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Incidence and mortality risk of congestive heart failure in atrial fibrillation patients: a community-based study over two decades

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Aims We sought to determine whether the incidence of and survival following congestive heart failure (CHF) in patients with atrial fibrillation (AF) have changed over time.
Methods and results Olmsted County, Minnesota residents diagnosed with first AF during 1980–2000 were identified and followed in medical records to 2004. The trends of incidence and survival of CHF over time were assessed. Of the 3288 subjects (mean age 71 $\pm$ 15 years) diagnosed with first AF and without CHF prior to or at AF diagnosis, 790 (24%) developed a first CHF during a mean follow-up of 6.1 $\pm$ 5.2 years (unadjusted incidence, 44 per 1000 person years). Age- and sex-adjusted CHF incidence was unrelated to calendar year of AF diagnosis ($P = 0.86$). The age- and sex-adjusted mortality risk following CHF was higher than that in patients without CHF (hazard ratio 3.4, 95% confidence interval 3.1–3.8, $P < 0.0001$). There were no detectable changes over time with respect to the absolute ($P = 0.94$) or the relative ($P = 0.68$) mortality risk after CHF diagnosis.
Conclusion In this study spanning two decades, there appeared to have been no significant reduction in terms of the incidence and mortality risk of CHF following first AF diagnosis.

Introduction

Atrial fibrillation (AF) is a public health problem that has reached epidemic proportion[1,2] in the USA,[3–5] Canada,[6] and Europe.[7,8] Studies have shown that AF may precipitate congestive heart failure (CHF)[6,9–13] and that CHF patients are also at an increased risk of AF.[14–17] Given that the management of AF has changed over time, it is possible that the incidence and prognosis of CHF in AF patients have improved. The objective of this study was to determine the time trends in incidence and survival of CHF in a community-based cohort of patients newly diagnosed with AF.

Methods

Study setting

This study was approved by the Mayo Foundation Institutional Review Board. Olmsted County, Minnesota, is geographically relatively isolated and has been shown to be well suited for the conduct of studies requiring long-term follow-up.[18] A previous study has shown that 96% of the women residents aged 65–74 returned to the Mayo Clinic within a 3-year period.[18]

Incident AF cohort

The medical records of Olmsted County, Minnesota residents who had first AF documented between January 1, 1980 and December 31, 2000, in any of the Mayo administrative databases (medical index, surgical index, electrocardiographic, and echocardiographic databases), were reviewed and followed to March 2004. Final inclusion in the study population required electrocardiographic confirmation of AF, and verification of the episode being the first recognized AF event for the person.

CHF during follow-up

The primary outcome of interest, first CHF event, was defined according to the Framingham criteria, requiring the presence of two major or one major and two minor criteria.[19] Subjects with CHF prior to or at the time of AF diagnosis were excluded from the analyses. Ascertainment of survival was based on the review of the medical records and death certificates, vital status information from Mayo Registration, Minnesota State Death Tapes, and Social Security Death Index.

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Definition of covariates

Chronic vs. paroxysmal AF was defined by whether there were recognizable intervening episodes of sinus rhythm. Coronary artery disease was defined by angiographic findings of lesions ≥50% in any of the three main arterial distributions, angina, or history of myocardial infarction. Myocardial infarction was defined by at least two of the three diagnostic criteria: compatible clinical presentation, diagnostic cardiac enzymes, and consistent electrocardiographic changes. Clinically diagnosed valvular heart disease was defined by the presence of a murmur on physical examination, with or without echocardiographic confirmation. Echocardiographically confirmed valvular heart disease was defined by more than mild stenosis or regurgitation or prior valve repair/replacement. Carotid artery disease referred to the presence of ≥50% stenosis in the carotid arteries by neurovascular imaging or prior intervention. Stroke was defined by the clinical documentation of the diagnosis with or without confirmatory findings on imaging studies. Systemic hypertension was defined by a physician's diagnosis, need for antihypertensive therapy, systolic blood pressure >140 mmHg, or diastolic blood pressure >90 mmHg on two or more occasions that were not associated with acute illness or injury. Diabetes mellitus was defined by physician's diagnosis and treatment with insulin or oral hypoglycaemic agents. Dyslipidaemia was defined by a total cholesterol ≥200 mg/dL, triglycerides ≥150 mg/dL, LDL cholesterol ≥130 mg/dL, or HDL cholesterol <40 mg/dL on two or more occasions or treatment with lipid-lowering agents. Smoking history was classified as past (>6 months prior) or current smoker. Regular alcohol use was defined by self-reported consumption of more than one drink per day regularly. Chronic obstructive pulmonary disease and hyperthyroidism were defined by documented clinical diagnoses. 'Lone AF' was defined by AF in the absence of overt cardiovascular disease or precipitating illness.[20]

