

# Contemporary use of devices in chronic heart failure in the Netherlands

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## Abstract

**Aims** Despite previous surveys regarding device implantation rates in heart failure (HF), insight into the real-world management with devices is scarce. Therefore, we investigated device implantation rates in HF with reduced left ventricular ejection fraction (LVEF) in 34 Dutch centres.

**Methods and results** A cross-sectional outpatient registry was conducted in 6666 patients with LVEF < 50% and with information about device implantation available [74 (66–81) years of age; 64% male]. Patients were classified into conventional pacemakers (PM,  $n = 562$ ), implantable cardioverter defibrillators (ICD,  $n = 1165$ ), and cardiac resynchronization therapy with defibrillator function (CRT-D,  $n = 885$ ) or pacemaker function only (CRT-P,  $n = 248$ ), or no device ( $n = 3806$ ). Centres were divided into ICD-implanting and CRT-implanting and referral centres. Overall, 17.5% had an ICD, 13.3% CRT-D, 3.7% CRT-P, and 8.4% PM. Of those with LVEF  $\leq 30\%$ , 42.5% had ICD or CRT-D therapy. A large variation in implantation rates existed between centres: 3–51% for ICD therapy, 0.3–44% for CRT-D therapy, 0–11% for CRT-P therapy, and 0–25% PM therapy. Implantation centres showed higher implantation rates of ICD, CRT-D, and CRT-P compared with referral centres [36% vs. 25% for defibrillators (ICD or CRT-D) and 17% vs. 9% for CRT devices (CRT-D or CRT-P), respectively,  $P < 0.001$ ], independently of other factors. A large number of clinical factors were predictive for device usage. Among other, LVEF < 40% and male sex were independent positive predictors for ICD/CRT-D use [odds ratio (OR) = 3.33,  $P < 0.001$ ; OR = 1.87,  $P = 0.019$ , respectively]. Older age was independently associated with less ICD/CRT-D (OR = 0.96 per year,  $P < 0.001$ ) and more CRT-P/PM use (OR = 1.03 per year,  $P = 0.006$ ).

**Conclusions** In this large Dutch HF registry, less than half of the patients with reduced LVEF received an ICD or CRT, even if LVEF was  $\leq 30\%$ , and a large variation between centres existed. Patients from implantation centres had more often ICD or CRT. More uniformity regarding guideline-based use of device therapy in clinical practice is needed.

**Keywords** Heart failure; Electrical device therapy; Implantable cardioverter defibrillator; Cardiac resynchronization therapy; Real-world heart failure management

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## Introduction

Prognosis worsens when chronic heart failure (HF) remains untreated or when it is treated insufficiently; accordingly, physicians' adherence to treatment guidelines is a strong predictor of better prognosis (1,2). Nevertheless, suboptimal

treatment is often present though not well recognized (3,4). Explanatory factors influencing the decision making of physicians regarding HF treatment have not been sufficiently studied. Both in Europe and in the USA, large regional variations exist in the use of HF medication (5,6), and this may also apply to the use of device therapy (7). Despite the fact that HF

guidelines are similar in Europe, Eastern European countries showed a significantly lower implantation rate of implantable cardioverter defibrillators (ICD) and/or cardiac resynchronization therapy (CRT) (7,8). Besides regional differences, significant inequalities have been shown for race and sex: particularly women and minority patients received less often ICDs despite eligibility according to international HF guidelines (9). Device therapy rates are lower in elderly patients despite the fact that guidelines recommend device therapy regardless of age (10–12).

Recent surveys found rising implantation rates of ICDs and CRT over the past decade. However, the absolute use remains poor (13–15). However, patients in these surveys were often not representative to the real-world HF population and were younger than those in clinical practice (14–16). In addition, only tertiary centres were included, and HF patients with co-morbidities were excluded in some surveys (14,17).

To gain more insight into the real-world contemporary management of device therapy in patients with chronic HF and reduced left ventricular ejection fraction (LVEF), we performed a cross-sectional study of contemporary HF care regarding device therapy, using the CHECK-HF (Chronisch Hartfalen ESC-richtlijn Cardiologische praktijk Kwaliteitsproject Hartfalen) registry that consists of more than 10 000 HF patients seen at HF outpatient clinics in the Netherlands. Because basically all patients in the Netherlands are seen at the outpatient clinic of hospitals and not in private practices, and no further exclusion criteria were applied, this HF population is representative for the real-world management of patients with chronic HF.

