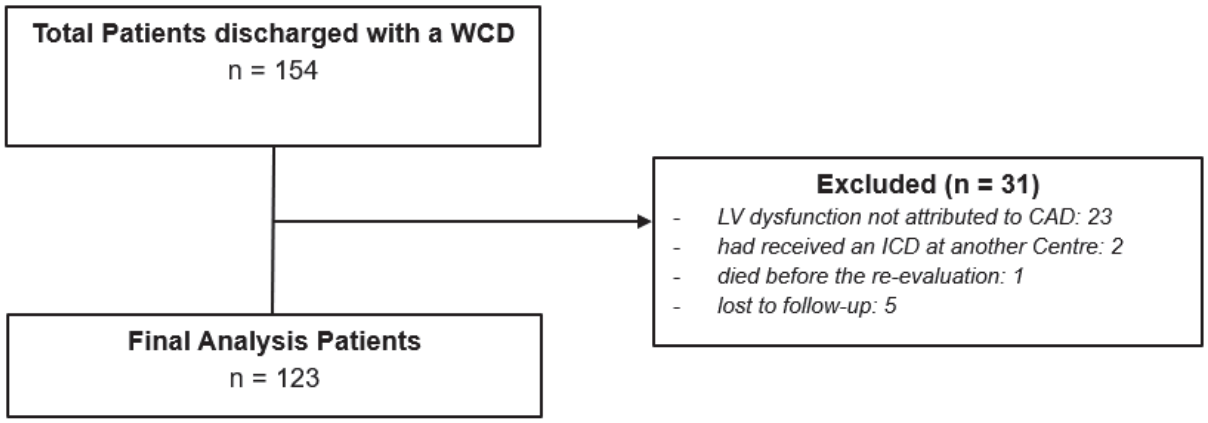
Ethical Approval

The study was approved by the SFHC Ethics Committee. All data were fully anonymized before being accessed and the source of data was made from patient records. The study was conducted in accordance with the Declaration of Helsinki.

Results

Out of the 154 patients discharged with a WCD during the study period, 31 patients were excluded. Twenty-three had LV dysfunction not attributed to CAD, two had received an ICD in another center, one died before re-evaluation, and five were lost to follow-up.

Figure 1 summarizes the selection procedure.



WCD = wearable cardioverter defibrillator, LV = left ventricle, CAD = coronary artery disease, ICD = implantable cardioverter-defibrillator

Fig 1. Study flow chart

Characteristics of the study population

The study population consisted of 123 patients, with a mean age of 65.6±11.9 years; of the 123 patients, 102 were men and 21 were women, with a sex ratio of 4.8 (in favor of men).

Frequency of patients receiving implantable cardioverter-defibrillator

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Figure 2 shows that, overall, 51 (41.5%) patients were implanted with an ICD.

