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RESEARCH ARTICLE

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Regional differences in survival after ICD implantation

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ABSTRACT

Background: The implantable cardioverter-defibrillator (ICD) remains the cornerstone in the prevention of sudden cardiac death. Cost-effectiveness depends on survival after implantation. In Belgium there are unexplained major differences in 3-year mortality after ICD implantation. Centre volume and socio-economic differences might affect survival after implantation.

Methods: In total, 9647 patients underwent a first ICD implantation between February 2010 and 2016 in Belgium and were retrospectively compared for demographics, 30-day and 3-year mortality. Chi-squared and Mann-Whitney U tests were used to determine differences across centre volume.

Results: Low-volume centres treated patients with different characteristics and implanted more patients with ischaemic heart disease (50.2 vs 47.9%, $p=0.002$), in primary prevention (66.7 vs 62.0%, $p<0.001$) and with overall more comorbidities. Kaplan-Meier survival analysis showed a significant higher 3-year mortality in low-volume centres (16.3 vs 11.4%, $p<0.001$). After adjudication with a multivariable Cox model, centre volume remained an independent predictor of 3-year mortality (low volume HR 1.300 [95% CI 1.124–1.504]. However similar 30-day mortality (0.6% in low vs 0.5% in high volume centres, $p=0.393$) suggests that implantation related determinants alone are insufficient to explain the long-term survival difference. Socio-economic factors like regional average income (wealth) and overall survival (health) also were associated with the survival difference between low- and high-volume centres.

Conclusions: There exist large survival differences after ICD implantation between implanting centres in Belgium that cannot only be explained by a volume–outcome effect. Centres size and characteristics are inhomogeneous and vary according to different socio-economic variables. Some of these variables are also significantly associated with survival and warrant further investigation.

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ICD implantation; volume–outcome relationship; mortality; sudden cardiac death

Introduction

Sudden cardiac death (SCD) due to ventricular arrhythmia remains a major health problem. The implantable cardioverter-defibrillator (ICD) is a clinically well-established therapy in the prevention of SCD [1]. However, the implantation of an ICD comes at a cost, both health-related due to possible complications as well as financially. Survival after implantation is a key-determinant of cost-effectiveness of this therapy that is paid upfront [2–4]. Survival after implantation is determined by clinical characteristics of the selected patients, procedural outcome and patient care after implantation. As only arrhythmic death can be prevented by an ICD, ideally only patients with a high arrhythmic but low non-arrhythmic risk of death should be implanted. Post-procedural complications may arise during or after implantation procedure, which could increase mortality in the short term. In the long term, survival differences could be determined by differences in quality of medical care, as well as lifestyle differences between patients or by (un)favourable socio-economic background.

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Based on the summary report of budget indicators for ICD implantations in Belgium performed in the period 2011-2013 published by Belgian health authorities we showed that a significant three-fold difference exists in 3-year mortality after ICD implantation across ICD implanting centres in Belgium [5]. The 3-year mortality ranged from 7.5 to 23.4% between the 23 implanting centres. A multivariable analysis based on the aggregated data per centre, identified centre volume, infection rate and proportion of primary prevention implantations as significant predictors of 3-year mortality. With the current study we explore the determinants of mortality after ICD implantation in Belgium based on individual patient data since these disparities may be caused by inter-patient differences and not by inter-hospital variations.

Methods

Data source

Together with the Belgian Heart Rhythm Association (BeHRA), the Belgian governmental health care institution (RIZIV/INAMI) keeps track of every ICD implantation through the Quality Electronic Registration of Medical acts, Implants and Devices (QERMID) registry. Participation of the 23 ICD implanting centres is compulsory for reimbursement purposes. Regarding mortality data, this registry is linked to the Crossroads Bank for Social Security of Belgium. A database was extracted from this registry for further analyses as previously described [6]. The ethical committee of the University Hospitals of Leuven approved analysis on this retrospective database (S63906).

Patient selection

Patients with a primo ICD implantation performed between 1 February 2010 and 1 February 2016 were eligible for inclusion in this analysis. We limited the analysis to patients with at least three years of follow-up to minimise bias. Furthermore, we excluded non-Belgian patients and patients with an unknown residency because of missing socio-economic parameters and uncertainty about their vital status.

Socio-economic and volume parameters

Based on the NIS code (a numeric code for the regional areas of Belgium) included in the registry, the region of living was added on the level of the arrondissements. Arrondissements are the smallest possible geographical division where specific data on average income and population numbers are available through STATBEL, the Belgian statistical office.

The average income and the population density was retrieved with 2014 as year of reference (middle of data collection). Income was considered low when below percentile 25 (<16.324 euro/year), middle between percentile 25 and 75 and high when above percentile 75 (>18.882 euro/year). Similar division was made for population density with percentile 25 (<190 persons/km^2) and percentile 75 (>573 persons/km^2).

Centre volume was defined by the median primo implantation rate across all implanting centres during the duration of the study. Centre volume was considered low if a centre implanted less than or equal to 65 new ICDs per year and high if a centre implanted more than 65 ICDs per year.

At last, we introduced the amount of primo ICD implantations per year for every 1000 inhabitants (ICD-1000) of an arrondissement as an indicator of regional wealth in healthcare.