## Methods

The methods of the CHECK-HF (Chronisch Hartfalen ESC-richtlijn Cardiologische praktijk Kwaliteitsproject Hartfalen) registry have been published earlier (18). HF outpatient clinics were invited to participate in this registry. In total, 34 Dutch centres participated over a period of 3 years (2013–2016). They were asked to include all current HF patients cross-sectionally. The centres included between 37 and 2529 patients (median 240, interquartile range 154–320 patients). The major inclusion criterion was presence of diagnosis of HF, based on the most recent ESC guidelines criteria at time of inclusion (19). Information on patient characteristics, main cause of HF, basic echocardiographic and electrocardiographic measurements, co-morbidities, and some laboratory results were recorded. This study was conducted according to the Declaration of Helsinki. Ethical approval was provided for anonymously analysing existing patient data by the Ethical Committee of the Maastricht University Medical Centre, the Netherlands. All patients provided informed consent. Patients were divided into HF with preserved

ejection fraction (HFpEF) defined as HF symptoms, LVEF  $\geq$  50% and signs of structural or functional cardiac abnormalities and not having any known history of LVEF  $<$  50%, and patients HF with reduced ejection fraction (LVEF  $<$  50%). Only the latter group was included in this study and was further divided into two groups based on the most recent guidelines (5,11): HFmrEF (LVEF 40–49%) and HFrfEF (LVEF  $<$  40%) in supplementary analyses. In some patients, reduced LVEF was only known semi-quantitatively, which are shown separately. Because of lack of information on LVEF, 283 patients were excluded. Patients were classified according to implanted devices into the following groups: conventional single or dual chamber pacemakers (PM), ICD, cardiac resynchronization therapy with defibrillator function (CRT-D) or with pacemaker function only (CRT-P), or no implanted device. Centres were divided into those that implant ICD and CRT devices (implantation centres) and those that only implant conventional PM (referral centres). No centre did not implant any device.

## Statistics

Results are presented as frequencies (%), mean ( $\pm$  standard deviation), or median (interquartile range), as appropriate. Between-group comparisons were performed using the independent samples *T*-test, Mann–Whitney *U* test, the one-way analyses of variance, Kruskal–Wallis *H*-test, or Pearson  $\chi^2$ , as appropriate. Multivariable predictors of device therapy were sought using binary logistic regression analysis, using the stepwise backward procedure (inclusion at  $P < 0.05$ , exclusion at  $P > 0.10$ ). All variables with  $P < 0.2$  at baseline were included for multivariable analysis. Using the stepwise forward procedure or simply entering all variables into equation did not result in clinically meaningful differences (data not shown). As preimplantation values are not known, QRS duration was not considered in these analyses. Results of logistic expression are presented as odds ratio and level of significance. A two-sided alpha of 0.05 was considered to be statistically significant. All calculations were performed with the use of the SPSS statistical package version 25.0 (SPSS Inc, Chicago, Illinois).

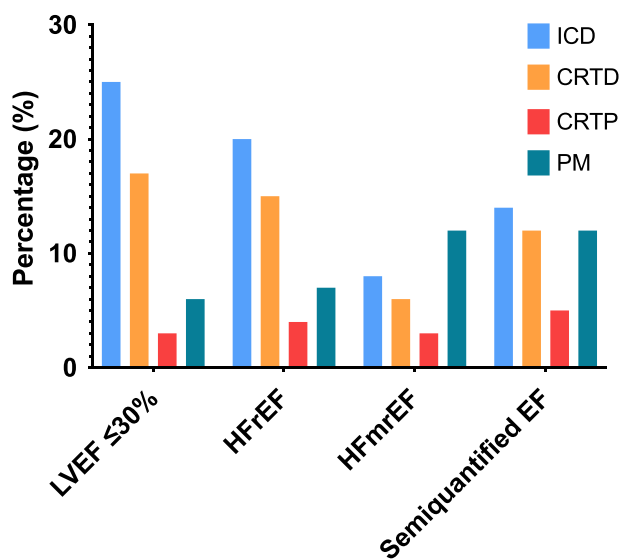
## Results

Of the 10 910 patients included in the CHECK-HF registry, 8360 patients (73.6%) had an LVEF  $<$  50%. Of these patients, information about the use of devices was available in 6666 patients (79.7%). Of these, 2860 patients (42.9%) had any device: 562 patients (8.4%) had a PM, 1165 (17.5%) an ICD, 885 (13.3%) a CRT-D, and 248 (3.7%) a CRT-P. Thus, 2050 patients (30.8%) had a defibrillator implanted and 1133 (17.0%) a CRT device. In the group of patients with known LVEF  $<$  40%

(HF<sub>r</sub>EF), 2231 (46.4%) had any device, compared with 316 (28.6%) of the HF<sub>m</sub>rEF patients and 313 (41.7%) of patients with semi-quantified LVEF. When taking into account the indication according to ESC guidelines for ICD or CRT-D regarding LVEF (LVEF ≤ 30%), 928 patients (42.5%) with LVEF ≤ 30% ( $n = 2185$ ) had either an ICD or CRT-D. The use of ICD, CRT (CRT-D and CRT-P), and PM in HF<sub>r</sub>EF, HF<sub>m</sub>rEF, semi-quantified LVEF, and LVEF ≤ 30% is shown in *Figure 1*.

