ORIGINAL ARTICLE

How Many Patients Admitted for Heart Failure Are Eligible for Cardiac Resynchronization Therapy? Analysis of the Andalusian Heart Failure Registry (RAIC) Study

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Introduction and objectives. The objective was to determine what percentage of patients admitted for heart failure met criteria for cardiac resynchronization therapy.

Methods. The study involved registry data on heart failure admissions at 16 public hospitals in Andalusia, Spain between May and July 2004. Criteria for cardiac resynchronization therapy from American College of Cardiology and American Heart Association guidelines were applied: a left ventricular ejection fraction ≤0.35, New York Heart Association functional class III or IV, and a QRS interval >120 ms. Outcome was evaluated at 3 months. Multivariate (ie, logistic regression) analysis was used to identify independent variables associated with meeting resynchronization therapy criteria.

Results. The study included 674 patients (43.3% women, mean age 71 [11] years). Of these, 5.6% met resynchronization therapy criteria at admission. There was no significant difference in the cardiovascular event rate at 3 months between patients who met resynchronization therapy criteria and those who did not (34.2% vs 23.4%, respectively). Admitting hospital (odds ratio [OR]=0.30; 95% confidence interval [CI], 0.11-0.79), ischemic etiology (OR=2.71; 95% CI, 1.26-5.81), the presence of left bundle branch block (OR=14.97; 95% CI, 5.95-37.64), and mitral regurgitation (OR=4.18; 95% CI, 1.93-9.04) were all independently associated with meeting resynchronization therapy criteria at both admission and short-term follow-up.

Conclusions. The percentage of patients who met cardiac resynchronization therapy criteria was small, but their short-term prognosis was poor. A number of clinical variables associated with meeting resynchronization therapy criteria were identified.

Key words: *Heart failure. Resynchronization therapy. Epidemiology.*

¿Cuántos pacientes ingresados por insuficiencia cardiaca son elegibles para terapia de resincronización cardiaca? Análisis del estudio RAIC (Registro Andaluz de Insuficiencia Cardiaca)

Introducción y objetivos. Nuestro objetivo fue evaluar qué porcentaje de pacientes ingresados por insuficiencia cardiaca presentaba criterios para resincronización.

Métodos. Registro prospectivo de pacientes ingresados por insuficiencia cardiaca en 16 hospitales andaluces entre mayo y julio de 2004. Se analizó la presencia de criterios para resincronización cardiaca según las guías de la American Heart Association/American College of Cardiology (fracción de eyección ventricular izquierda ≤ 0,35, grado funcional III-IV de la New York Heart Association, complejo QRS > 120 ms). Se evaluó el pronóstico a los 3 meses. Mediante análisis multivariable (regresión logística) se estudió qué variables se relacionaban de manera independiente con la presencia de criterios para resincronización.

Resultados. Se incluyó a 674 pacientes (43,3% mujeres, edad media 71 ± 11 años). Un 5,6% de los pacientes reunía criterios de resincronización en el momento del ingreso. La tasa de sucesos cardiovasculares a 3 meses (el 34,2 frente al 23,4%) no fue distinta entre los pacientes con y sin criterios para resincronización. El servicio de ingreso (*odds ratio* [OR] = 0,30; intervalo de confianza [IC] del 95%, 0,11-0,79), junto con la etiología isquémica (OR = 2,71; IC del 95%, 1,26-5,81), la presencia de bloqueo de rama izquierda (OR = 14,97; IC del 95%, 5,95-37,64) y la regurgitación mitral (OR = 4,18; IC del 95%, 1,93-9,04) se relacionaron de manera independiente con la presencia de criterios para resincronización, tanto en el momento del ingreso como en el seguimiento a corto plazo.

Conclusiones. El porcentaje de pacientes que reunieron criterios para resincronización cardiaca fue pequeño y su pronóstico fue malo a corto plazo. Se identificó una serie de variables clínicas como relacionadas con la elegibilidad para resincronización cardiaca.