Statistical analysis

Baseline patient characteristics and mortality were described and compared with stratification by centre volume. We used a Chi-squared test for categorical variables (presented as number with percentage) and Mann-Whitney *U* test for continuous variables (presented as mean with standard deviation). To explore the relationship between mortality and centre volume, a survival analysis was performed using the Kaplan-Meier estimator. This relationship was further explored using Cox regression analysis. Univariate analysis was followed by a multivariable Cox proportional hazard model to adjust for confounding factors (based on a univariate p-value <0.100), returning hazard ratios (HR) with their 95% confidence interval (CI) and p-value. A HR exceeding 1 indicates an increased mortality risk. Proportional hazard assumptions were assessed using Schoenfeld residuals and visual interpretation of the proportional hazard plots. Collinearity in the final model was assessed using a covariance matrix of the final model. Correlation between ICD availability (number of ICD devices for every 1000 inhabitants) and income parameters were performed using a linear regression analysis and Kruskal Wallis test. Statistical analyses were performed using SPSS (IBM Statistics, version 27, IBM Corp., Armonk, NY, USA) and GraphPad (GraphPad Prism, version 9.1.1, GraphPad Software, San Diego, CA, USA).

Results

Patient characteristics

We included 9647 patients with a first ICD implantation. Mean age was 61.8 ± 13.7 years, most implantations were performed in men (79.7%). The highest proportion of implantations were due to ischaemic heart disease (IHD, 48.7%), followed by non-ischaemic heart disease (NIHD, 33.7%) and arrhythmogenic heart disease (AHD, 15.4%). Only a minority of patients were implanted because of congenital heart disease (CHD, 0.5%). There was a predominance of primary prevention indication over secondary prevention (63.6 vs 36.4%). Single- and dual chamber devices (VVI + DDD) were the most common used (74.6%). The use of cardiac resynchronisation therapy (CRT-D) devices (25.4%) was in line with the number of patients with a QRS duration >150 ms (24.1%). Most patients experienced some degree of heart failure symptoms and functioned in NYHA class II (52.1%) or III (31.2%). Atrial fibrillation (AF) was the most prevalent comorbidity (21.8%). The majority of patients belonged to the middle-income group (44.7%) and lived in highly populated areas (46.9%).

Mortality after ICD implantation

The average follow-up was 5.05 ± 2.13 years with an overall 3-year mortality of 13.0% ($N = 1255$). Patients who died within three years were significant older (68.7 ± 10.8 vs 60.8 ± 13.8 years, $p < 0.001$), had a lower left ventricular ejection fraction (LVEF, 30.7 ± 12.9 vs 36.0 ± 16.1%, $p < 0.001$) and were more often male (83.2 vs 79.1%, $p < 0.001$) with IHD (60.6 vs 46.9%, $p < 0.001$) (Table 1). Furthermore, 3-year mortality was more prevalent in the poor (low income 30.8 vs 22.4%, $p < 0.001$) with a higher comorbidity burden. About one third of patients were implanted in a low-volume centre.

Table 1. Baseline patient characteristics stratified by 3-year mortality.

		Total		Survival ≤ 3 years		Survival > 3 years		
		$N = 9647$		$N = 1257$		$N = 8390$		p-value
		Mean	SD	Mean	SD	Mean	SD	
Age		61.8	13.7	68.7	10.8	60.8	13.8	<0.001
LVEF		35.3	15.8	30.7	12.9	36.0	16.1	<0.001
ICD-1000		0.157	0.041	0.154	0.043	0.158	0.041	0.001
		Number	%	Number	%	Number	%	
Sex	F	1961	20.3%	211	16.8%	1750	20.9%	<0.001
	M	7686	79.7%	1046	83.2%	6640	79.1%	
Heart Disease	NIHD	3250	33.7%	393	31.3%	2857	34.1%	<0.001
	IHD	4697	48.7%	762	60.6%	3935	46.9%	
	AHD	1485	15.4%	87	6.9%	1398	16.7%	
	CHD	45	0.5%	4	0.3%	41	0.5%	
	OTHER	170	1.8%	11	0.9%	159	1.9%	
NYHA	I	1590	16.5%	65	5.2%	1525	18.2%	<0.001
	II	5030	52.1%	679	54.0%	4351	51.9%	
	III	3008	31.2%	507	40.3%	2501	29.8%	
	IV	19	0.2%	6	0.5%	13	0.2%	
QRS	<120	6688	69.3%	777	61.8%	5911	70.5%	<0.001
	120–150	636	6.6%	109	8.7%	527	6.3%	
	150–180	1788	18.5%	291	23.2%	1497	17.8%	
	>180	535	5.5%	80	6.4%	455	5.4%	
EC	VVI or DDD	7195	74.6%	880	70.0%	6315	75.3%	<0.001
	CRT	2452	25.4%	377	30.0%	2075	24.7%	
Type of prev.	Primary	6133	63.6%	767	61.0%	5366	64.0%	0.043
	Secondary	3514	36.4%	490	39.0%	3024	36.0%	
AF	1	2098	21.7%	421	33.5%	1677	20.0%	<0.001
Diabetes	1	1321	13.7%	266	21.2%	1055	12.6%	<0.001
COPD	1	671	7.0%	166	13.2%	505	6.0%	<0.001
Neuro	1	522	5.4%	101	8.0%	421	5.0%	<0.001
Onco	1	344	3.6%	73	5.8%	271	3.2%	<0.001
RF	1	764	7.9%	216	17.2%	548	6.5%	<0.001
Income	Middle	4308	44.7%	485	38.6%	3823	45.6%	<0.001
	Low	2265	23.5%	387	30.8%	1878	22.4%	
	High	3074	31.9%	385	30.6%	2689	32.1%	
Pop. Dens.	Middle	4435	46.0%	581	46.2%	3854	45.9%	0.467
	Low	686	7.1%	99	7.9%	587	7.0%	
	High	4526	46.9%	577	45.9%	3949	47.1%	
Centre Volume	Low	3189	33.1%	519	42.3%	2670	31.8%	<0.001