Baseline characteristics of the included patients are shown in *Table 1*. The mean age of the patients was 74 years, and almost two-thirds was male. Patients with ICD or CRT-D were younger of age, whereas patients with PM were older (*Figure 2*). The male predominance was significantly larger in ICD and CRT-D patients compared with the other groups. Moreover, a larger part of all women did not have any device in comparison with men (65% vs. 53% respectively,  $P < 0.001$ , *Figure 3*). Ischaemic heart disease was the most common cause of HF. Most patients were in New York Heart Association (NYHA) functional class II, and only a few were in NYHA functional class IV. Overall, patients with PM or CRT-P were in a higher NYHA class; they were older and had a longer QRS duration and slightly more co-morbidities. They also used less HF medication, especially renin-angiotensin receptor blockers (RAS inhibitor), beta-blockers, and mineralocorticoid receptor antagonists (MRA) (*Table 1*). Use of triple therapy (meaning beta-blocker and RAS inhibitor and MRA) was highest in patients with ICD and CRT-D, in comparison with CRT-P, PM, and patients without device (Supporting Information, *Figure S1*).

**Figure 1** Use of ICD, CRT, and PM in patients with LVEF ≤ 30%, patients with HF<sub>r</sub>EF, patients with HF<sub>m</sub>rEF, and patients with only semi-quantitatively measured LVEF.



## Implantation rates between centres

Use of devices differed significantly across centres ( $P < 0.001$ ). Implantation rates of ICD varied between 3% and 51%. Accordingly, rates for CRT-D and CRT-P were 0.3–44% and 0–11%, respectively. Single ventricular PM implantation varied between 0% and 25% (*Figure 4*).

There was a significant difference in ICD and CRT implantation rates between patients from implantation centres and referral centres [36% vs. 25% for defibrillators (i.e. ICD and CRT-D) and 17% vs. 9% for CRT-devices (i.e. CRT-D and CRT-P), respectively,  $P < 0.001$ ]. No significant difference was seen in patients with PM. Patients from the referring centres were slightly older, had a higher NYHA classification, more often non-ischaemic DCM as cause for HF, more renal failure, less hypercholesterolaemia, and underwent fewer interventions. Moreover, more patients from referring centres used HF medication than patients from implantation centres, in particular more diuretics, beta-blockers, and MRAs (Supporting Information, *Table S1*).

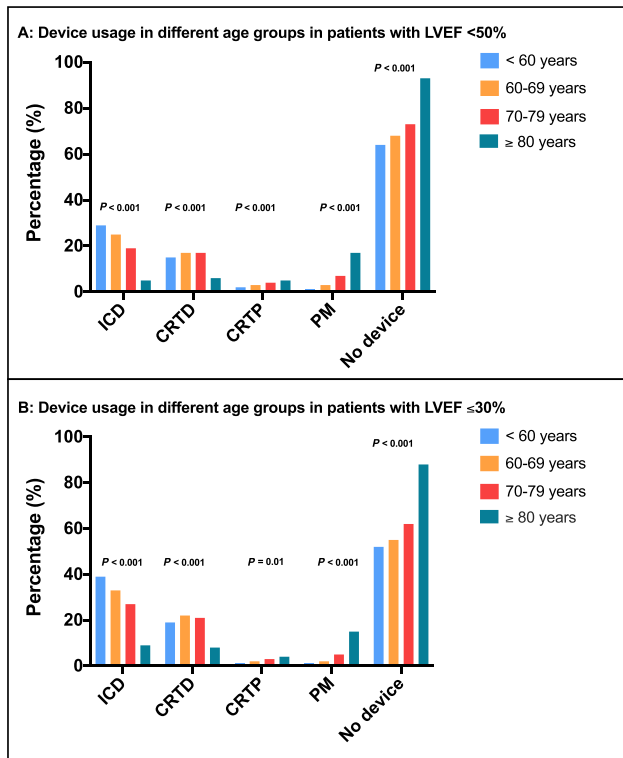
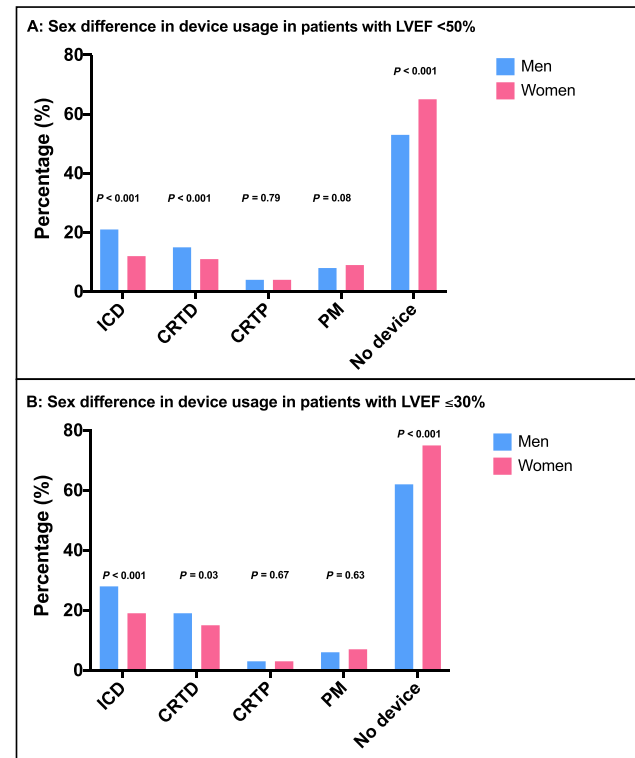
## Predictors of device therapy