Palabras clave: *Insuficiencia cardiaca. Resincronización. Epidemiología.*

The investigators of the RAIC are listed at the end of the article.

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ABBREVIATIONS

CRT: cardiac resynchronization therapy
LBBB: left bundle branch block

INTRODUCTION

Heart failure represents a growing medical and epidemiological problem due to the increasing average age of the population and better survival among patients with ischemic heart disease. It is characterized by high rates of morbidity and mortality,[1,2] even though advances have been made in determining its pathophysiology, diagnosis, and therapeutic management.

Although cardiac resynchronization therapy (CRT) has been developed as a additional therapy in selected patients with heart failure in recent years,[3,4] the number of devices implanted for CRT in Spain is below the European average despite a recent marked increase.[5]

Cardiac resynchronization therapy has become widespread after the results of the COMPANION[6] and CARE-HF[7] studies were published, but the percentage of patients with heart failure would meet the criteria for CRT according to currently available data remains controversial. These doubts arise because estimates are based on highly selected samples of patients, who are usually participants in clinical trials.

The aim of our study was to analyze a broad unselected sample of patients admitted to several hospitals in Andalusia, Spain, for heart failure and to establish what percentage of them met the criteria for CRT, as well as what variables might be related to the presence of these criteria.

METHODS

This prospective registry included the first 50 consecutive patients admitted to each of the 16 Andalusian hospitals participating in the study (regardless of the type of service and level of care provided by the hospital [13 were secondary and tertiary care hospitals and 3 were regional hospitals]) over a 3-month period (May-July, 2004) for heart failure. All centers had a cardiology service, although in some cases this service was affiliated to the internal medicine service for administrative purposes but distinct from internal medicine in terms of the care provided.

Heart failure was defined according to the clinical criteria of the European Society of Cardiology.[8,9]

Patients were excluded from the analysis if heart failure was due solely to valve disease.

Eligibility for CRT was based on the criteria presented in the American Heart Association/American College of Cardiology (AHA/ACC) guidelines: QRS duration greater than or equal to 120 ms, left ventricular ejection fraction (LVEF) less than or equal to 0.35, and New York Heart Association (NYHA) functional class III or IV despite optimal medical therapy with angiotensin converting enzyme (ACE) inhibitors/angiotensin II receptor antagonists (ARAII), and beta blockers.[10] If LVEF had not been determined, the patient was not considered eligible for CRT.

Epidemiological characteristics (age, sex, service, traditional cardiovascular risk factors), clinical data (days in hospital, prior myocardial infarction, previous pharmacotherapy, prior heart failure, NYHA functional class, comorbidity, independent living [defined as self sufficiency for basic tasks such as washing and eating], previous admissions to hospital, triggering factors, symptoms [dyspnea, orthopnea, nocturnal paroxysmal dyspnea], and signs [jugular engorgement, lung crackling, gallop rhythm, murmurs, peripheral edemas, hepatosplenomegaly, ascites]), electrocardiographic data (heart rate, atrial fibrillation, QRS, and PR interval, criteria for left ventricular hypertrophy, left bundle branch block [LBBB]), laboratory analyses (hemoglobin, blood glucose, renal function, lipid profile, and electrolytes), and echocardiographic data (from examination on admission, systolic, and/or diastolic dysfunction, LVEF, left ventricular dilatation, and significant mitral valve regurgitation [moderate or severe]). Likewise, the overall number of cardiovascular deaths (during admission and outside hospital), as well as the treatment being taking on discharge, were recorded.

After 3 months, follow-up assessed the clinical course (death, readmission for heart failure, functional class) and the degree of compliance with the treatment prescribed on discharge.

The data were processed with the SPSS version 11.0 (SPSS Inc) statistical package. Quantitative variables were expressed as means (SD), and qualitative ones as percentages. Qualitative variables were compared with the χ^2 test or the Fisher exact test. The Student *t* test was used to compare differences between quantitative variables. The multivariate analysis was done using a logistic regression model in which variables were included with different distribution in the bivariate analysis, as well as those that have been shown to be related to the asynchrony in previous studies (age, sex, prior infarction, LBBB, service, significant mitral valve regurgitation, and presence of atrial fibrillation), with the final selection of variables being done by the "introduce" method. The strength of the association was determined using the odds rate (OR) adjusted to a 95% confidence interval (CI). A *P* value less than .05 was considered significant for 2-tailed tests.