Left ventricular ejection fraction, LVEF. Number of ICDs per 1000 persons in an arrondissement, ICD-1000. Non-ischaemic heart disease, NIHD. Ischaemic heart disease, IHD. Arrhythmogenic heart disease, AHD. Congenital heart disease, CHD. Electrode configuration, EC. Prevention, prev. Atrial fibrillation, AF. Chronic obstructive pulmonary disease, COPD. Renal failure, RF. Population density, Pop. Dens.

Centre volume and survival

Patients implanted in low-volume centres were compared to patients implanted in high-volume centres (Table 2). Low-volume centres implanted on average younger patients (61.4 ± 13.3 vs 62.0 ± 13.9, $p < 0.001$) with lower LVEF (34.2 ± 14.6 vs 35.9 ± 16.4, $p = 0.001$) and more IHD (50.2 vs 47.9%, $p < 0.001$). There was a lower penetrance of CRT-D therapy (22.4 vs 26.9%; $p < 0.001$). Patients implanted in low-volume centres had in general more comorbidities and were from poorer (low income 54.1 vs 8.4%, $p < 0.001$) and less densely populated areas (low population density 19.6 vs 0.9%, $p < 0.001$). We noticed a significant higher 3-year mortality rate in low-wolume ($N = 520$, 16.3%) vs high-volume centres ($N = 735$, 11.4%) ($p < 0.001$) while 30-day mortality was not different in low-volume centres ($N = 19$, 0.6%) vs high-volume ($N = 32$, 0.5%) ($p = 0.394$). In addition, the Kaplan-Meier estimator showed a significant 3-year mortality difference between low- and high-volume centres (log-rank $p < 0.001$, Figure 1).

Predictors of mortality

To adjust for confounding factors, we performed a multivariable Cox proportional hazard model (Table 3). There is a significant impact on 3-year mortality of increasing age (HR 1.047 with 95% CI 1.041–1.054), increasing heart failure symptoms as translated in the NYHA functional status (class IV vs I, HR 4.667 with 95% CI 1.991–10.943), secondary prevention indication (HR 1.435 with 95% CI 1.271–1.619) and most of the comorbidities. A better-preserved LVEF predicted a survival benefit (HR 0.980 with 95% CI 0.975–0.986) as did the use of CRT (HR 0.715 with 95% CI 0.566–0.903). Poorer people had worse survival (HR 1.239 with 95% CI 1.062–1.447). Implantation in a low-volume centre was likewise associated with higher mortality (HR 1.300 with 95% CI 1.124–1.504).

Table 2. Baseline patient characteristics stratified by centre volume.

		Total		Low volume		High volume		
		$N = 9647$		$N = 3189$		$N = 6458$		p-value
		Mean	SD	Mean	SD	Mean	SD	
Age		61.8	13.7	61.4	13.3	62.0	13.9	<0.001
LVEF		35.3	15.8	34.2	14.6	35.9	16.4	0.001
ICD-1000		0.157	0.041	0.131	0.043	0.171	0.034	<0.001
		Number	%	Number	%	Number	%	
Sex	F	1961	20.3%	642	20.1%	1319	20.4%	0.737
	M	7686	79.7%	2547	79.9%	5139	79.6%	
Heart Disease	NIHD	3250	33.7%	1087	34.1%	2163	33.5%	<0.001
	IHD	4697	48.7%	1602	50.2%	3095	47.9%	
	AHD	1485	15.4%	417	13.1%	1068	16.5%	
	CHD	45	0.5%	15	0.5%	30	0.5%	
	OTHER	170	1.8%	68	2.1%	102	1.6%	
NYHA	I	1590	16.5%	486	15.2%	1104	17.1%	<0.001
	II	5030	52.1%	1760	55.2%	3270	50.6%	
	III	3008	31.2%	937	29.4%	2071	32.1%	
	IV	19	0.2%	6	0.2%	13	0.2%	
QRS	<120	6688	69.3%	2234	70.1%	4454	69.0%	0.256
	120–150	636	6.6%	223	7.0%	413	6.4%	
	150–180	1788	18.5%	562	17.6%	1226	19.0%	
	>180	535	5.5%	170	5.3%	365	5.7%	
EC	VVI or DDD	7195	74.6%	2475	77.6%	4720	73.1%	<0.001
	CRT	2452	25.4%	714	22.4%	1738	26.9%	
Type of prev.	Primary	6133	63.6%	2127	66.7%	4006	62.0%	<0.001
	Secondary	3514	36.4%	1062	33.3%	2452	38.0%	
AF	1	2098	21.7%	733	23.0%	1365	21.1%	0.038
Diabetes	1	1321	13.7%	586	18.4%	735	11.4%	<0.001
COPD	1	671	7.0%	307	9.6%	364	5.6%	<0.001
Neuro	1	522	5.4%	210	6.6%	312	4.8%	<0.001
Onco	1	344	3.6%	123	3.9%	221	3.4%	0.279
RF	1	764	7.9%	310	9.7%	454	7.0%	<0.001
Income	Middle	4308	44.7%	892	28.0%	3416	52.9%	<0.001
	Low	2265	23.5%	1725	54.1%	540	8.4%	
	High	3074	31.9%	572	17.9%	2502	38.7%	
Pop. Dens.	Middle	4435	46.0%	1440	45.2%	2995	46.4%	<0.001
	Low	686	7.1%	625	19.6%	61	0.9%	
	High	4526	46.9%	1124	35.2%	3402	52.7%	
3-year mortality	1	1257	13.0%	519	16.3%	738	11.4%	<0.001