Multivariable predictors of the device usage are shown in *Table 2*. Only patients with complete information on all variables were included in multivariable analyses ( $n = 3447$ ). Patients not included for multivariable analysis ( $n = 3219$ ) due to lack of some data had a slightly higher NYHA class (NYHA functional class I was observed in 13% in the group of excluded patients vs. 14% in the group of included patients; NYHA functional class II in 57% vs. 61%, respectively; NYHA functional class III in 28% vs. 24%, respectively; and NYHA functional class IV in 3% vs. 1%, respectively), had less often no co-morbidities (26% vs. 20%, respectively), and less often had LVEF semi-quantitatively measured (10% vs. 13%, respectively), but the differences were relatively small and of no clinical relevance. HF<sub>r</sub>EF was a strong predictor of ICD and CRT use, as suspected. Age was also an independent predictor: the younger the patient, the higher the chance of having an ICD or CRT-D implanted (*Figure 2A*). Meanwhile, older patients were more likely to have a PM. This was also true for patients with LVEF < 30% (*Figure 2B*). Men were more likely to receive ICD or CRT-D therapy compared with women. An ischaemic cause of HF including interventions such as PCI and CABG was a strong predictor of ICD or CRT use. On the other hand, atrial fibrillation as cause of HF was associated with less ICD and CRT implantation. Patients with co-morbidities were more likely to have ICD or CRT. The use of ICD and CRT-D was significantly higher in implantation centres as compared with referral centres independently of other variables. Time between HF diagnosis and device implantation was not independently associated for the use of ICD, CRT, or PM (*Table 2*).