RESULTS

Of the 795 patients included in the general registry, 121 were excluded on the grounds of having valve disease

only, and so 674 patients were included in the final analysis. The main epidemiological, clinical, analytical, electrocardiographic, and echocardiographic characteristics are shown in Table 1.

Associated comorbidity was high: 19.1% had a history of chronic renal failure and 14.5% had suffered a prior stroke. Chronic pulmonary disease was reported for 23.9% of the patients. Despite the high mean age, most of the patients led a self-sufficient life.

Almost all patients had at least mild dyspnea on admission (97.9%), with a predominance of NYHA functional classes III and IV (43.0% and 39.8%, respectively). After 3 months, the percentage of patients in functional class III or IV decreased to 24.2%.

During admission, echocardiography was done in 63.4% of the patients, although if we include those with previous echocardiography, the entire sample had undergone echocardiographic assessment. Overall, 50.5% of the patients had LVEF<45%.

Almost half the patients had atrial fibrillation (42.4%). Although 27% of the patients had LBBB, QRS duration of longer than 120 ms was reported in 31%.

In total, 35 patients (5.2%) died and 1.2% (8 patients) suffered sudden death while in hospital.

A clear increase in treatment could be observed after admission, with a significant increase in the percentage of patients receiving drugs of all pharmacological groups, particularly ACE inhibitors/ARA-II and beta-blockers (Table 2).

The mortality rate at follow-up after 3 months was 8.6% (7.6% corresponded to cardiovascular deaths) and 19.6% had been readmitted after 3 months. Almost a fourth of the population—162 patients (24%)—died of cardiovascular causes or were readmitted during follow-up (Figure 1). The patients who met the criteria for CRT at the time of admission had a higher mortality and/or readmission rate, although this difference was not statistically significant (34.2% vs 23.4%; *P*=.13) (Figure 1). The percentage of major cardiovascular events in the specific group of patients who were admitted to cardiology services and who met the criteria for CRT on admission was similar to that of those who did not meet these criteria (28.1% vs 21.3%; *P*=.37). However, differences were apparent when criteria for CRT at follow-up after 3 months were analyzed (48.3% vs 19.7%; *P*<.001). The patients admitted to cardiology services had a different clinical profile to those admitted to internal medicine (Table 3).

Patients with previous diagnosis of heart failure had a higher rate of major cardiovascular events during follow-up (29.8% vs 16.3%; *P*<.001). Furthermore, a greater percentage of those with prior heart failure were eligible for CRT on admission (8.3% vs 2.1%; *P*=.001) and at 3 months (6.5% vs 2.1%; *P*=.007).

At 3 months, 75.8% were still in NYHA functional class I or II and 83.7% were still receiving the prescribed treatment on discharge.

TABLE 1. **General Characteristics***

Age, y	71.3 (11.1)
Women	287 (43.3%)
HT	482 (71.5%)
DM	315 (46.7%)
DL	236 (35.0%)
Smokers	213 (31.6%)
Prior AMI	178 (26.4%)
Prior heart failure	386 (57.3%)
Previous admissions for heart failure	398 (59.1%)
Self-sufficient	554 (82.2 %)
Etiology	
Ischemic heart disease	295 (43.8%)
HTHD	311 (46.1%)
Idiopathic	68 (10.1%)
Service	
Cardiology	394 (58.5%)
Internal medicine	257 (38.1%)
Echocardiography	
On admission	427 (63.4%)
Previously	289 (42.9%)
Dilated LV	352 (52.2%)
LV>60 mm	168 (24.9%)
LVEF≤35%	224 (33.2%)
LVEF≤45%	341 (50.6%)
Moderate-severe MR	163 (24.2%)
ECG	
HR, L/min	90 (26)
Sinus rhythm	397 (58.9%)
AF	286 (42.4%)
QRS, ms	120 (31)
QRS>120 ms	209 (31%)
PR>150 ms	226 (33.5%)
LBBB	182 (27.0%)