Left ventricular ejection fraction, LVEF. Number of ICDs per 1000 persons in an arrondissement, ICD-1000. Non-ischaemic heart disease, NIHD. Ischaemic heart disease, IHD. Arrhythmogenic heart disease, AHD. Congenital heart disease, CHD. Electrode configuration, EC. Prevention, prev. Atrial fibrillation, AF. Renal failure, RF. Chronic obstructive pulmonary disease, COPD. Population density, Pop. Dens.

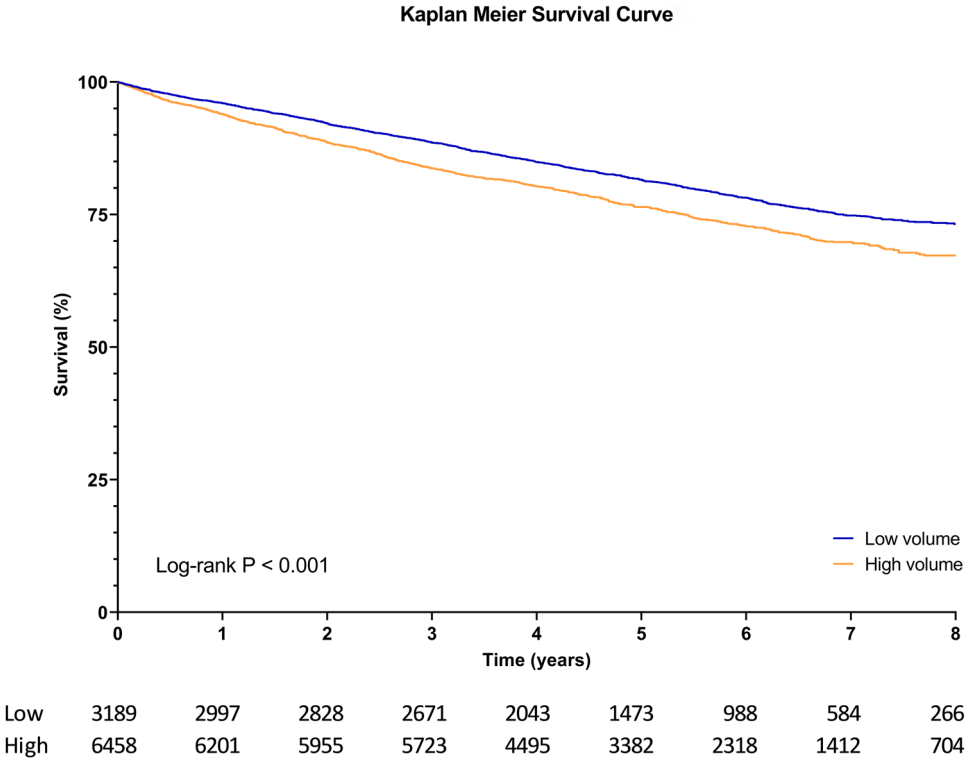

Figure 1. *Upper part:* Kaplan Meier survival curve stratified by centre volume for 3-year survival after ICD implantation (log-rank $p < 0.001$). *Lower part:* Survival table with numbers at risk.

Table 3. Multivariable Cox regression analysis regarding 3-year mortality.

			95% Confidence interval		
		Hazard Ratio	Lower	Upper	*p*-value
Age		1.047	1.041	1.054	<0.001
LVEF		0.980	0.975	0.986	<0.001
Sex		1.053	0.905	1.227	0.503
Heart disease	NIHD	ref			
	IHD	1.199	1.054	1.364	0.006
	AHD	1.463	1.124	1.905	0.005
	CHD	2.283	0.843	6.184	0.104
	Other	1.247	0.672	2.315	0.484
NYHA	I	ref			
	II	1.695	1.286	2.234	<0.001
	III	2.219	1.624	3.031	<0.001
	IV	4.667	1.991	10.943	<0.001
QRS	<120	Ref			
	120–150	1.195	0.938	1.523	0.149
	150–180	1.119	0.882	1.420	0.355
	>180	0.973	0.714	1.327	0.864
EC	CRT	0.715	0.566	0.903	0.005
Type of prev.	Secondary	1.435	1.271	1.619	<0.001
AF		1.411	1.251	1.592	<0.001
Diabetes		1.324	1.153	1.521	<0.001
COPD		1.676	1.420	1.978	<0.001
Neuro		1.180	0.960	1.449	0.116
Onco		1.482	1.168	1.879	0.001
RF		1.651	1.419	1.921	<0.001
Income	Middle	Ref			
	Low	1.239	1.062	1.447	0.007
	High	1.118	0.976	1.280	0.107
Centre volume	Low	1.300	1.124	1.504	<0.001
ICD-1000		0.776	0.173	3.480	0.740