Statistical analysis

Baseline characteristics were summarized in terms of mean values and standard deviations, or frequency numbers and per cents, and assessed for trends across the calendar year of AF diagnosis (regarded as a continuous variable). Linear regression analyses were used for the baseline continuous variables and logistic regression analyses for binary variables, with adjustment for age and sex. Only linear trends, in the case of continuous variables, or linear logistic trends, in the case of binary variables, were considered. The cumulative incidence of first CHF after AF was estimated using the Kaplan–Meier method and associated confidence intervals (CIs) based on Greenwood's formula. In addition, we also assessed the cumulative incidence at 1 and 5 years for six subgroups: those with left ventricular systolic function that was (i) preserved (ejection fraction ≥50%), (ii) impaired (ejection fraction <50%), and (iii) unknown and those with incident AF categorized as (iv) paroxysmal, (v) chronic, or (vi) 'lone AF'. These subgroups are of special clinical interest, because left ventricular function and arrhythmia type at AF diagnosis may provide prognostic information in terms of CHF development. As we do not have comprehensive diastolic function data for many of the patients, we stratified the population on the basis of their systolic function. In addition, little data are available as to how chronic vs. paroxysmal AF at first presentation compares in terms of CHF risk and whether 'lone AF' is associated with lower CHF risk. The trend in CHF incidence over calendar year was assessed using Cox proportional hazards model, with age, sex, and calendar year of AF diagnosis in the model, as well as interactions between sex and calendar year. Cox models for the prediction of time to CHF based on the clinical variables at the time of first AF events were developed using backward selection. The proportional hazards assumption was tested for the resulting model, by saving the predicted 'risk score' ($R = X'\beta$) and re-fitting the model, including R and R*TIME. The association of first CHF with subsequent survival was estimated, using time-dependent proportional hazards models, with age, sex, and calendar year of AF diagnosis as covariables in addition to the time-dependent variable of CHF. Interactions between CHF and each of age, sex, and calendar year were also considered to assess whether the relative risk associated with CHF varied as a function of any of these variables. A multivariable model for survival was estimated using backward stepwise selection, including the time-dependent variable of CHF. Proportional hazards were tested within this model by saving the 'time-independent' portion of the risk score and adding and testing interactions of time with it and with CHF. The fixed clinical variables included in the multivariable models were body mass index, 1/creatinine, log fasting glucose, heart rate at AF diagnosis, paroxysmal AF, history of coronary artery disease, prior myocardial infarction, coronary revascularization, cardiac surgery, echocardiographically confirmed valvular heart disease, peripheral artery disease, carotid artery disease, stroke, systolic hypertension, diabetes mellitus, dyslipidaemia, smoking, regular alcohol use, chronic obstructive pulmonary disease, hyperthyroidism, and malignancy. All tests of significance were two-tailed, and P-value less than 0.05 was considered statistically significant. No formal statistical procedure for multiple comparisons was carried out, and all P-values reported are nominal.

Results

A total of 4618 subjects (mean age 73 ± 14 years, 51% men) were confirmed to have developed first AF between 1980 and 2000. Of these, 1330 were excluded because of evidence of CHF prior to or at the time of AF diagnosis. The study population, thus, consisted of the remaining 3288 subjects (mean age 71 ± 15 years, 53% men). Of these, 790 (24%; mean age 76 ± 11 years, 45% men) developed first CHF during a mean follow-up time of 6.1 ± 5.2 years (median 5.1; interquartile range 1.8–9.2), and 365 of whom required hospitalization and dismissed with a primary diagnosis of CHF. In addition, 1978 died. *Table 1* shows the baseline characteristics of the study population, stratified by the calendar year of AF diagnosis. Of the study population, 2502 patients (76%) presented initially with paroxysmal AF; and 421 (17%) of these patients developed chronic AF over a mean follow-up time of 6.2 ± 5.2 years (median 5.2; interquartile range 1.7–9.3).