Figure

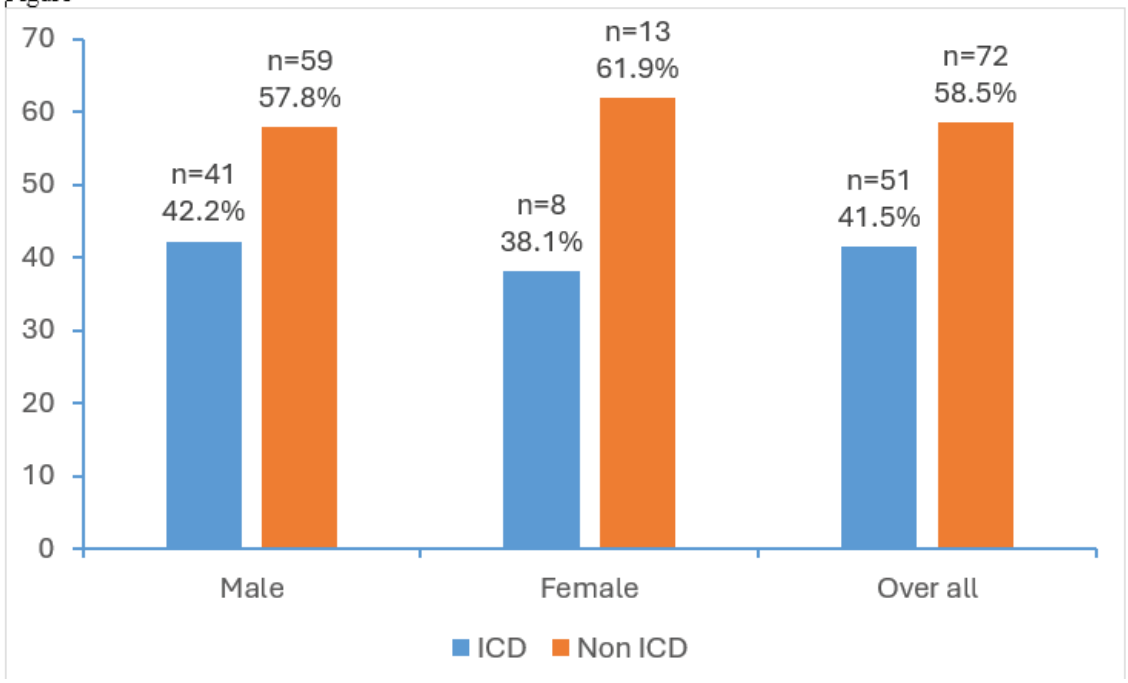

Figure 2. Frequency of ICD implantations

Sociodemographic characteristics, Cardiovascular risk factors and history

The sociodemographic characteristics, cardiovascular risk factors and patient history are presented in Table 1. Patients who were implanted were more often over 60 years of age and hypertensive, compared to those who were not implanted. Additionally, they more frequently had dyslipidemia and non-cardiac atherosclerotic disease. They less frequently had a history of left ventricular dysfunction.

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Table 1. Sociodemographic characteristics, Cardiovascular risk factors and history of patients according to ICD implantation statutes

Variables	Overall (N=123)	Non-implanted (N=72)	Implanted (N=51)	p value
Age (years)	65.6 ± 11.9	64.3 ±12.3	67.4 ± 11.2	0.168
Sex				0.464
Male	102 (83.0)	59 (81.9)	43 (84.3)	
Female	21 (17.0)	13 (18.1)	8 (15.7)	
CVRF				
Age ≥ 60 years	84 (68.3)	46 (63.9)	38 (74.5)	**0.037**
Hypertension	51 (41.5)	16 (22.2)	35 (68.6)	**0.024**
Diabetes	40 (32.5)	26 (36.1)	14 (27.5)	0.208
Cigarette smoking	65 (52.8)	39 (54.2)	26 (51.0)	0.434
Coronary heredity	11 (8.9)	6 (8.3)	5 (9.8)	0.509
Alcohol abuse	20 (16.3)	14 (19.4)	6 (11.8)	0.188
Dyslipidemia	34 (27.6)	18 (25.0)	16 (31.4)	**0.042**
Obesity	42 (34.1)	15 (20.8)	9 (17.6)	0.421
Cardiovascular history				
ischemic heart disease	33 (26.8)	20 (27.8)	13 (25.5)	0.472
Non-ischemic heart disease	16 (13.0)	10 (13.9)	6 (11.8)	0.476
Atherosclerotic disease other than heart	20 (16.3)	10 (13.9)	10 (19.6)	**0.013**
Atrial fibrillation	31 (26.1)	17 (24.3)	14 (28.6)	0.376
history of LV dysfunction	23 (18.7)	16 (22.2)	7 (13.7)	**0.017**
AKI at admission	42 (34.1)	23 (31.9)	19 (37.3)	0.337

Data are expressed as mean ± standard deviation, absolute (n) and relative (in percent) frequencies. CVRF = cardiovascular risk factor, LV = left ventricular, AKI = acute kidney injury

Clinical, electrocardiographic, echocardiographic and biological characteristics

Table 2 illustrates the clinical, electrocardiographic, echocardiographic, and laboratory characteristics of the study population, and compares them between patients who were implanted with an ICD and those who were not. Ninety (73.2%) patients had severe left ventricular dysfunction (less than 35%) following an acute infarction, while 33 (26.8%) patients had it as a result of chronic coronary lesions.

Patients who were implanted had significantly more severe left ventricular dysfunction following an acute infarction and more congestive disease at stage 3 or 4 of the Killip classification, compared to those who have not been implanted. They also had a significantly lower left ventricular ejection fraction at the time of hospital discharge and before the implantation of the ISC. However, no significant difference was observed when comparing the biological parameters of the two groups.

