

Lifetime Risk for Developing Congestive Heart Failure

The Framingham Heart Study

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Background—Congestive heart failure (CHF) is an increasing public health problem.

Methods and Results—Among Framingham Heart Study subjects who were free of CHF at baseline, we determined the lifetime risk for developing overt CHF at selected index ages. We followed 3757 men and 4472 women from 1971 to 1996 for 124 262 person-years; 583 subjects developed CHF and 2002 died without prior CHF. At age 40 years, the lifetime risk for CHF was 21.0% (95% CI 18.7% to 23.2%) for men and 20.3% (95% CI 18.2% to 22.5%) for women. Remaining lifetime risk did not change with advancing index age because of rapidly increasing CHF incidence rates. At age 80 years, the lifetime risk was 20.2% (95% CI 16.1% to 24.2%) for men and 19.3% (95% CI 16.5% to 22.2%) for women. Lifetime risk for CHF doubled for subjects with blood pressure \geq 160/100 versus $<$ 140/90 mm Hg. In a secondary analysis, we only considered those who developed CHF without an antecedent myocardial infarction; at age 40 years, the lifetime risk for CHF was 11.4% (95% CI 9.6% to 13.2%) for men and 15.4% (95% CI 13.5% to 17.3%) for women.

Conclusions—When established clinical criteria are used to define overt CHF, the lifetime risk for CHF is 1 in 5 for both men and women. For CHF occurring in the absence of myocardial infarction, the lifetime risk is 1 in 9 for men and 1 in 6 for women, which highlights the risk of CHF that is largely attributable to hypertension. These results should assist in predicting the population burden of CHF and placing greater emphasis on prevention of CHF through hypertension control and prevention of myocardial infarction. (*Circulation*. 2002;106:3068-3072.)

Key Words: heart failure ■ risk factors ■ hypertension ■ myocardial infarction

In the past 2 decades, congestive heart failure (CHF) has become an increasingly important public health problem. CHF affects 4.8 million Americans, and it is the leading cause of hospitalization for people aged 65 years and over in the United States. From 1979 to 1999, hospitalizations for CHF rose 155%, to 962 000 per year.¹ With the aging of the population and improved survival after acute myocardial infarction (MI), these trends are likely to continue. Although CHF has been described as an emerging epidemic in cardiovascular disease,² there have been no studies to date of the lifetime risk for developing CHF.

See p 2997

The concept of lifetime risk allows consideration of the absolute cumulative risk of an individual developing a given disease during his or her remaining lifetime. Lifetime risk estimates account for the risk of developing the disease of

interest and the risk of competing causes of death. Lifetime risks may be more easily understood by the lay public than relative risks, because they answer the question, what is the absolute risk of developing this disease during the remaining life span? The Framingham Heart Study, with its long-term follow-up and careful documentation of risk factors and events, provides a unique opportunity to estimate the lifetime risk for CHF and to explore factors that may modify remaining lifetime risk in men and women at different ages.

Methods

Subjects

The Framingham Heart Study was established in 1948, when 5209 residents of Framingham, Mass, aged 28 to 62 years, were enrolled in a prospective epidemiologic cohort study. In 1971, an additional 5124 subjects (offspring of original cohort subjects and offspring spouses) were enrolled in the Framingham Offspring Study. Study design and entry criteria for both cohorts have been detailed

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TABLE 1. Age- and Sex-Specific Baseline Characteristics of Subjects Free of CHF at Index Examination

	Age, y									
	35–44		45–54		55–64		65–74		75–84	
	Men (n=745)	Women (n=749)	Men (n=719)	Women (n=731)	Men (n=744)	Women (n=941)	Men (n=449)	Women (n=611)	Men (n=177)	Women (n=293)
Hypertension, %	27.4	15.1	39.8	31.4	50.5	46.7	60.4	69.9	60.5	77.5
Prior MI, %	0.6	0	4.5	0.4	8.9	1.6	10.9	3.8	15.8	4.1
ECG LVH, %	0.4	0.1	0.6	0.4	1.9	0.5	3.8	3.0	2.8	8.2

Hypertension indicates systolic blood pressure ≥ 140 mm Hg, diastolic blood pressure ≥ 90 mm Hg, or receiving medical therapy; LVH indicates left ventricular hypertrophy.

elsewhere.^{3,4} For the present analysis, all subjects who participated in an examination between 1971 and 1996 were eligible provided that they were examined at least once between the ages of 40 and 94 years and that they had follow-up after the earliest eligible examination. Subjects with a history of CHF before age 40 years or before their index examination were excluded (n=91).