Incidence of CHF following first AF

The unadjusted incidence of CHF in this study population was 44 per 1000 person years (95% CI, 41–47). Age was strongly related to CHF development ($P < 0.0001$), but not to gender after age adjustment ($P = 0.59$). An early clustering of first CHF events was evident after initial AF diagnosis (*Figure 1A*). Within the first 12 months, the cumulative CHF incidence was 7.8% (95% CI, 6.8–8.8). Thereafter, new CHF developed at ∼3% per year, with a cumulative CHF rate of 20% at 5 years (95% CI, 18.4–21.5) (*Figure 1B*).

Echocardiography was performed in 1659 patients (50%) within 30 days of AF diagnosis. Of these, 1349 had left ventricular ejection fraction ≥50%, 310 had ejection fraction <50%, and ejection fraction was unknown in 1629 patients. The 1- and 5-year cumulative incidence of CHF for these subgroups is shown in *Table 2*. The CHF risk for those with unknown ejection fraction appeared more similar to those who had preserved systolic function. The incidence of CHF

Table 1 Baseline characteristics of the study population, stratified by the calendar year of AF diagnosis

Variable	Overall ($n = 3288$)	Calendar year of AF diagnosis				*P*-value*
		1980–1984 ($n = 561$)	1985–1989 ($n = 633$)	1990–1994 ($n = 858$)	1995–2000 ($n = 1236$)	
Age (years)	71.0 ± 15.0	70.3 ± 15.2	70.6 ± 14.7	70.8 ± 15.4	71.7 ± 14.9	0.044
Men	1756 (53)	304 (54)	350 (55)	458 (53)	644 (52)	0.710
BMI (kg/m^2)	27.1 ± 6.0	26.0 ± 5.3	26.4 ± 5.4	27.3 ± 6.0	27.8 ± 6.5	<0.0001
l/creatinine (dL/mg)	0.94 ± 0.32	0.90 ± 0.25	0.94 ± 0.28	0.95 ± 0.29	0.94 ± 0.37	0.024
Log fasting glucose	4.66 ± 0.25	4.65 ± 0.27	4.65 ± 0.23	4.67 ± 0.26	4.67 ± 0.23	0.024
HR at AF (b.p.m.)	114 ± 32	115 ± 32	115 ± 32	113 ± 31	115 ± 32	0.695
Paroxysmal AF	2502 (76)	409 (73)	485 (77)	638 (74)	970 (78)	<0.001
History of CAD	995 (30)	167 (30)	218 (34)	224 (26)	386 (31)	0.820
Prior myocardial infarction	444 (14)	91 (16)	78 (12)	102 (12)	173 (14)	0.390
Coronary revascularization	360 (11)	33 (6)	51 (8)	85 (10)	191 (15)	<0.0001
History of cardiac surgery	328 (10)	41 (7)	55 (9)	82 (10)	150 (12)	<0.0001
Clinically diagnosed VHD	550 (17)	60 (11)	86 (14)	147 (17)	257 (21)	<0.0001
Echo-confirmed VHD	480 (15)	22 (4)	64 (10)	138 (16)	256 (21)	<0.0001
Peripheral artery disease	319 (10)	48 (9)	68 (11)	88 (10)	115 (9)	0.613
Carotid artery disease	133 (4)	16 (3)	30 (5)	35 (4)	52 (4)	0.249
Stroke	261 (8)	54 (10)	48 (8)	70 (8)	89 (7)	0.077
Systemic hypertension	2513 (76)	369 (66)	484 (76)	668 (78)	992 (80)	<0.0001
Diabetes mellitus	488 (15)	86 (15)	78 (12)	128 (15)	196 (16)	0.349
Dyslipidaemia	1222 (37)	97 (17)	161 (25)	306 (36)	658 (53)	<0.0001
Smoking	1862 (57)	312 (56)	369 (58)	478 (56)	703 (57)	0.540
Regular alcohol use	413 (13)	63 (11)	92 (15)	115 (13)	143 (12)	0.971
COPD	638 (19)	125 (22)	137 (22)	154 (18)	222 (18)	0.010
Hyperthyroidism	39 (1.2)	8 (1.4)	15 (2.4)	6 (0.7)	10 (0.8)	0.041
History of malignancy	892 (27)	117 (21)	178 (28)	225 (26)	372 (30)	<0.001