*LBBB indicates left bundle branch block; HTHD, hypertensive heart disease; DL, dyslipidemia; DM, diabetes mellitus; ECG, electrocardiogram; AF, atrial fibrillation; HR, heart rate; LVEF, left ventricular ejection fraction; Hb, hemoglobin; HT, hypertension; AMI, acute myocardial infarction; MR, mitral valve regurgitation; LV, left ventricle.

TABLA 2. **Treatment on Hospital Admission and Discharge***

	Before, %	After, %
Diuretics	59.9	93.2
ACE inhibitors/ARA-II	59.6	85.2
Beta-blockers	30.4	48.8
Nitrates	NR	45.1
Anticoagulants	NR	38.4
Antiplatelet agents	40.4	53.9
Statins	NR	38.7

*ARA-II indicates angiotensin II antagonists; ACE, angiotensin converting enzyme; NR, not recorded.

On admission, 5.6% of the population (38 patients) met the criteria for CRT. This percentage decreased at 3 months (5.03%; 31 patients of the 616 who were still alive). If CRT had been ruled out for patients with atrial fibrillation, only 21 patients (3.11%) would have been

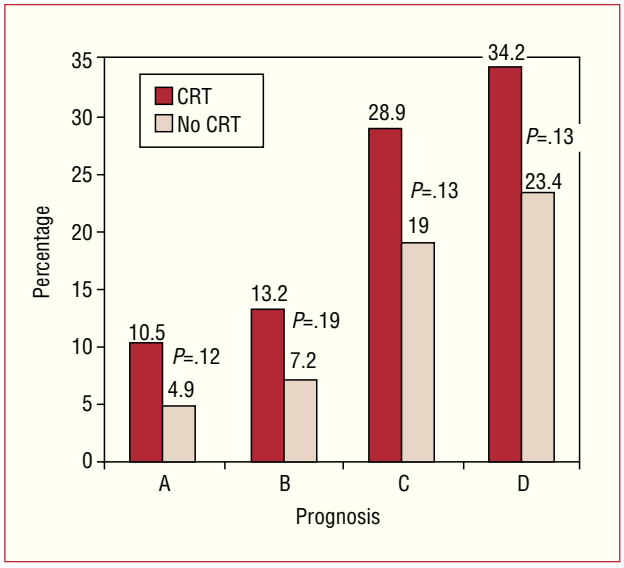

Figure 1. Prognosis for the patients according to presence of criteria for cardiac resynchronization therapy on admission and after 3 months.
A: death during admission. B: cardiovascular death after 3 months. C: hospital readmission after 3 months. D: death or hospital readmission after 3 months.
CRT indicates criteria for cardiac resynchronization therapy.

eligible on admission, and at follow-up after 3 months, the percentage of eligible patients would have decreased further to 2.92% (18 patients) (Figure 2).

In the bivariate analysis (Table 4), on admission, greater percentages of eligible patients were notable for men compared to women (7.3% vs 3.4%; *P*=.02), patients admitted to cardiology services compared to those admitted to internal medicine (8.1% vs 2.3%; *P*=.003), and patients with prior myocardial infarction (20% vs 10.1%; *P*=.003), LBBB (17.6% vs 1.2%; *P*<.001), and significant mitral regurgitation (12.3% vs 3.5%; *P*<.001). After 3 months, greater increases in the percentages of patients eligible for CRT were seen for patients under 75 years old (6.9% vs 2.3%; *P*=.01), men (8.1% vs 1.1%; *P*<.001), patients admitted to cardiology services (7.8% vs 0.9%; *P*<.001), patients with prior myocardial infarction (8.8% vs 3.7%; *P*=.01), and patients with LBBB (13.8% vs 2.0%; *P*<.001).