Case Ascertainment

Interim cardiovascular events were ascertained from medical histories, physical examinations, ECGs, and review of interim medical records, including hospital and attending physicians' records and chest radiograph reports, of those who appeared and those who failed to appear for scheduled study examinations. All suspected cardiovascular events were reviewed by a panel of 3 physicians who applied established criteria for such events.⁵ Methods for defining the occurrence of overt CHF in the Framingham Heart Study have been described in detail elsewhere.⁶

Statistical Analysis

All statistical analyses were performed with SAS statistical software.⁷ For calculation of the lifetime risk for CHF, a modified technique of survival analysis was used, as described previously.^{8,9} Because few subjects survived past age 94 years, lifetime risk estimates were calculated only through age 94. Each subject in the study sample was followed up from entry through 1996 until either the year of a first CHF event, the year of death, or attainment of age 95 years. Remaining lifetime risk was calculated separately for men and women at index ages of 40, 50, 60, 70, and 80 years.

We also examined the lifetime risk for CHF according to blood pressure strata. For each index age, we stratified subjects according to the blood pressure measurement at the examination most closely preceding the index age and not more than 6 years before it. Subjects were stratified into the following 3 groups according to blood pressure: systolic < 140 and diastolic < 90 mm Hg; systolic 140 to 159 or diastolic 90 to 99 mm Hg; and systolic ≥ 160 or diastolic ≥ 100 mm Hg. In separate analyses, we included subjects who were receiving antihypertensive therapy at the index age in the highest blood pressure stratum and then repeated the analysis assigning blood pressure stratum regardless of treatment status.

We performed a secondary analysis to examine the remaining lifetime risk for CHF attributable to causes other than MI. In this analysis, we excluded subjects with a history of recognized or unrecognized MI before or at the index examination and only considered those who developed CHF without an intervening MI during follow-up.

Results

There were 3757 men and 4472 women in the study sample. These subjects were followed up from 1971 through 1996 for a total of 124 262 person-years. The baseline characteristics of the study sample at the index examination are shown in Table 1. During follow-up, 583 subjects developed CHF and 2002 died without prior CHF.

Lifetime Risk for CHF

The remaining lifetime risk for CHF for men and women at selected index ages is shown in Table 2 (top). The lifetime risk for CHF was 1 in 5 for both men and women, regardless of the index age. Remaining lifetime risk did not change across index ages because of rapidly increasing CHF incidence rates with advancing age (Figure).

Lifetime Risk for CHF by Blood Pressure Strata

For this analysis, data were available for 3433 men and 4199 women. The lifetime risks for CHF by blood pressure strata at selected index ages are shown in Table 3. At almost all index ages in men and women, there was a 2-fold gradient in remaining lifetime risk for CHF from the lowest to highest blood pressure. When we assigned blood pressure stratum using the average of all blood pressure measurements obtained at study clinic visits in the 6 years before each index age, we obtained substantially the same results (data not shown).

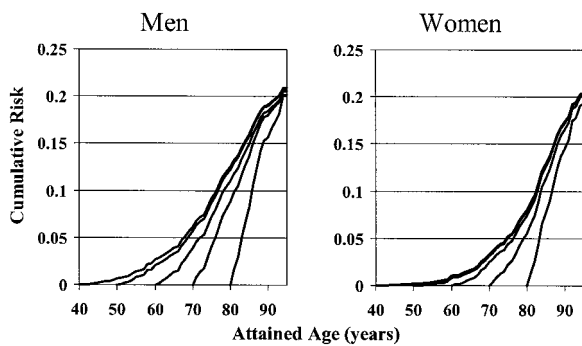
Comparison of Short-Term Risk Versus Lifetime Risk for CHF

Table 4 demonstrates the utility of considering absolute lifetime risk compared with shorter-term risks. For younger subjects, the short-term risk is exceedingly low, whereas the lifetime risk is high. For older subjects, short-term risks

TABLE 2. Remaining Lifetime Risk for CHF and for CHF in Absence of Antecedent MI in Men and Women at Selected Index Ages