**P*-value for trends across calendar year of AF diagnosis, considered as a continuous variable, by linear regression analysis for continuous variables and logistic regression analysis for binary variables, with adjustment for age and sex. BMI, body mass index; HR, heart rate; CAD, coronary artery disease; VHD, valvular heart disease; Echo-confirmed, echocardiographically confirmed; COPD, chronic obstructive pulmonary disease. Values are given as mean ± SD or number (per cent).

at 1 and 5 years appeared higher for those who initially presented with chronic AF, as opposed to paroxysmal AF. The incidence of CHF development for those presenting initially as 'lone AF' was remarkably low (*Table 2*).

Trends in incidence of CHF following first AF

The age- and sex-adjusted incidence trends of CHF by Cox regression showed that calendar year of AF diagnosis was not independently predictive of CHF ($P = 0.86$) (*Table 3*) (*Figure 2*). This lack of a detectable trend in CHF incidence held even if the patients who had 'lone AF' were excluded from the analysis ($P = 0.74$), or if we restrict the trend analysis to those presenting initially with paroxysmal AF ($P = 0.72$) vs. those whose first presentation was chronic AF ($P = 0.69$).

In a multivariable Cox model for the prediction of CHF following first AF diagnosis with adjustment for age, sex, and multiple comorbid conditions (*Table 4*), calendar year of AF diagnosis was negatively associated with first CHF development ($P = 0.026$). Among other factors, advancing age, body mass index, history of myocardial infarction, valvular heart disease, and chronic obstructive pulmonary disease were the most significant independent predictors (all $P < 0.0001$).

When the proportional hazards assumption was tested for the CHF risk created by this final model, there was strong evidence of non-proportionality, such that the relative risk was highest early on and decreased over time. Specifically, the estimated multiplier for the log (relative hazard) at time zero was 1.837 ± 0.055 and the rate of decrease in the multiplier was 0.219 ± 0.007 per year, implying 'equal hazard' at 8.4 years after AF onset.

Trends in survival following post-AF CHF

Mortality risk was related to age and sex (both $P < 0.0001$). After age and sex adjustment, post-AF CHF was associated with increased mortality risk [hazard ratio (HR) 3.4, 95% CI 3.1–3.8, $P < 0.0001$], and this relative hazard associated with CHF was not related to calendar year of AF diagnosis ($P = 0.68$) or to sex ($P = 0.13$), but was negatively associated with age ($P < 0.0001$). The estimated HR associated with CHF was 5.9 at age 50 and 3.3 at age 80. There was also no trend in the absolute mortality risk following CHF ($P = 0.94$). The 95% CI for the HR of survival (adjusted for age and sex) following CHF development in 2000, when compared to that in 1980, was 0.75–1.37. After multiple adjustments including age, sex, and comorbidities, post-AF CHF remained independently predictive of death ($P < 0.0001$) (*Table 5*).

When the proportional hazards model for both the fixed covariates and the CHF was tested, we found that the time-independent risk had a decreasing association with hazard, with an initial multiplier of 1.704 and a slope of −0.192 per year (equality implied at 8.9 years). In contrast, the log (hazard) associated with CHF had an increasing trend over time, with

an initial coefficient of 0.568 (HR 1.76) and a slope of 0.166 per year, implying a coefficient of 1.40 (HR 4.05) at 5 years.

Discussion

Our data showed that CHF developed in a large proportion of patients following first AF with a very high incidence within year 1 of AF diagnosis and that there were no detectable changes over a 21-year period in terms of either age- and sex-adjusted incidence of CHF following first AF or the absolute or relative mortality risk after CHF diagnosis in these patients. However, an apparent decrease in CHF incidence over time was evident after adjustment for multiple risk factors and comorbidities, suggesting that patients at first AF were a progressively 'sicker' group over time.