**Table 1** Baseline characteristics of patients with ICD, CRT, and PM

	Total (n = 6666)	No device (n = 3806)	ICD (n = 1165)	CRT-D (n = 885)	CRT-P (n = 248)	PM (n = 562)	P-value
Age (years) (n = 6666)	74 [66–81]	75 [59–91]	68 [52–84]	70 [57–83]	78 [66–90]	81 [71–91]	<0.001
Male (n = 6635)	4256 (64)	2248 (59)	883 (59)	630 (71)	155 (63)	340 (61)	<0.001
BMI (kg/m <sup>2</sup> ) (n = 6163)	27 ± 5	27 ± 5	28 ± 5	28 ± 5	27 ± 5	27 ± 5	0.001
Heart rate (beats/min) (n = 6576)	71 ± 13	72 ± 14	69 ± 13	72 ± 11	72 ± 11	74 ± 12	<0.001
RR systolic (mmHg) (n = 6591)	124 ± 20	127 ± 20	121 ± 18	125 ± 20	127 ± 22	126 ± 19	<0.001
RR diastolic (mmHg) (n = 6597)	70 ± 11	72 ± 11	70 ± 11	72 ± 11	71 ± 11	70 ± 11	0.01
NYHA (n = 6599)							<0.001
NYHA I	876 (13)	446 (12)	206 (18)	153 (17)	27 (11)	44 (8)	
NYHA II	3872 (58)	2283 (61)	659 (57)	481 (55)	139 (57)	310 (56)	
NYHA III	1727 (26)	970 (26)	266 (23)	228 (26)	75 (31)	188 (34)	
NYHA IV	124 (2)	65 (2)	24 (2)	17 (2)	5 (2)	13 (2)	
Oedema (n = 4914)	602 (74)	315 (12)	101 (12)	93 (13)	20 (10)	73 (16)	0.09
Euolemic (n = 4332)	3983 (60)	2143 (93)	701 (91)	627 (92)	170 (91)	342 (88)	0.09
LVEF (n = 4946)	32 ± 10	33 ± 10	29 ± 9	29 ± 9	32 ± 10	37 ± 11	<0.001
LVEF ≤ 30% (n = 6666)	2185 (41)	1036 (49)	548 (25)	380 (17)	59 (2)	135 (6)	<0.001
HFrEF (n = 6666)	4810 (72)	2579 (54)	976 (20)	735 (15)	180 (4)	340 (7)	<0.001
HFmrEF (n = 6666)	1105 (17)	789 (71)	86 (8)	61 (6)	34 (3)	135 (12)	<0.001
Semi-quantified HFmrEF (n = 6666)	751 (11)	438 (58)	103 (14)	89 (12)	34 (5)	87 (12)	0.001
QRS (ms) (n = 5519)	121 [100–154]	110 [69–151]	118 [75–161]	156 [114–198]	159 [122–196]	162 [98–226]	<0.001
<b>Causes of HF (n = 6455)</b>							
Ischaemic	3376 (51)	1785 (49)	787 (70)	453 (52)	107 (44)	244 (46)	<0.001
Non-ischaemic DCM	1262 (19)	652 (18)	224 (20)	234 (27)	71 (29)	81 (15)	<0.001
HHD	285 (4)	197 (5)	18 (2)	36 (4)	13 (5)	21 (4)	<0.001
Valvular disease	987 (15)	630 (17)	133 (12)	79 (9)	23 (10)	122 (23)	<0.001
AF	1310 (20)	886 (24)	133 (12)	89 (10)	31 (13)	171 (32)	<0.001
Conduction	275 (4)	96 (3)	53 (5)	60 (7)	12 (5)	54 (10)	<0.001
<b>Co-morbidities (n = 6073)</b>							
Anaemia	285 (4)	142 (4)	54 (5)	46 (6)	12 (5)	31 (6)	0.052
Hypertension	2421 (36)	1462 (41)	342 (22)	296 (38)	103 (46)	218 (44)	<0.001
Hypercholesterolaemia	838 (13)	420 (12)	204 (20)	126 (16)	35 (16)	53 (11)	<0.001
DM type 2	1558 (23)	894 (25)	250 (24)	219 (28)	53 (24)	142 (29)	0.209
COPD	1108 (17)	677 (19)	164 (16)	135 (17)	46 (21)	86 (17)	0.098
OSAS	392 (6)	187 (5)	86 (8)	70 (9)	14 (6)	35 (7)	<0.001
Hyperthyroidism	174 (3)	79 (2)	31 (3)	30 (4)	8 (4)	26 (5)	0.001
Hypothyroidism	280 (4)	135 (4)	60 (6)	37 (5)	15 (7)	33 (7)	0.004
Renal failure (eGFR < 60 mL/min/1.73 m <sup>2</sup> )	3436 (52)	2029 (54)	526 (53)	399 (58)	131 (66)	351 (73)	<0.001
PAD	423 (6)	233 (7)	92 (9)	55 (7)	15 (7)	28 (6)	0.09
No co-morbidities	1265 (19)	871 (25)	200 (23)	105 (19)	27 (16)	62 (15)	<0.001
<b>Interventions (n = 5852)</b>							
PCI	1382 (21)	673 (19)	361 (37)	220 (34)	43 (23)	85 (20)	<0.001
Valvular repair/replacement	419 (6)	193 (5)	58 (6)	79 (12)	22 (12)	67 (16)	<0.001
CABG	1157 (17)	539 (15)	292 (30)	183 (28)	42 (22)	101 (24)	<0.001
Other	201 (3)	91 (3)	37 (4)	39 (6)	7 (4)	27 (6)	<0.001
No intervention	3172 (48)	2305 (64)	352 (36)	233 (36)	90 (48)	192 (45)	<0.001
<b>Medication (n = 6666)</b>							
Diuretics	5578 (84)	3202 (84)	963 (83)	722 (82)	198 (90)	492 (88)	0.008
Statins	3493 (52)	1758 (46)	755 (65)	573 (65)	134 (54)	273 (49)	<0.001
ACE-inhibitors or ARB	5318 (80)	2123 (56)	650 (56)	494 (56)	134 (54)	251 (45)	<0.001
ARNI	23 (0.3)						
Beta-blockers	5594 (84)	3217 (85)	1022 (88)	745 (84)	198 (90)	412 (73)	<0.001
MRA	3744 (56)	2108 (55)	689 (59)	518 (59)	114 (46)	315 (56)	0.001
Ivabradin	337 (5)	192 (5)	74 (6)	45 (5)	7 (3)	19 (3)	0.04
Digoxin	1115 (17)	698 (18)	128 (11)	145 (16)	46 (19)	98 (17)	<0.001
Amiodarone	653 (10)	183 (5)	204 (18)	173 (20)	33 (13)	60 (11)	<0.001

Values are mean ± standard deviation, median [interquartile range], or n (%). ACE-inhibitors, angiotensin-converting enzyme inhibitors; AF, atrial fibrillation; ARB, angiotensin receptor blocker; ARNI, angiotensin receptor neprilysin inhibitor; BMI, body mass index; CABG, coronary artery bypass graft; COPD, chronic obstructive pulmonary disease; CRT, cardiac resynchronization therapy; DCM, dilated cardiomyopathy; DM, diabetes mellitus; HF, heart failure; HFmrEF, heart failure with mid-range ejection fraction (i.e. 40% to 49%); HFrEF, heart failure with reduced ejection fraction (i.e. <40%); HHD, hypertensive heart disease; ICD, implantable cardio defibrillator; LBBB, left-bundle branch block; MRA, mineralocorticoid receptor antagonist; NYHA, New York Heart Association; OSAS, obstructive sleep apnoea syndrome; PAD, peripheral artery disease; PCI, percutaneous coronary intervention; PM, pacemaker; renal failure, either renal failure in medical history or eGFR < 60 mL/min/1.73 m<sup>2</sup>; RR, blood pressure.