Index Age, y	Men	Women
Lifetime risk for CHF (95% CI)		
40	21.0 (18.7–23.2)	20.3 (18.2–22.5)
50	20.9 (18.6–23.2)	20.5 (18.3–22.6)
60	20.5 (18.1–22.9)	20.5 (18.3–22.8)
70	20.6 (17.8–23.4)	20.2 (17.8–22.6)
80	20.2 (16.1–24.2)	19.3 (16.5–22.2)
Lifetime risk for CHF without MI (95% CI)		
40	11.4 (9.6–13.2)	15.4 (13.5–17.3)
50	11.6 (9.7–13.4)	15.5 (13.6–17.5)
60	11.9 (9.8–13.9)	15.8 (13.7–17.8)
70	12.6 (10.1–15.1)	16.2 (14.0–18.5)
80	13.8 (10.0–17.6)	16.1 (13.4–18.8)

All values are percentages.



Cumulative risk for CHF at selected index ages for men and women. Lifetime risk for CHF for given index age is cumulative risk through age 94 years.

accumulate more rapidly, as also indicated by the slopes of the curves in the Figure.

Lifetime Risk for CHF Without Antecedent MI

There were 3571 men and 4416 women without a history of MI (or CHF) at the index examination. During follow-up of 117 849 person-years, 374 subjects developed CHF without an antecedent MI, whereas 2251 subjects died or had an incident MI before the development of CHF. At age 40 years, the lifetime risk for CHF without antecedent MI was 1 in 9 for men and 1 in 6 for women (Table 2, bottom).

Discussion

Principal Findings

The lifetime risk for CHF is 1 in 5 for men and women. At all ages, the remaining lifetime risk for CHF is as high for women as for men. However, our data suggest differing degrees of importance for hypertension versus MI as risk

TABLE 4. Comparison of Short-Term vs Lifetime Cumulative Risks of CHF for Men and Women at Selected Index Ages

Index Age, y	Men		Women	
	5-Year Risk	Lifetime Risk	5-Year Risk	Lifetime Risk
40	0.2	21.0	0.1	20.3
50	0.8	21.0	0.1	20.5
60	1.3	20.5	0.7	20.5
70	4.0	20.6	2.2	20.2
80	8.3	20.2	7.8	19.3

All values are percentages.

factors for CHF in women and men. Comparison of the lifetime risk for CHF without antecedent MI (Table 2, bottom) with the overall lifetime risk for CHF (Table 2, top) provides insight into the differing causes of CHF. The lifetime risk for CHF for women free of MI was 1 in 6 compared with 1 in 5 for all women, which indicates that factors other than MI play a relatively greater role. In contrast, the lifetime risk was approximately half as great in men free of MI (1 in 9) compared with all men (1 in 5), which indicates the importance of antecedent MI in men.

These data provide new insights into the long-term risk for CHF and the effect of known risk factors. In general, the present study supports prior findings¹⁰ from shorter-term studies and estimates of population-attributable risks for the development of CHF associated with different risk factors.¹¹ In the latter study, hypertension accounted for 59% of the population-attributable risk of CHF in women compared with 39% in men. The present study highlights the significant association between hypertension and long-term risk for CHF in both men and women. The lifetime risk is doubled for men and women with blood pressure $\geq 160/100$ compared with $<140/90$ mm Hg.

TABLE 3. Remaining Lifetime Risk for CHF According to Blood Pressure Strata and Treatment Status at Selected Index Ages

Index Age, y	Lifetime Risk for CHF					
	Men			Women		
	SBP <140 and DBP <90 mm Hg	SBP 140–159 or DBP 90–99 mm Hg	SBP ≥ 160 or DBP ≥ 100 mm Hg	SBP <140 and DBP <90 mm Hg	SBP 140–159 or DBP 90–99 mm Hg	SBP ≥ 160 or DBP ≥ 100 mm Hg
Treated subjects included in highest blood pressure stratum						
40*	14.8	22.9	27.9	12.0	20.2	28.9
50†	17.3	25.4	27.0	12.4	25.2	26.6
60	17.4	19.6	29.0	14.4	21.3	27.4
70	15.1	20.3	27.8	14.3	17.1	24.5
80	10.1	19.4	27.9	10.7	10.0	23.9
Treatment status ignored						
40*	15.6	23.2	27.4	12.0	20.4	29.5
50†	16.8	27.1	27.4	12.4	26.5	24.4
60	18.1	20.7	30.0	15.9	21.8	27.1
70	18.2	22.0	27.3	15.4	22.6	24.3
80	16.6	23.3	27.0	17.1	17.0	24.4

SBP indicates systolic blood pressure; DBP, diastolic blood pressure.