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Table 2. Clinical, electrocardiographic, echocardiographic and biological parameters

Variables	All patients n=123	Non-implanted (n=72)	Implanted (n=51)	p
Type of Coronary Syndrome				0.019
Acute coronary syndrome	90 (73.2)	50 (69.4)	40 (78.4)	
Chronic coronary syndrome	33 (26.8)	22 (30.6)	11 (21.6)	
Congestive picture (Killip stage)				0.046
KC-I	43 (35.0)	27 (37.5)	16 (31.4)	
KC-II	49 (39.8)	30 (41.6)	19 (37.2)	
KC-III	22 (17.9)	10 (14.0)	12 (23.5)	
KC-IV	9 (7.3)	5 (7.0)	4 (8.0)	
Rhythm and conduction disorder at admission				
SVT + EEC in CICU	10 (8.1)	2 (2.8)	8 (15.7)	
USVT in CICU	23 (18.7)	12 (16.7)	11 (21.6)	
Severe conduction disorder	2 (1.6)	2 (2.8)	12 (16.7)	
Recovered Cardiac arrest	9 (7.3)	4 (5.6)	5 (9.8)	0.184
LVEF at discharge	27.2 ± 5.7	28.3 ± 5.6	25.7 ± 5.5	0.013
LVEF before implantation	38.7 ± 8.8	44.1 ± 5.6	31.1 ± 6.5	<0.001
LDL-C (g/L)	1.01 (0.86-1.12)	1.0 (0.88-1.20)	0.8 (0.77-1.11)	0.373
HDL-C (gl/L)	0.4 (0.38-0.43)	0.4 (0.37-0.49)	0.4 (0.37-0.44)	0.776
Ratio LDL/HDL	2.1 (1.97-2.41)	2.2 (1.98-2.50)	2.0 (1.76-2.44)	0.304
NT-proBNP at discarge (pg/mL)	1677.0 (1500.0-2000.0)	1507.0 (1340-1870.9)	2100.0 (1600-2800)	0.499
Pic de Troponine (mg/dL)	372.0 (227.2-893.0)	348.5 (227-951.9)	386.0 (155-1998)	0.309
Peak CPK (picog/dL)	204.0 (141.0-254.0)	185.5 (129-264.2)	226.0 (109.0-325.0)	0.681
Creatinine (umol/L)	88.0 (85.0-92.0)	88.5 (85.0-94.0)	87.0 (82.0-95.0)	0.179

Data are expressed as mean ± standard deviation, absolute (n) and relative (in percent) frequencies, medians with interquartile ranges (IQRs) in parentheses. KC = Killip-Kimball Class, SVT= Supraventricular tachycardia, EEC= External Electrical Cardioversion, CICU= Cardiac Intensive Care Unit, USVT = unsustained ventricular tachycardia, LVEF = left ventricular ejection fraction, LDL-C = low-density lipoprotein-cholesterol, HDL-C = high-density lipoprotein, NT-proBNP = N-terminal pro b-type natriuretic peptide, CPK = Creatine phosphokinase

Angiographic. cardiac MRI and therapeutic characteristics

Table 2 shows the angiographic. cardiac and therapeutic characteristics of the patients. categorized by whether or not they were implanted. Tritroncular coronary status was the most common. followed by montroncular and bitroncular. There was no significant difference in the distribution of these statuses between implanted and non-implanted patients. The anterior interventricular artery was the coronary artery most often revascularized. followed by the right coronary and then the circumflexe. There was no statistically significant difference between implanted and non-implanted patients in the revascularized coronary artery.

76 (61.8%) patients were revascularized within 2 hours or more. Patients who received an ICD. had more frequent revascularization within 2 hours or more compared to those who did not receive one and were more likely to have delayed MRI enhancement.

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Table 3. Angiographic and magnetic resonance imaging parameters according to implantation status

Variables	All patients n=123 (%)	Non-implanted n=72 (%)	Implanted n=51 (%)	P
Coronary Status				0.919
Monovessel	40 (32.5)	24 (33.3)	16 (31.4)	
Bivessel	31 (25.2)	17 (23.6)	14 (27.5)	
Trivessel	52 (42.3)	31 (43.1)	21 (41.2)	
Revascularized artery				**0.037**
RCA	18 (14.6)	12 (16.7)	6 (11.8)	
Cx-Marginal	14 (11.4)	11 (15.3)	3 (5.9)	
LAD	91 (74.0)	49 (68.1)	42 (82.4)	
Revascularization delay				**0.006**
<2 hours	47 (38.2)	32 (44.4)	15 (29.4)	
≥ 2 hours	76 (61.8)	40 (55.6)	36 (70.6)	
LGE	67 (54.5)	35 (48.6)	32 (62.7)	**0.045**

Data are expressed as absolute (n) and relative (in percent) frequencies. RCA = right coronary artery, Cx-Marginal = circumflex and marginal artery, LAD = left anterior descending artery, LGE = late gadolinium enhancement.