**Figure 2** Implantation rates in different age groups.**Figure 3** Sex differences in implantation rates.

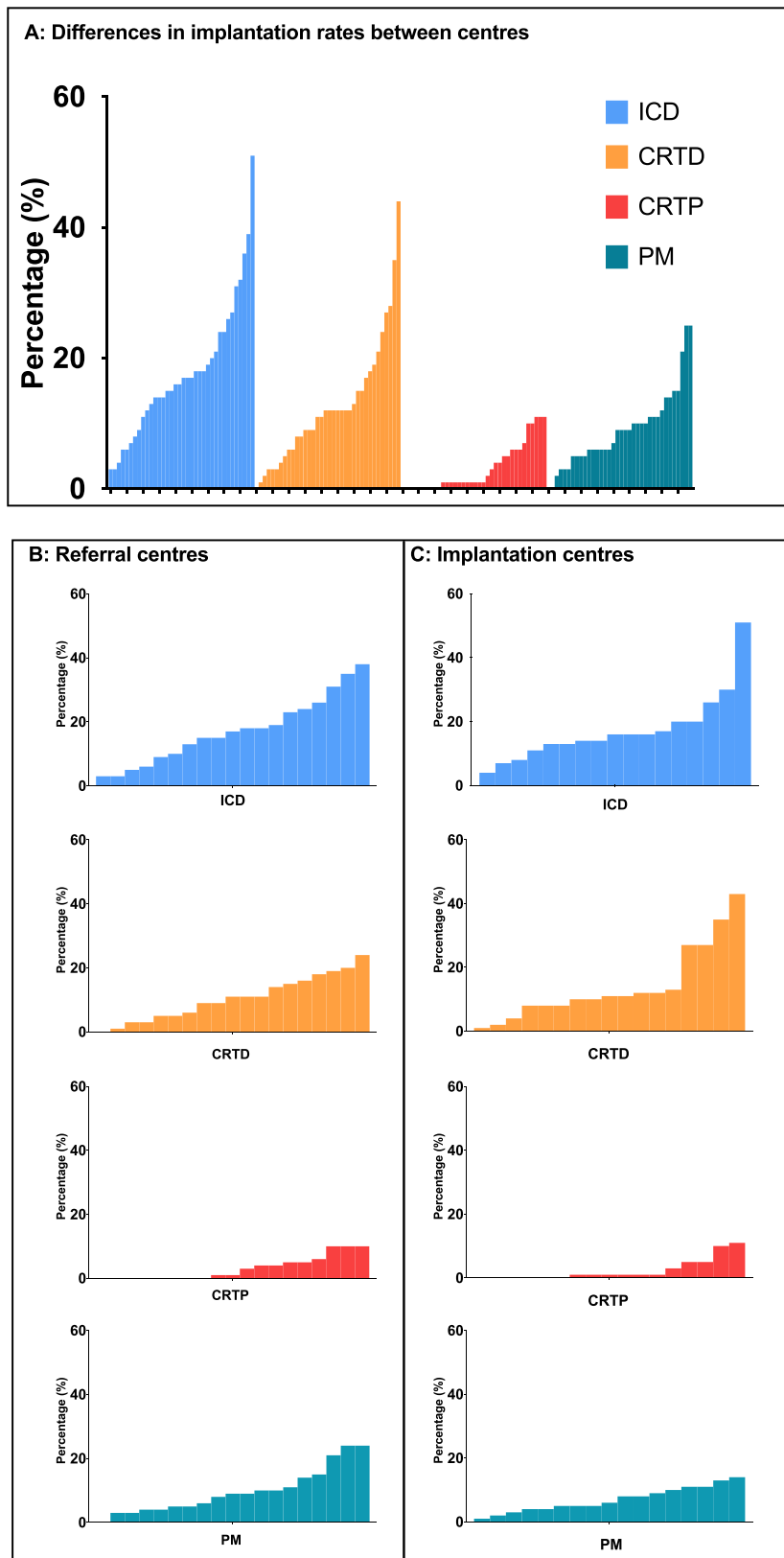
## Discussion

In this cross-sectional study of current device therapy in a real-world setting of HF management, there were three main observations. First, implantation rates of both ICD and CRTD were lower than what could be expected from guideline recommendations (11,19), even in patients with LVEF  $\leq$  30%. Second, there was great variation across centres for all types of devices. Interestingly, implantation centres had higher ICD and CRT implantation rates than referral centres, independent of clinical factors. Third, there were other demographic predictors for device therapy such as age, sex, cause of HF, co-morbidities, and cardiac interventions.