All values are percentages.

*Calculated through age 85 years because of limited length of follow-up.

†Calculated through age 90 years because of limited length of follow-up.

Public Health Implications

Compared with a lifetime risk for CHF of 1 in 5, a woman at age 40 years has a remaining lifetime risk for breast cancer of 1 in 8,¹² and the lifetime risk for coronary heart disease at age 40 years is 1 in 2 for men and 1 in 3 for women.⁸ At age 50 years, the lifetime risks for hip fracture, a major cause of morbidity in older persons, are 1 in 6 for white women and 1 in 20 for white men.¹³

With the aging of the population, the concomitant increase in the number of hypertensive individuals, and improved post-MI survival, CHF has become a major public health concern.² However, despite the growing epidemic of CHF, community-based epidemiologic investigations of heart failure have been difficult to perform because of difficulty defining the diagnosis.¹⁴ Other investigators have relied on the Framingham criteria to study CHF in community populations.^{15,16} National health statistics regarding CHF may be significantly flawed because of the current reliance on death certificate data.¹⁷ Goldberg and Konstam¹⁴ have therefore urged that more population-based studies be performed to understand the risks, incidence, and prognosis of CHF. The present study addresses some of the deficiencies in knowledge about the epidemiology of CHF.

The lifetime risk estimates presented here are useful for researchers and policy makers in predicting the population burden of CHF. In addition, lifetime risk data may be compared between different diseases to allow appropriate allocation of resources for competing causes of morbidity and mortality. Given that CHF is already the leading cause of hospitalization in the elderly, significant public health efforts should be aimed at reducing the incidence of CHF.

Clinical Implications

The present data also may be useful in developing cost-effective strategies for the primary prevention of CHF. In younger individuals with low short-term risk (Table 4), the high lifetime risk might be more useful in motivating long-term lifestyle modification efforts aimed at prevention of hypertension or MI. In older individuals with hypertension, the rapidly accumulating risk of CHF, even in the context of high risk of death from other causes, indicates the importance of immediate intervention. A lower number of hypertensive subjects and shorter duration of treatment would be required to prevent 1 CHF event among older hypertensive patients.

The present observational study design cannot predict the effect of antihypertensive therapy on reducing lifetime risk for CHF; only randomized clinical trials can do so. The known benefit of antihypertensive therapy may not be readily observed (Table 3), because current methods of lifetime risk estimation do not allow for updating of covariates over time. Nonetheless, our estimates of lifetime risk for CHF by blood pressure strata, combined with results from clinical trials, may help guide clinicians and patients in decision-making regarding prevention of CHF through antihypertensive therapy.

Clinical trials have demonstrated $\approx 50\%$ reductions in CHF incidence with active treatment of hypertension in older individuals.^{18,19} Thus, effective therapies exist for major reductions in CHF incidence if awareness of the problem, identification of high-risk patients, and treatment and control of hypertension can be achieved more widely in clinical practice. In addition, prevention of MI and increased use of proven therapies after MI would be expected to further reduce the incidence of CHF.

Potential Limitations

The Framingham Heart Study cohort is composed almost exclusively of white individuals, which may limit the generalizability of our findings to other ethnic groups, in whom the risks of CHF and contributing roles of predisposing conditions may differ. It is possible that because of their participation in periodic examinations, Framingham subjects may have been motivated to modify risk factors and reduce their lifetime risk for CHF. Furthermore, we used clinical criteria to identify overt cases of CHF, which may have led to an underestimation of the true lifetime risk for CHF.

With many diseases, lifetime risk decreases at older index ages, because older subjects have a shorter remaining life span, and depletion of susceptible individuals occurs at younger ages. However, with CHF, which is overwhelmingly a disease of the elderly, the increasing incidence with advancing age outpaces the increasing mortality from competing causes. We estimated the cumulative lifetime risk for CHF rather than the Kaplan-Meier cumulative incidence, which tends to overestimate the risk for disease when the competing risk of death is high. For example, for men at age 40 years, the lifetime risk for CHF is 21.0% compared with a Kaplan-Meier cumulative incidence of 52.4%. Thus, lifetime risk estimates more accurately reflect the population burden of disease.

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