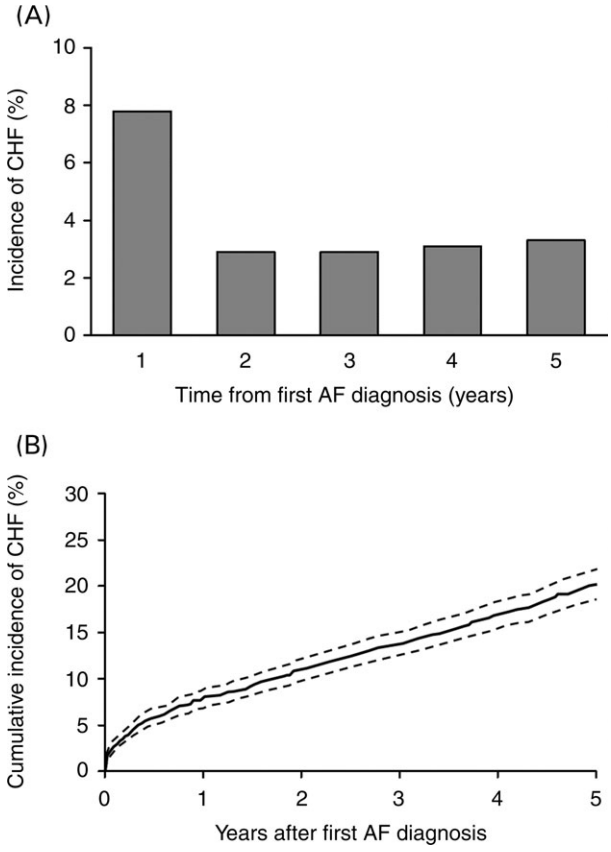

Figure 1 (*A*) Incidence of first CHF by the time from first AF diagnosis and (*B*) cumulative incidence of first CHF following first AF.

CHF development in AF patients

In evaluating the relationship between AF and CHF, caution must be exercised in implicating a cause-and-effect relationship between the two conditions, which has been proposed by some investigators.[21,22] The fact that AF and CHF appeared equally likely to have been the initial diagnosis in the Framingham Heart Study[15] raises the possibility that AF and/or CHF may actually be the later manifestations of a common pathophysiological cascade. Regardless, both these conditions have been concerned to be of 'epidemic' proportions.[2] One in four of the AF patients in this study developed CHF during follow-up and that the lifetime risk of AF in the Framingham Heart cohort was also one in four.[23]

Our current understanding of CHF development among AF patients suggests that at least some cases are tachycardia-induced cardiomyopathy.[9,21] In our study, the incidence of CHF was higher for those with impaired, as opposed to preserved, left ventricular systolic function at baseline. In addition, the rhythm or rate control agents used in the management of AF often have negative inotropic effects, which may contribute to CHF development. Many of the AF patients have multiple comorbid conditions[24] and are at risk of CHF also from these concurrent pathologies. This is further substantiated by the fact that 'lone AF' in this study was associated with a very low risk of CHF even at year 5 after initial AF diagnosis.

Trends in incidence of CHF following first AF

With multiple medical and technological advances for the management of AF,[25,26] it is reasonable to speculate that CHF incidence following AF diagnosis may decrease over time. In this study, calendar year of AF diagnosis was not a significant predictor of CHF development in age- and sex-adjusted models (*Table 3*). In contrast, calendar year of AF diagnosis was negatively associated with CHF development in a multivariate model, after adjusting for multiple comorbid conditions (*Table 4*). These findings suggest a possible null summation effect on CHF incidence as a result of the positive impact from advances in management and the negative impact from greater longevity and burden of comorbidities over time.