Factors associated with ICD implantation

As illustrated in table 4, logistic regression analysis revealed that being 60 years of age or older, having hypertension, dyslipidemia, a history of left ventricular dysfunction, a revascularization time of less than 2 hours, late elevation to cardiac MRI, sustained ventricular tachycardia, and a left ventricular ejection fraction of less than or equal to 20% were all factors associated with the risk of ICD implantation. However, multivariate analysis showed that only age equal to or greater than 60 years, arterial hypertension, revascularization time less than 2 hours, sustained ventricular tachycardia, and a left ventricular ejection fraction of less than or equal to 20% at discharge from the hospital were independently associated with the risk of ICD implantation. These factors were found to increase the risk by two, three, three, four and three times, respectively.

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Table 4. Factors associated with ICD implantation

Variables	Univariate Analysis		Multivariate Analysis	
	P	OR (CI 95 %)	p	aOR (CI 95 %)
Age				
<60 years		1		1
≥60 years	**0.021**	2.65 (1.75-3.65)	**0.015**	1.99 (1.77-3.08)
Hypertension				
NO		1		1
Yes	**0.006**	2.69 (1.98-4.38)	**0.037**	2.52 (1.57-5.99)
Dyslipidemia				
NO		1		1
Yes	**0.044**	1.71 (1.18-3.04)	0.141	2.05 (0.79-3.41)
History of LV dysfunction				
NO		1		1
Yes	**0.024**	0.36 (0.21-0.47)	0.195	0.47 (0.15-1.48)
Revascularization delay				
≥2 hours		1		1
<2 hours	**0.029**	2.92 (1.90-4.11)	**0.012**	2.89 (1.82-5.34)
Late cardiac MRI enhancement				
NO		1		1
Yes	**0.044**	1.78 (1.31-3.70)	0.244	1.63 (0.72-3.72)
SVT + EES in CICU				
NO		1		1
Yes	**0.001**	3.51 (2.32-5.10)	**0.004**	3.60 (1.97-5.23)
LVEF on discharge				
>20%		1		1
≤20%	**0.015**	2.98 (1.86-5.11)	**0.019**	3.39 (1.92-9.38)

OR = Odds Ratio, aOR = Adjusted Odds Ratio, LV = left ventricular, MRI = Magnetic resonance imaging, SVT = Supraventricular tachycardia, EES = external electrical cardioversion, CICU = Cardiac Intensive Care Unit, LVEF = left ventricular ejection fraction

Discussion

This retrospective study aimed to identify factors associated with ICD implantation in patients with IHD and severe LVD. Our findings offer valuable insights into the cardiovascular risk profiles, sociodemographic characteristics, arrhythmic patterns, echocardiographic parameters, and therapeutic factors that are significantly linked to the likelihood of ICD implantation. These determinants could serve as critical elements in refining clinical decision-making and optimizing the timing of ICD implantation decision in this high-risk population.

Study Population Characteristics

The study cohort primarily consisted of men (83%) with a mean age of 65.6 years, which is a typical demographic seen in patients suffering from severe left ventricular dysfunction. This has been observed before in several large-scale registries, such as ADHERE(21) and OPTIMIZE-HF(22) in the USA, the European Heart Failure Surveys (EHFS) I (23) and II (24), the ESC-HF Pilot Registry(25) in Europe, and the international ALARM-HF registry(26). These registries have shown that IHD predominantly affects older adults (27). The male predominance is consistent with previous studies, which also report a higher prevalence of heart failure and related complications in men (28). Additionally, the mean age aligns with the common age range at which heart failure with severe systolic dysfunction is most prevalent. While the age distribution was broad, the

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association between older age and the likelihood of ICD implantation supports prior findings that age is a critical factor in clinical decision-making for ICD implantation (29). This can be attributed to the increased vulnerability of older patients to arrhythmic events due to the structural and electrical remodeling of the heart with advancing age (30).

Frequency of ICD Implantation

The 41.5% implantation rate observed in this cohort falls within the expected range for patients with severe left ventricular dysfunction, as indicated by previous studies. The decision to implant an ICD in these patients is often guided by the risk of SCD, particularly in those with a LVEF of less than or equal to 35%, which was a key criterion for inclusion in our study. Although only 41.5% of patients ultimately received an ICD, this is consistent with the selection criteria that emphasize the identification of high-risk individuals based on both clinical and diagnostic findings (31).

Sociodemographic and Cardiovascular Risk Factors

The analysis of sociodemographic factors revealed that patients who received ICDs were more likely to be hypertensive, dyslipidemic, and older than 60 years, which aligns with the established literature on CVRF in heart failure. Hypertension and dyslipidemia are well-known contributors to the development of heart failure and the progression to severe LVD (32, 33). Moreover, a history of non-cardiac atherosclerotic disease was more frequently seen in the ICD group, further highlighting the association between systemic atherosclerosis and the risk of arrhythmic events (34).