Implantation rates have increased in recent years. A US university centre registry showed an increase of ICD use in HF patients with LVEF  $\leq$  40% from 11% to 66% and CRT use from 0% to 39%, respectively, between 1993–1995 and 2006–2009 (17). This increase in implantation rates in recent years was seen in multiple surveys (13–15). Implantation rates from the CHECK-HF registry were slightly higher than implantation rates from most registries performed earlier (7,8,13,20). This suggests that guideline adherence regarding device therapy in HF has improved. Nevertheless, overall implantation rates remain lower than expected. In our registry, less than half of the HF patients with LVEF  $\leq$  30% received an ICD or CRTD, which can only partly be explained by medical factors.

We found large variation in implantation rates across centres, which can be explained by medical factors only to a very limited extent. This variation between centres has also been observed previously in the USA (6) as well as in Europe (7). Indeed, implantation rates varied between 0% and 80% in the USA, for which no explanation could be found (6), which is in line with our findings. Although there was less variation in our study when compared with other registries, it remains in a range unexplained by differences in patients' characteristics. Therefore, though not tested, it is likely that the way of decision making for device implantation is not uniform, despite the uniform recommendations from guidelines provided by the ESC (11). Further, patients treated in implantation centres were significantly more likely to receive ICD and CRT therapy, respectively, in comparison with patients treated in referral centres. This difference was largely independent of clinical factors. A possible explanation for this difference is that clinicians, especially those from referral centres, focus more on HF medication therapy and, therefore, underappreciate the incremental value of an ICD on top of optimal medical therapy (6,8). In our survey, more patients from referral centres had been given HF medication in comparison with patients from implantation centres. It is possible that physicians working in referral centres tend to focus on HF medication while managing HF patients and are thus more reluctant to refer patients to another centre for device

**Figure 4** Variation in implantation rates across (A) all centres, (B) referral centres, and (C) implantation centres.



**Table 2** Multivariable predictors of device therapy

N = 3447	ICD/CRT-D (n = 650)		CRT-D/CRT-P (n = 547)		PM/CRT-P (n = 152)	
	OR	P-value	OR	P-value	OR	P-value
Age	0.96	<0.001	—	—	1.03	0.006
Male	1.87	0.019	—	—	—	—
RR systolic	0.99	0.017	—	—	—	—
HFrEF	3.33	<0.001	3.56	<0.001	—	—
Ischaemic HF	2.42	<0.001	—	—	—	—
Non-ischaemic HF	1.93	<0.001	—	—	2.42	0.001
Valvular HF	—	—	0.54	0.006	0.37	0.018
Conduction disorder caused HF	1.60	0.012	2.49	<0.001	—	—
AF caused HF	0.50	<0.001	0.44	<0.001	—	—
No co-morbidity	0.73	0.028	—	—	—	—
Hypertension	—	—	1.36	0.030	—	—
DM II	—	—	—	—	0.49	0.036
Hyperthyroidism	0.28	0.014	0.33	0.151	—	—
Hypercholesterolaemia	1.51	0.001	—	—	—	—
PCI	1.45	0.003	—	—	—	—
CABG	1.45	0.007	—	—	—	—
Valvular replacement	—	—	2.04	0.007	3.55	0.002
Other intervention	2.67	<0.001	3.24	<0.001	—	—
ACE/ARB	—	—	—	—	1.87	0.090
Amiodarone	3.44	<0.001	2.46	<0.001	—	—
Implantation centre	1.29	0.024	—	—	0.55	0.012
Time since HF diagnosis	1.08	0.091	1.06	0.102	0.86	0.083

OR, odds ratio; other abbreviations as in Table 1.

therapy. In contrast, physicians working in implantation centres may apply device therapy earlier and focus somewhat less on medical therapy. It should be noted, however, that neither medical therapy nor device therapy was according to the guideline recommendations in both implantation and referral centres. This suggests that there remains room for improvement of both medical therapy and device therapy in basically all centres despite different focus between the two types of centres. Unfortunately, the lack of longitudinal data and direct knowledge of indications for different therapies in the CHECK-HF registry makes it impossible to verify these suggestions. Nevertheless, the findings support the notion that the optimal treatment of patients requires special attention to the combination of device therapy, optimal medical therapy, and other integral aspects of HF management.