The lack of improvement in the incidence of CHF was consistent with the finding from the AF Follow-up Investigation of Rhythm Management (AFFIRM) study that the rate of CHF development did not differ between the rate and the rhythm control strategies.[27] As there is already evidence that incidence of AF is increasing,[28] and if the trend of post-AF

Table 2 Kaplan–Meier estimates of 1- and 5-year cumulative incidence of CHF in the overall study population and in six subgroups

Subgroup	*n*	Mean age, years	Men, %	1 year, % (95% CI)	5 years, % (95% CI)
Overall	3288	71 ± 15	53	7.8 (6.8–8.8)	20.0 (18.4–21.5)
LV ejection fraction ≥50%	1349	69 ± 16	51	7.2 (5.8–8.6)	18.0 (15.7–20.3)
LV ejection fraction <50%	310	71 ± 14	67	19.3 (14.5–23.8)	33.3 (27.1–38.9)
LV ejection fraction unknown	1629	73 ± 14	53	6.1 (4.9–7.4)	19.1 (16.8–21.4)
Paroxysmal AF at first diagnosis	2502	69 ± 16	55	6.7 (5.7–7.8)	17.6 (15.8–19.3)
Chronic AF at first diagnosis	777	77 ± 11	48	11.2 (8.9–13.4)	27.5 (23.8–31.0)
Lone AF at first diagnosis	264	52 ± 18	70	0.4 (0.0–1.2)	2.1 (0.3–4.0)

LV, left ventricular.

Table 3 Age, sex, and calendar year-adjusted models for the prediction of CHF

Variable	*n*	Hazard ratio (95% CI)	*P*-value
Age (per 10 years)[a]	3288	1.83 (1.70–1.96)	<0.0001
Men[a]	3288	0.96 (0.83–1.11)	0.590
Calendar year of AF[a]	3288	0.99 (0.99–1.01)	0.855
BMI (per 5 kg/m^2)	3242	1.19 (1.12–1.27)	<0.0001
l/creatinine (per dL/mg)	3270	0.44 (0.32–0.60)	<0.0001
Log fasting glucose	3230	2.71 (2.07–3.55)	<0.0001
HR at AF (per 10 b.p.m.)	3275	0.98 (0.96–1.00)	0.078
Paroxysmal AF	3288	0.86 (0.74–0.99)	0.044
History of CAD	3288	1.53 (1.32–1.77)	<0.0001
Prior myocardial infarction	3288	1.80 (1.51–2.16)	<0.0001
Coronary revascularization	3288	1.47 (1.19–1.80)	<0.001
History of cardiac surgery	3288	1.60 (1.30–1.97)	<0.0001
Valvular heart disease[b]	3288	1.95 (1.63–2.32)	<0.0001
Peripheral artery disease	3288	1.57 (1.28–1.93)	<0.0001
Carotid artery disease	3288	2.06 (1.53–2.77)	<0.0001
Stroke	3288	1.33 (1.04–1.69)	0.022
Systemic hypertension	3288	1.57 (1.28–1.93)	<0.0001
Diabetes mellitus	3288	1.96 (1.64–2.35)	<0.0001
Dyslipidaemia	3288	1.22 (1.04–1.43)	0.013
Smoking	3288	1.28 (1.10–1.50)	0.002
Regular alcohol use	3288	0.98 (0.76–1.25)	0.862
COPD	3288	1.54 (1.30–1.83)	<0.0001
Hyperthyroidism	3288	0.77 (0.40–1.49)	0.438
History of malignancy	3288	1.17 (0.99–1.38)	0.059

BMI, body mass index; HR, heart rate; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease.
[a]Age, adjusted for sex and calendar year of AF diagnosis; men, adjusted for age and calendar year of AF diagnosis; and calendar year of AF diagnosis, adjusted for age and sex.
[b]Echocardiographically confirmed valvular heart disease.

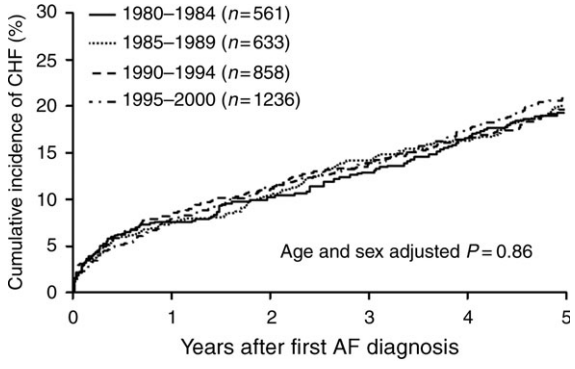

Figure 2 Time trends for cumulative incidence of first CHF following first AF.

CHF incidence is not decreasing, we can anticipate an absolute increase in the magnitude of CHF burden associated with new AF development.