Interestingly, patients who received an ICD were less likely to have a history of LVD. This finding is somewhat unexpected, as one would assume that a history of chronic LVD would predispose patients to worse outcomes and potentially lead to earlier ICD implantation. However, this may reflect the fact that ICD implantation was more often triggered by acute episodes of heart failure, rather than the chronicity of LVD.

Angiographic and Cardiac MRI Characteristics

Regarding angiographic and cardiac MRI findings, we observed no significant differences between the implanted and non-implanted groups in terms of coronary status or revascularization patterns. This suggests that the decision to implant an ICD should not solely be based on the coronary anatomy or the extent of coronary artery disease, but rather influenced by the clinical course and arrhythmic risk.

Delayed enhancement on cardiac MRI, which is a marker of myocardial injury, was also more common in the ICD group. This finding further supports the role of myocardial damage and scar tissue in predisposing patients to life-threatening arrhythmias and thus the need for an ICD.

Factors Associated with ICD Implantation

Our multivariate analysis identified several key factors independently associated with ICD implantation. This included age greater than or equal to 60 years, hypertension, revascularization time of less than 2 hours, sustained ventricular tachycardia, and a left ventricular ejection fraction (LVEF) of less than or equal to 20%.

The association between advanced age and ICD implantation is consistent with previous studies, which have shown that older patients are at a higher risk for arrhythmic events, particularly those with severely depressed LVEF (35, 36). Age-related changes in the myocardial architecture, electrical remodeling, and the increased incidence of comorbidities (such as hypertension) likely contribute to this heightened arrhythmic risk. The significant association between hypertension and ICD implantation underscores the importance of managing blood pressure in heart failure patients, as persistent hypertension can contribute to adverse cardiac remodeling, increasing the risk of arrhythmic events and SCD.

In this study, revascularization within 2 hours of presentation was associated with ICD implantation. This finding suggests that patients with more acute ischemic events may require closer monitoring and early interventions, such as ICD implantation, to prevent sudden death.

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Sustained ventricular tachycardia, an established marker of electrical instability, was a significant predictor of ICD implantation, as expected. The presence of sustained ventricular arrhythmias has long been recognized as an indication for ICD therapy, as these arrhythmias are associated with a higher risk of sudden cardiac death. Finally, the relationship between a low LVEF (≤20%) and ICD implantation is well-established in the literature. Severe LVD remains one of the strongest predictors of arrhythmic death, and patients with LVEF ≤20% are considered at very high risk for sudden cardiac death.

Strengths, Limitations and Future Directions

Strengths of the study

- This is a study of data from an unselected population, a specific institution, reflecting current clinical practice and bridging the gap between controlled clinical trials and daily patient treatment.
- The study contains a comprehensive dataset, with a wide range of clinical, electrocardiographic, MRI, echocardiographic and biological characteristics, allowing a multidimensional assessment of the risk of ICD implantation. This holistic approach allows an understanding of the factors that determine the probability of a ICD implantation indication.

Limitations and Future Directions

This study has several limitations. First, the retrospective design of the study may introduce bias, particularly in the selection of patients for ICD implantation. The decision to implant an ICD is complex and may be influenced by factors not captured in our analysis, such as patient preferences, comorbidities, or clinical judgment. Second, the relatively small sample size and single-center design limit the generalizability of the findings. Future prospective, multicenter studies with larger cohorts are needed to confirm these results and further elucidate the factors that guide ICD implantation in patients with acute heart failure and severe left ventricular dysfunction.

Conclusion

Our study highlights several key factors associated with the decision to implant an ICD in patients with IHD and severe left ventricular dysfunction, including age, hypertension, sustained ventricular tachycardia, timely revascularization, and a low LVEF. These findings reinforce the importance of early risk stratification in this high-risk population and support the use of ICDs in appropriately selected patients to prevent sudden cardiac death. Further research is needed to refine the criteria for ICD implantation and optimize the management of patients with severe heart failure.

Conflict of interest

The authors declared that they have any conflict of interest.

Contribution for authors

YVM and BPK wrote the first draft of the manuscript; YVM and PG prepared the database; ANN carried out the statistical analyses; YVM, FNN, JMMM, YDM, CMK, GMI, ANN, TKP, ESL, AMK, PG, FB, PMM, BB, TMT, and BPK have read and revised manuscript; BKP was the scientific coordinator of the work.

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