In the multivariate analysis, the presence of LBBB, prior myocardial infarction, significant mitral regurgitation, and the service to which the patients were admitted were identified as the variables independently associated with meeting the criteria for CRT on admission and at follow-up after 3 months (Table 5).

DISCUSSION

According to our findings, the characteristics of the patients admitted for heart failure differ significantly from those of patients enrolled in clinical trials and the

TABLE 3. **Bivariate Analysis for Comparison of Patients Admitted to Cardiology and Internal Medicine Services***

	Cardiology (n=394; 58.5%)	Internal Medicine (n=257; 38.1%)
≥75 years†	129 (32.7%)	146 (56.8%)
Women†	152 (38.6%)	127 (49.4%)
Hypertension	271 (68.8%)	195 (75.9%)
Diabetes mellitus	183 (46.4%)	125 (48.6%)
Dyslipidemia	141 (35.8%)	88 (34.2%)
Smokers	128 (32.5%)	80 (31.1%)
Kidney failure	66 (16.8%)	59 (23%)
Pulmonary disease†	71 (18%)	83 (32.3%)
Self sufficiency†	351 (89.1%)	183 (71.2%)
ACE Inhibitors/ARA-II	242 (61.4%)	150 (58.4%)
Beta-blockers†	147 (37.3%)	54 (21%)
Atrial fibrillation†	145 (36.8%)	128 (49.8%)
QRS>120 ms†	139 (35.3%)	64 (24.9%)
LBBB†	124 (31.5%)	55 (21.4%)
LV dilation†	83 (21.1%)	79 (30.7%)
Mitral regurgitation	98 (24.9%)	60 (23.3%)
Ischemic	182 (46.2%)	107 (41.6%)
Hypertensive†	158 (40.1%)	141 (54.9%)
Cardiovascular death	23 (5.8%)	26 (10.1%)
Readmissions	74 (18.8%)	56 (21.8%)
Major cardiovascular events	86 (21.8%)	72 (28%)

*LBBB indicates left bundle branch block; ARA-II, angiotensin II receptors; ACE, angiotensin converting enzyme; LV, left ventricular.
†*P*<.05.

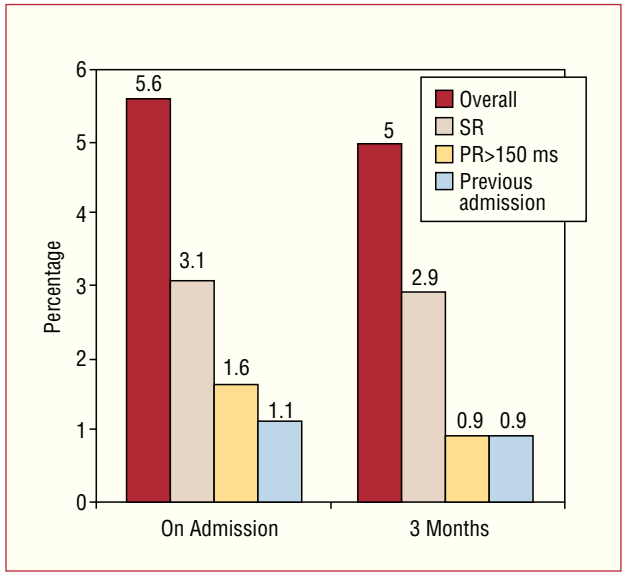

Figure 2. Percentage of patients who meet the criteria for cardiac resynchronization therapy (CRT) on admission and after 3 months in the general group (QRS>120 ms, NYHA functional class III-IV, and left ventricular ejection fraction ≤35%) and after progressive selection of patients for sinus rhythm (SR), prolonged PR>150 ms, and previous admission, according to the inclusion criteria of the COMPANION study.[6]

TABLE 4. **Eligibility for Cardiac Resynchronization Therapy According to Different Subgroups: Univariate Analysis***