The findings of the present study are in some contrast with findings in the GWTG-HF registry, where significant positive correlations were found between implantation rates and prescription rates of HF medication (7). Centres with higher ICD implantation rates were also more likely to adopt newer HF therapies, leading towards higher prescription rates of recommended HF medication. This difference between the findings of this and those of the GWTG-HF registry could be explained by the fact that, on average, medical therapy in the Dutch centres is more in concordance with guidelines than in US centres (6,21). However, this remains speculative as the available data do not allow to investigate causality.

As it may be suspected, the results of this registry revealed age to be an important factor in the decision making of device therapy in HF patients. Older patients were less likely to have ICD or CRT, in contrast to PM. ICD and CRT-D rates

were highest in patients <70 years, whereas PM rates were highest in patients >80 years. Previous studies has shown that the benefit of ICD therapy in terms of lifespan gain decreases during ageing because of the higher co-morbidity rates (22–24). The ESC guidelines state an expected survival of >1 year as a criterion for ICD and CRTD therapy (11). Because older patients have a lower life expectancy, in some cases, this may be considered a contraindication for ICD or CRT-D therapy by patient or clinician. Moreover, elderly patients may more often be rejected from implantation of a defibrillator device, because of the higher peri-operative risks and in-hospital mortality (25). However, co-morbidities seem to be greater predictors of complication risks than age alone, and the risk of peri-procedural complications is only slightly increased (25). Interestingly, co-morbidities were not a predictor of less ICD or CRT, in contrast to age in the present registry. In addition, it may be assumed that increasing survival becomes less important with increasing age. Although this has been found in elderly HF patients, the majority of even those aged 75 years or more still preferred longevity over quality of life (26).

Despite the fact that guideline recommendations regarding device therapy are equal for men and women (11), women are less likely to receive ICD therapy (9,27). Previous studies have shown that sex is an independent predictor of receiving ICD therapy, for both primary and secondary prevention (9, 27–29). This is in line with our results, where sex was an independent predictor for ICD or CRT-D therapy, and women were less likely to have ICD or CRT-D therapy. Exact reasons why the implantation rates in women are lower than in men are still unclear. This ambiguity could be

partly explained by the fact that, until now, only an average of 20% of the included patients in big randomized ICD trials is female. This fact makes it also difficult to explore potential causes for this sex difference (30–33). Still, there are numerous factors that could (partly) explain the lower implantation rates in women. First, men more often present with ischaemic HF and reduced LVEF, whereas women mainly present with non-ischaemic HF and preserved EF and are in that case not eligible for ICD therapy (33, 34). Second, women are, overall, older at time of presentation as compared with men and have a greater burden of co-morbidities (35), which may be important factors in the decision-making process. However, even when ICD therapy or CRT-D is indicated, men are more likely to undergo ICD or CRT-D implantation, irrespective of other confounders such as AF, chronic kidney disease, and age (35, 36). Third, longevity might be less important for women as compared with men (26), possibly influencing decision making. Despite these potential factors, the reduced implantation rate in women remains largely unexplained, in line with the present results.

### Study strengths and limitations

Because this study was conducted as a case–control design lacking some information, we were not able to specifically determine guideline adherence regarding device therapy. We are unable to verify if patients fulfilled the indication for device therapy according to the recommendations of the guidelines at the moment of inclusion in the registry. For example, some patients with reduced LVEF and no ICD or CRT-D might still be in the phase of up titrating HF medication and may recover after optimal medical therapy (OMT). Due to the cross-sectional nature of this registry, causality cannot be investigated. We also do not have information on individual patient's preferences. It is possible, particularly at older age, that patients had contraindications for ICD use or refrained from having a device implanted. As the data were collected at a certain timepoint unrelated to the data of implantation, indications for devices prior to implantation are unknown. This also includes the QRS duration or specific conduction abnormalities prior to implantation. Because patient data were collected retrospectively, based on existing patient files, some data were missing. Despite the fact that there were not many clinically significant differences between patients with and without missing data, this may have influenced our results. Only one-half of the Dutch centres with outpatient HF clinics participated in this study, together with only one out of eight university medical centres. Nevertheless, the percentage of contributing centres and patients is much higher than in other registries, which makes this registry a reasonable reflection of contemporary HF management in the Netherlands. Moreover, only patients in secondary care were included in this registry, and patients only treated in primary care were not considered.

It is likely that both patient population and treatment are different in primary care in the Netherlands as compared with our registry. Still, our population is a large and representative sample of the Dutch HF patients in secondary care.

## Conclusions

In a large Dutch registry of HF patients with both reduced and mid-range LVEF, there was large variation of implantation rates across participating centres. Referral centres used less ICD or CRT therapy, in comparison with centre implanting these devices. These findings suggest that better ways for achieving uniformity regarding guideline-based use of device therapy in clinical practice are desirable.

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## Conflict of interest

None declared.

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## Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

**Figure S1.** Use of HF medication in patients with LVEF <50% and patients with LVEF ≤30%

**Table S1.** Characteristics of patients from implantation and referral centers



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