Trends in survival following post-AF CHF

CHF following AF conferred substantial mortality risk, which was independent of age, sex, and multiple comorbidities in the prediction of survival. The lack of any improvement in survival over the two decades was in distinct contrast to the finding of a trend in improvement of overall survival of CHF patients (all CHF without specific reference to post-AF) in a different study.[29] Thus, the dual AF-CHF diagnosis probably identifies a sicker population, less amenable to improvement, and an overall poorer prognostic trajectory.

Table 4 Multivariable model for the prediction of CHF

Variable	Hazard ratio (95% CI)	*P*-value
Age (per 10 years)	1.77 (1.63–1.93)	<0.0001
Men	0.81 (0.69–0.95)	0.009
Calendar year of AF	0.98 (0.97–0.99)	0.026
BMI (per 5 kg/m^2)	1.15 (1.08–1.23)	<0.0001
l/creatinine (per dL/mg)	0.59 (0.44–0.81)	0.001
Log fasting glucose	1.80 (1.27–2.55)	<0.001
Paroxysmal AF	0.85 (0.73–0.99)	0.049
Prior myocardial infarction	1.63 (1.36–1.96)	<0.0001
Valvular heart disease[a]	1.96 (1.64–2.34)	<0.0001
Peripheral artery disease	1.25 (1.01–1.55)	0.044
Carotid artery disease	1.37 (1.00–1.88)	0.048
Systemic hypertension	1.32 (1.07–1.63)	0.011
Diabetes mellitus	1.31 (1.04–1.66)	0.022
COPD	1.50 (1.26–1.78)	<0.0001
History of malignancy	1.25 (1.06–1.47)	0.009

BMI, body mass index; COPD, chronic obstructive pulmonary disease.
[a]Echocardiographically confirmed valvular heart disease.

Table 5 Multivariable models for the prediction of death

Variable	Hazard ratio (95% CI)	*P*-value
CHF event	3.26 (2.94–3.62)	<0.0001
Age (per 10 years)	1.05 (0.75–1.46)	0.783
Age × age (per 100 years)	1.04 (1.01–1.06)	0.002
Men	1.13 (1.01–1.26)	0.035
BMI (per 5 kg/m^2)	0.86 (0.82–0.90)	<0.0001
l/creatinine (per dL/mg)	0.81 (0.67–0.98)	0.031
HR at AF (per 10 b.p.m.)	1.04 (1.03–1.06)	<0.0001
Coronary revascularization	0.80 (0.68–0.94)	0.005
Peripheral artery disease	1.23 (1.07–1.41)	0.003
Stroke	1.42 (1.23–1.65)	<0.0001
Systemic hypertension	1.34 (1.17–1.53)	<0.0001
Diabetes mellitus	1.53 (1.36–1.73)	<0.0001
Smoking	1.14 (1.02–1.27)	0.017
COPD	1.41 (1.26–1.57)	<0.0001
History of malignancy	1.52 (1.38–1.67)	<0.0001

Age × age, age square term; BMI, body mass index; HR, heart rate; COPD, chronic obstructive pulmonary disease.

Limitations

There were inherent biases associated with the retrospective design. The identification of AF cases relied on confirmation by electrocardiogram and that the patients were seen at the Mayo Clinic. Patients might not have been included, because their AF was silent and undetected. The Framingham criteria of CHF were used both for the exclusion of patients from entry into the study population and for the detection of new cases after AF diagnosis. These criteria are strictly clinical and the sensitivity for CHF ascertainment might be lower, if echocardiographic measurements had

been included as part of the definition. Data with respect to the medical therapy prior to CHF diagnosis or ventricular rate after treatment were not readily available, and how these factored into the incidence and mortality trends is not known. The population of the Olmsted County, Minnesota is predominantly white, and the extent to which we can generalize the findings to other ethnic/racial groups remains to be determined.

Conclusions

This community-based longitudinal cohort study showed that a large proportion of the patients diagnosed with first AF developed subsequent CHF. Within the period 1980–2000, there was no detectable change in incidence of CHF or the mortality risk after CHF development in patients diagnosed with first AF.

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Conflict of interest: there are no financial conflicts on the part of any authors.

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