	CRT Criteria		CRT Criteria 3 Months	
	n	n=674 (%)	n	n=616 (%)
≥75 years	287	12 (4.2%)	256	6 (2.3%)†
<75 years	387	26 (6.7%)	360	25 (6.9%)
Men	382	28 (7.3%)†	347	28 (1.7%)†
Women	292	10 (3.4%)	269	3 (1.1%)
Cardiology	394	32 (8.1%)†	370	29 (7.8%)†
Internal medicine	257	6 (2.3%)	226	2 (0.9%)
Prior AMI	178	18 (10.1%)†	159	14 (8.8%)†
No prior AMI	496	20 (4.0%)	457	17 (3.7%)
LBBB	182	32 (17.6%)†	160	22 (13.8%)†
No LBBB	492	6 (1.2%)	456	9 (2.0%)
Mitral regurgitation	163	20 (12.3%)†	148	11 (7.4%)
No mitral regurgitation	511	18 (3.5%)	468	20 (4.3%)

*LBBB indicates left bundle branch block; AMI, acute myocardial infarction; CRT, cardiac resynchronization therapy.
†$P<.05$.

TABLE 5. **Multivariate Analysis: Variables Independently Associated With Eligibility for Cardiac Resynchronization Therapy***

	OR	95% CI	*P*
CRT on admission			
Admission to internal medicine	0.30	0.11-0.79	.01
Prior AMI	2.71	1.26-5.81	.01
LBBB	14.97	5.95-37.64	<.001
Significant mitral valve regurgitation	4.18	1.93-9.04	<.001
CRT at 3 months			
Admission to internal medicine	0.25	0.08-0.78	.01
Prior AMI	2.65	1.17-6.00	.01
LBBB	17.25	6.36-46.82	<.001
Significant mitral valve regurgitation	3.20	1.41-7.23	<.001

*LBBB indicates left bundle branch block; CI, confidence interval; OR, odds ratio; CRT, cardiac resynchronization therapy.

percentage of patients admitted to hospital with heart failure who meet the criteria for CRT is much lower than previous estimates.[11] Furthermore, we could identify a series of variables independently related to meeting the criteria for CRT, both on admission and during a short-term follow-up.

Given that the patient populations that participate in clinical trials are highly selected, the percentage of patients in clinical trials who meet criteria for CRT cannot be extrapolated to the general population of patients with heart failure. Analysis of data from prospective hospital registries is therefore interesting as such registries can allow conclusions to be drawn that are applicable to unselected patient populations with heart failure.

Although it has been estimated that approximately 10% of the patients with heart failure would meet the criteria for CRT,[12] this figure is derived from analysis of a small number of studies, with CRT eligibility rates ranging from 3% for patients with chronic heart failure[13] to 5% for patients admitted for heart failure.[14]

This percentage would increase among those with an implantable automatic defibrillator (around 10%)[15] and would be even higher among patients being assessed for heart transplantation (14%-23%).[16,17] In the most recent analysis, the percentage of those eligible was 1% to 3% among patients discharged after admission for heart failure and 17% to 21% for those with heart failure attended in a specialist clinic.[11] However, at present, no studies have been published that have analyzed this aspect in Spain.[2,18]

The data on the percentage of patients eligible for CRT obtained from studies done in patients at the time of admission or discharge would overestimate the actual percentage because, after 4 to 6 weeks of stabilization, almost half the patients are in NYHA functional class I or II.[19] In our case, we should remember that 40.9% of the patients did not have a history of heart disease, that is, these patients were admitted for new-onset heart failure, which first has to be stabilized and treated. In these patients, the subsequent treatment response would be what indicates whether criteria for CRT are met (assuming that the electrocardiographic and echocardiographic characteristics do not change, as would be expected in a period of just 3 months). In our study, we could discern a minor decrease in the percentage of patients who met the criteria for eligibility for CRT at follow-up after 3 months, probably because of the improvement in functional class.