Left ventricular ejection fraction, LVEF. Number of ICDs per 1000 persons in an arrondissement, ICD-1000. Non-ischaemic heart disease, NIHD. Ischaemic heart disease, IHD. Arrhythmogenic heart disease, AHD. Congenital heart disease, CHD. Electrode configuration, EC. Prevention, prev. Atrial fibrillation, AF. Renal failure, RF. Chronic obstructive pulmonary disease, COPD.

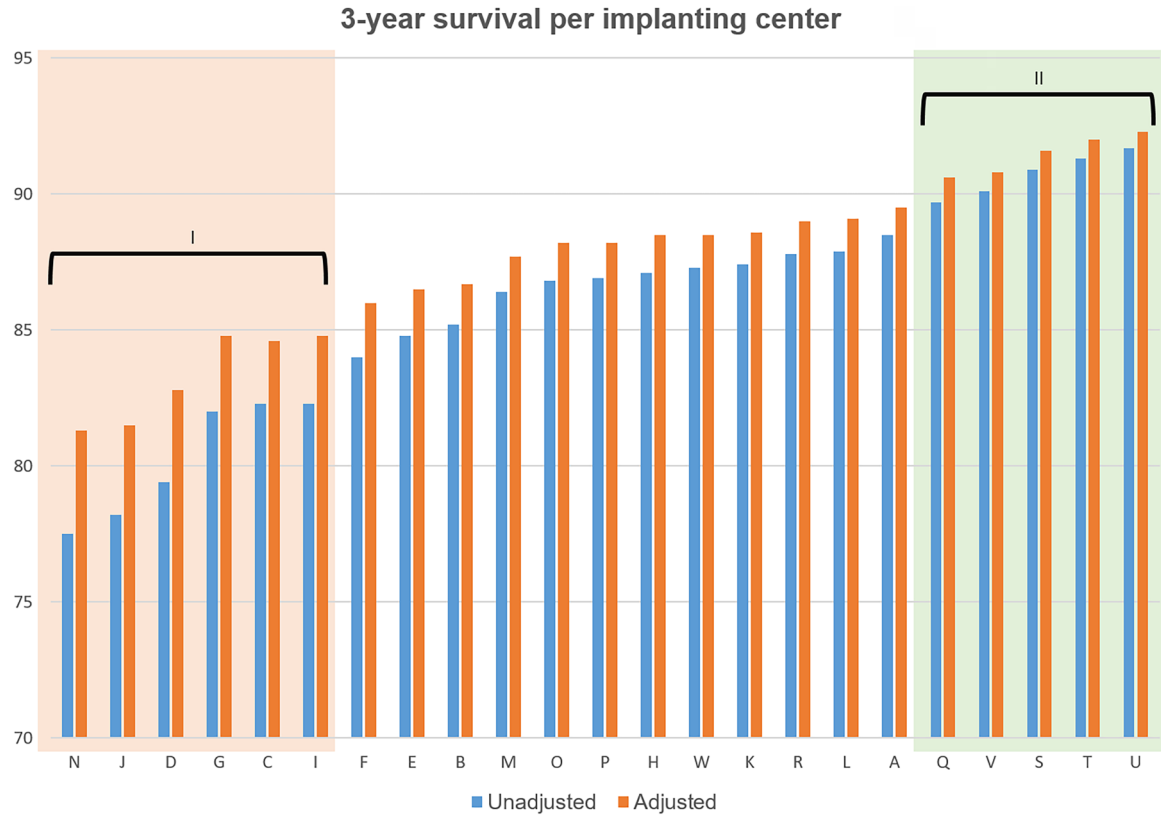

Figure 2. Unadjusted and adjusted survival rates per implanting centre.

To evaluate if the volume-outcome relationship might be due to complication rates, additional comparisons of baseline characteristics and multivariable Cox proportional hazard models were performed for 30-day and 1-year mortality (supplemental appendix tables S1–S4). Regardless of the timing after implantation a higher NYHA status, secondary prevention indication and an oncological history were associated with worse outcome while a better preserved LVEF and the use of CRT led to a survival advantage. Centre volume was not associated with 30-day or 1-year mortality in this analysis.

While the crude 3-year mortality ranged from 8.3 to 22.5% between implanting centres, the estimated 3-year mortality was reduced to 7.7 and 18.7%, respectively, when accounting for the mean of covariates (Figure 2).

ICD availability: wealth and health

Unadjusted Cox analysis showed a higher mortality in people living in poorer districts (Supplemental Appendix Table S5). However, when adjusting for the main regions of Belgium (Flanders, Brussels and Wallonia), low income lost its significance (HR 1.124 with 95% CI 0.896–1.410) as predictor of mortality. Similarly, the power of the volume-outcome effect decreased (HR 1.255 with 95% CI 1.065 – 1.478) (Supplemental Appendix Table S6). As an indicator of regional wealth, we explored ICD-1000 which correlated significantly with the average income of the area of residency (R^2 = 0.097, p = 0.042; Figure 3) with a lower ICD availability in poorer areas (0.137 ± 0.047 in low income, 0.167 ± 0.042 in middle income and 0.159 ± 0.027 in high income areas, $p < 0.001$). High-volume centres were located in areas with a higher average income (18221€/year compared to 15759€/year, p = 0.007) (Figure 4). Furthermore, it is important to notice the regional distribution of high- vs low-volume centres in Belgium with a north/south division with in general a lower life expectancy in the southern part of Belgium (Figure 5).

Discussion

After correction for individual patient characteristics, there remains a significant up to 2.5-fold difference in 3-year mortality after new ICD implantation between the ICD implanting centres in Belgium, while there was no significant difference in 30-day mortality. Despite significant differences in baseline patient characteristics between high- and low-volume centres, a multivariable Cox model showed a remaining impact of

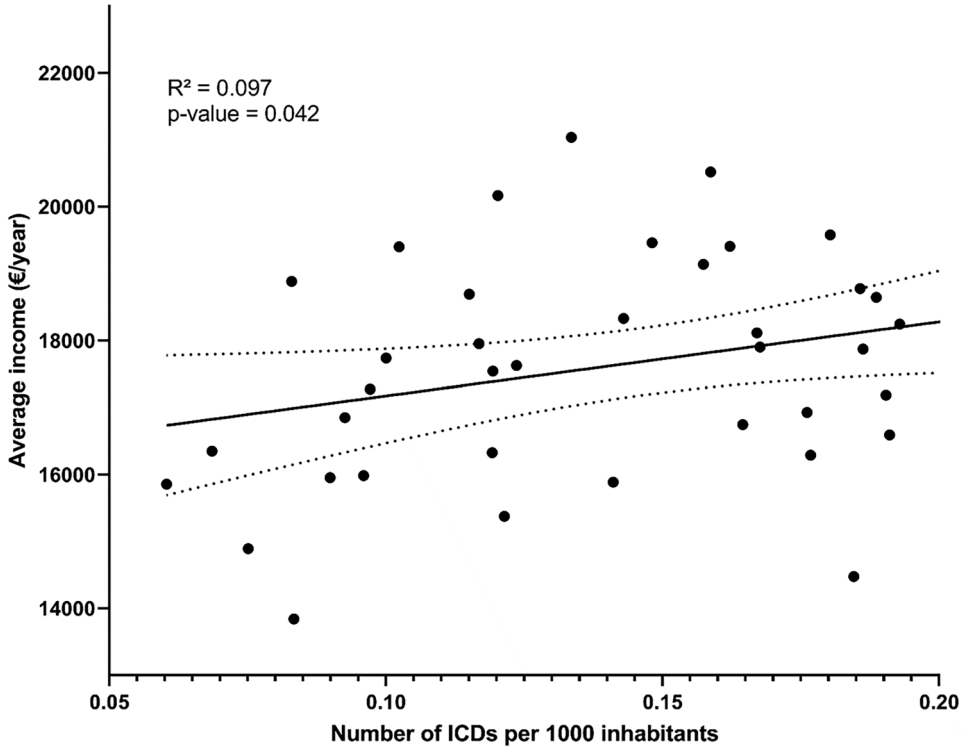

Figure 3. Relationship between number of ICDs per 1000 persons (ICD-1000) and the average income.

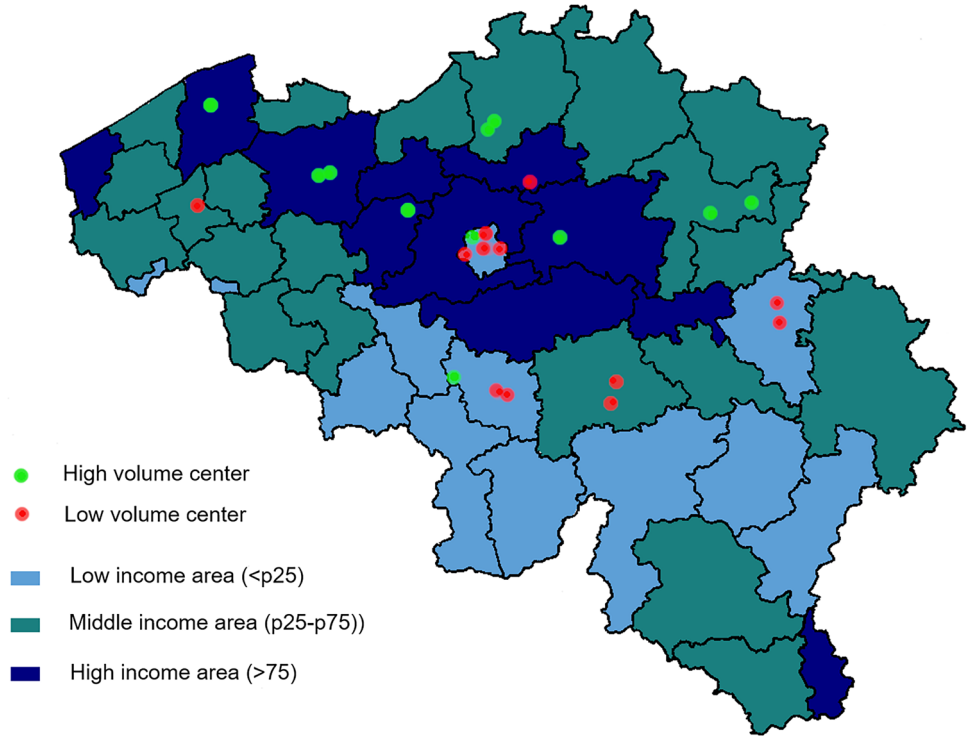

Figure 4. Distribution of ICD implanting centres in Belgium with indication of the average income.

centre volume after adjusting for known confounders on long-term mortality. This relationship between volume and long-term survival seems confounded by regional socio-economic parameters.