Another fact that should be mentioned is that compliance with criteria for CRT does not imply that the technique will be carried out in all cases. Factors such as age and comorbidity in patients can influence their prognosis, and so CRT should be considered for such patients. In our study, both the mean age and the percentage of patients over 75 years old (42.1%) were high. Furthermore, a substantial percentage of patients had a history of chronic renal failure, pulmonary disease, or cerebrovascular disease, which would further reduce the true percentage of patients eligible for CRT. It is also true, however, that most of the patients were self-sufficient (another aspect that should be considered for the indication of CRT).

We should also mention that, although the American guidelines establish consensus criteria for the indication of CRT, the main clinical trial on which they are based, the COMPANION study, had stricter CRT eligibility criteria because the criteria of functional status and width of the QRS complex, the need for admission to hospital

in the preceding 6 months, sinus rhythm, and PR interval longer than 150 ms also had to be met, in addition to left ventricular dysfunction.[6] If these criteria are strictly applied, the percentage of those eligible for CRT would decrease still further. Thus, it would decrease to 3.11% on admission and to 2.92% after 3 months if sinus rhythm had to be present; would further decrease to 1.63% on admission and 0.9% after 3 months if prolonged PR interval were required; and finally, it would decrease to 1.18% (8 patients) on admission if patients had to have been hospitalized previously.

In our study, a higher percentage of eligibility for CRT was observed among patients admitted to cardiology services than among those admitted to internal medicine, although it should be remembered that the 2 groups were not homogeneous—there were more elderly patients and women among those admitted to internal medicine as well as patients with more concurrent disease and fewer patients treated with beta blockers. Furthermore, the variables directly related to performing CRT, that is, presence of LBBB and QRS duration of more than 120 ms, were more prevalent among patients admitted to cardiology services, which would have favored a greater percentage of eligibility for CRT in these patients. A greater percentage of patients with LBBB will obviously be eligible for CRT because LBBB is one of the criteria for indication of this technique. The greater eligibility for CRT of patients with a history of acute myocardial infarction (AMI) could be related to a worse clinical profile among these patients, although this was not analyzed in the present study. Likewise, the presence of significant mitral regurgitation was associated with higher CRT eligibility rates, which could be related to a worse clinical profile for these patients and a trend towards a wider QRS complex (greater ventricular dilatation and more advanced functional classes).

The population included in our study is very heterogeneous, and so those eligible for CRT are diluted by the remaining patients. In fact, the percentage of those eligible for CRT increased when selected samples were studied (for example, when patients with heart failure were monitored in specialist clinics).[11]

Resynchronization in patients with atrial fibrillation is a controversial topic, and so we decided to do a supplementary eligibility analysis after excluding patients with atrial fibrillation (Figure 2). In this case, the eligibility decreased considerably (due to the higher percentages of patients in atrial fibrillation) by almost half, both at admission and after 3 months. Subsequently, the statistical analysis was done after also including patients in atrial fibrillation, as the American guidelines do not consider this condition as an exclusion criterion,[10] and several studies indicate that these patients would also benefit from CRT.[20-23] The new echocardiographic techniques based on tissue Doppler examinations will probably enable patients in atrial fibrillation who would benefit from CRT to be selected. Likewise, electrical cardioversion to sinus rhythm followed by atrial pacing could help increase the number of responders to atrial fibrillation because the number of relapses of this arrhythmia would be reduced.

Although some authors think that CRT might be an attractive therapeutic strategy from the economic point of view, as it is associated with a significantly lower rate of admission to hospital but has a similar cost to other treatments used for heart failure,[24] it is important to determine the actual number of patients who could benefit from this technique for planning resource allocation. In our study, a high rate of events in the short-term follow-up was observed among patients who met the criteria for eligibility for CRT, due mainly to the high rate of hospitalizations (Figure 1).

Limitations

Given that patients were included from hospitals from different levels of care and different regions, a bias could have occurred in the data collection. We tried to overcome this through consensus meetings before the start of the study.

The fact that we included both patients with a first diagnosis of heart failure and those known to have the condition, despite being a possible source of bias, does, in our opinion, ensure that the population more closely resembles the "real world" of daily clinical practice.

In any case, the strength of this registry lies in its prospective nature, even though it may be subject to some methodological limitations.

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