Determinants of survival after ICD implantation

To date, cost-effectiveness of ICD therapy depends largely on survival after ICD implantation [3]. Selecting the patients who will benefit from their ICD and

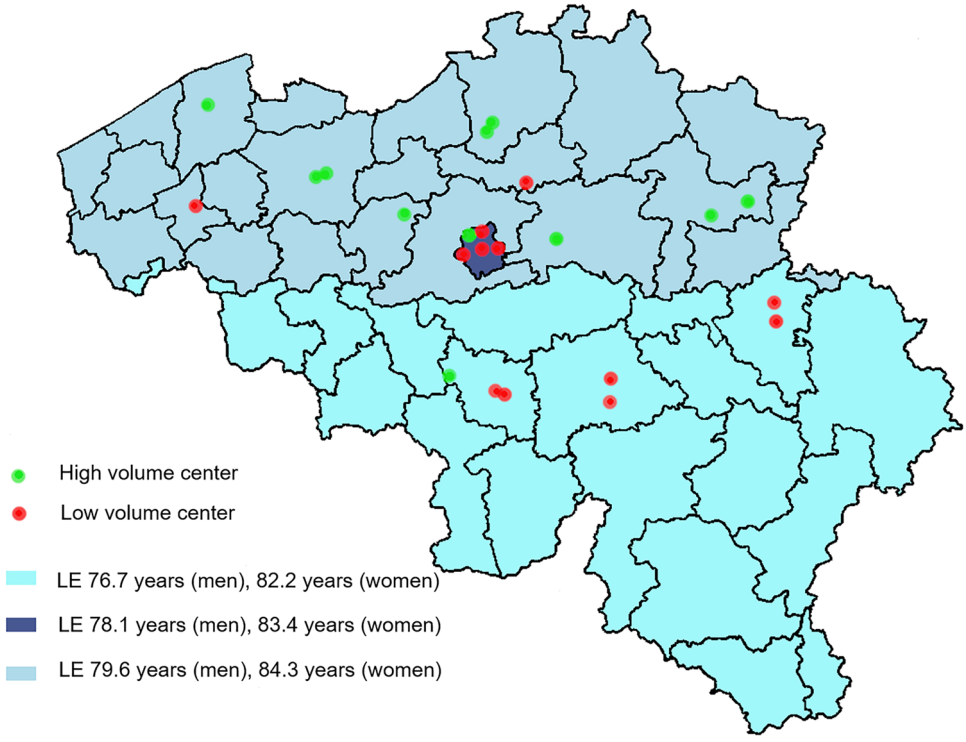

Figure 5. Distribution of ICD implanting centres in Belgium with annotation of the three main regions with their life expectancy (LE).

excluding the patient who will experience premature death from any cause is still the Holy Grail in ICD therapy practice. Most well-known risk factors like increasing age, ischaemic heart disease, worse functional status according to NYHA classification, lower LVEF, a history of atrial fibrillation and non-cardiac comorbid status were predictors of mortality. Our findings are in line with the retrospective analysis provided by Lee et al. [7] Medical comorbidity indeed modulates the ICD benefit, but does not necessarily precludes effectiveness warranting patient-tailored decision making [8, 9]. Additionally, there was an association between lower average income and mortality as well as between centre volume and mortality. The latter suggesting volume might partly explain the discrepancy in mortality between implanting centres.

Is it all about volume?

Previous studies have shown that higher volume of procedures can lead to better outcomes, but the volume-outcome effect is a much-discussed topic and the body of research in this field deals with surgical procedures or is limited to short-term outcomes [10–12]. When looking at the volume–outcome effect in pacemaker implantation practice, an inverse relationship was found with lower volumes being associated with higher complication rates [13]. About ICD and CRT implantation, volume affects the rate of procedure-related adverse events, but the long-term consequences on mortality of ICD implantation-volume remains unexplored [14, 15]. Therefore, our findings of a long-term volume-outcome relationship on mortality is interesting and deserves critical appraisal.

As "practice makes perfect", a common explanation for the volume-outcome relationship is that high-volume centres have more experience, which would lead to less peri-procedural complications and therefore a better outcome. This would predominantly affect short-term mortality and one would therefore expect an initial discrepancy between low- and high-volume centres with a stable gap in mortality afterwards. However, in our study the initial discrepancy is low with a similar 30-day mortality (log-rank, $p = 0.393$; Supplemental Appendix figure S1), but steadily increasing over time with significant divergence of survival curves at 1-year (log-rank, $p < 0.001$, supplemental appendix figure S2). This finding might thus also suggest differences in patients' selection between centres, some being more conservative and stricter with ICD indications in the sickest patients, and some being more liberal, implanting more patients with less comorbidities, which finally would turn in better spontaneous survival. On the other hand, acute complications can have a long-term impact [16]. Furthermore, high-volume centres may have more trainees, with

implantations performed by a trainee being associated with worse short-term outcome [17]. Therefore, implanter experience alone is insufficient as explanation of the survival difference.

Other contributing parameters might be differences in interfering factors (e.g. patient characteristics and referral bias), differences in quality of care and statistical limitations to correct for all confounding variables. Admittedly, low-volume centres tended to implant sicker patients as they had on average a lower LVEF and more comorbidities, which might attenuate the survival benefit associated with ICD implantation. Indeed, Steinberg et al. noticed a reduced benefit of ICD in primary prevention with increasing comorbidities in trial populations [8]. Real-world data from Chan et al. showed a higher all-cause mortality in patients implanted with an ICD in primary prevention if they had major comorbid conditions and higher age [9]. In low-volume centres, more patients with kidney disease were implanted while end-stage chronic kidney disease is both associated with higher cardiac implantable electronic device (CIED) infection risk as well as mortality [18]. The only predictors of mortality that were more prevalent in high volume centres were secondary prevention indication, NYHA class III and higher age. However, it is well known that the calendar age does not necessarily reflects the biological age of a patient and an absolute difference of 8.1 months does not seem clinically relevant. Therefore, it is important to identify other contributing factors besides centre volume and patient characteristics in the long-term survival after implantation.

Quality of care

Another part of the explanation might be structural differences between high- and low-volume centres. Recently, Taccone et al. showed that the outcome of COVID-19 patients admitted to the ICU was negatively affected if hospitals had a high number of newly created ICU beds or at moments of high ICU overflow [19]. This emphasises the importance of adequate staffing ratios.

There might also be a contribution of differences in follow-up. CIED follow-up has evolved from periodic checks in-hospital (with limited datapoints) towards continuous monitoring that could enable early intervention [20]. Currently, there is no reimbursement for remote monitoring in Belgium, a tool that might affect outcome [21, 22]. High-volume centres often have access to higher financial resources, which facilitates the use of remote monitoring. A survey among the implanting centres, in which 21 out of 23 centres responded, showed that almost half of the high-volume centres (5 out of 11) use remote monitoring in more than 75% of their ICD implanted patients. By contrast, only a minority of low volume centres (2 out of 10) use remote monitoring in this proportion of patients. Nevertheless, there are currently no standardised protocols on how to implement multiparametric (remote) monitoring in clinical practice [23]. Workflow optimisation—with attention to patient privacy and local legal requirements—and optimal use of resources are essential to make remote monitoring a success story [24]. Furthermore, the majority of high-volume centres (5 out of 11) keep their patients in follow-up with a referral ratio of less than 25% whereas this is much less the case for low volume centres (2 out of 10) (unpublished data).

It is important to note that significantly less CRT devices were implanted in low volume centres while CRT device are associated with better 3-year survival. So, more CRT pacing means lower mortality. Conversely, in non-CRT patients, reducing RV pacing to a strict minimum by optimising device programming can have a favourable effect on outcomes [25].

Wealth and health

Investigating the impact of socio-economic variables on ICD outcome is challenging. Much attention has been paid to the relationship between income and survival. It might be possible that patients with low income do not seek specialist advice as often with higher ratios of loss-to-follow-up. However, Belgian social security covers most of health care costs. Similarly, a Danish study by Winther-Jensen et al. showed that patients with the highest incomes are more likely to receive an ICD and have a better survival [26]. Similarly, we found a positive correlation between ICD-1000 and the average income. Furthermore, high-volume centres were in more wealthy regions. ICD availability might thus be a parameter for regional wealth that correlates with regional health. Equal distribution of resources is necessary to overcome this issue.

Limitations

In a quest to optimise the use of health care budgets, policymakers seek to quantify the quality of healthcare with mortality—thanks to its uniform definition—as the most unambiguous and easy parameter to register and compare. However, a better survival does not

necessarily equal a better quality. It might be more appropriate to compare differences in QALY between the centres, but this is not possible with our dataset.

With the current dataset it was not possible to correct for local differences in life expectancy which might influence our findings. Spatial disparities in survival endure within similar social groups beyond the socio-economic composition of the region they are living in [27]. Moreover, we cannot correct for whether or not optimal medical treatment (OMT) was used as we did not had access to the electronic medical records of the patient but are limited to the parameters included in the QERMID registry as designed by the government. Differences in penetration of OMT might play in role in the survival differences. Furthermore, we could not correct for individual income as this parameter was derived from the area of residency. We did not correct for volume of each implanting physician independently. Besides, only total mortality was available and used for this analysis, without separating between cardiac and non-cardiac mortality, arrhythmic and non-arrhythmic mortality, device-related and non-device-related mortality.

Dichotomising centre volume based on the median of implantations performed over the six-year period also have drawbacks as it is not possible to reveal a continuous relationship between volume and mortality.

At last, given the retrospective nature of this study, there is a possibility of residual unknown confounders.

Conclusion

There exist large survival differences after ICD implantation between implanting centres in Belgium that cannot only be explained by a volume-outcome effect. Centres size and characteristics are inhomogeneous and vary according to different socio-economic variables. Some of these variables are also significantly associated with survival and warrant further investigation.

Disclosure statement

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