Aging-Associated Cardiovascular Changes and Their Relationship to Heart Failure

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KEYWORDS

• Heart failure • Cardiovascular aging • Cardiac function
• Cardiac reserve

Although aging does not itself cause heart failure (HF), it does lower the threshold for manifestation of the disease. As the populations of most developed countries continue to become older, on average, the importance of aging as a risk factor for all cardiovascular disease (CVD) increases in kind (**Fig. 1**). In the United States alone, it is estimated that there will be 70 million people older than 65 by 2030, representing almost 25% of the population.[1] In many respects, HF can be thought of as the quintessential final cardiovascular aging pathway, representing the convergence of age-associated changes in cardiovascular structure and function, aging changes in other organ systems, and the progressive increase in cardiovascular diseases in the elderly.

With the success of treatment options for ischemic and valvular diseases, there is an increasing number of older individuals with some degree of cardiac damage, type B heart failure at a minimum, who are increasingly imperiled by the diminished cardiac reserve associated with normal aging. Half of all HF cases are found within the 6% of the US population that is older than 75[2] (reviewed by Najjar and colleagues[3]). These individuals often go on to develop more severe cardiac dysfunction with time. In contrast to other cardiovascular disorders, the prevalence of chronic heart failure (CHF) is increasing, with approximately 5.7 million Americans with CHF.[4] The incidence of HF doubles with each decade of life and the prevalence rises to almost 10% of those older than 80 years. CHF is a highly lethal condition, with significant mortality, morbidity, and associated costs in the older population. More than 90% of CHF deaths occur in adults older than 65 years. CHF is also the leading cause of hospitalization in Medicare beneficiaries, with those older than 65 accounting for 75% of the 1.1 million HF discharge diagnoses.[4]

This article focuses on what is known about normal cardiovascular aging and the role that aging-associated changes play in reducing cardiac reserve to make the heart more susceptible to failure. There are a number of factors that link aging to HF[5] and gradually reduce the amount of cardiac reserve until finally the heart is "more likely to fail" (**Fig. 2**).

1. Structural changes: There is significant structural change in the heart and vasculature (eg, vascular stiffening, increased left ventricular [LV] wall thickness [within normal limits], and fibrosis) with aging, leading to diastolic

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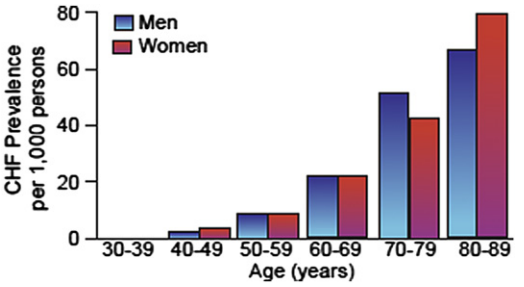

Fig. 1. Average prevalence of heart failure according to age and sex: Framingham Heart Study, 16-year follow-up. (*Data from* McKee PA, Castelli WP, McNamara PM, et al. The natural history of congestive heart failure: the Framingham study. N Engl J Med 1971;285:7796.)

dysfunction, increased afterload, and HF with preserved ejection fraction (HFpEF).[6,7] These are described individually in the *Cardiac structural* and *Central Arterial structural* sections later in this article.

2. Functional changes: There are functional changes and compensatory responses that the aged heart undergoes that diminish its ability to respond to increased workload and decrease its reserve capacity (eg, changes in maximal heart rate, end-systolic volume [ESV], end-diastolic volume [EDV], contractility, prolonged systolic contraction, prolonged diastolic relaxation, and sympathetic signaling). These are described individually in the *Cardiac functional*, *Vascular functional,* and *Arterial-ventricular interaction* sections later in this article.
3. Cardioprotection and repair processes: The cardiac mechanisms responsible for protection from injury and injury repair become increasingly defective with age, leading to accentuated adverse remodeling and increased dysfunction.
4. Increased CVD incidence and prevalence: There is a progressive increase in the prevalence of CVD (eg, coronary artery disease [CAD], hypertension, and diabetes), leading to the development of ischemic, hypertensive, or diabetic cardiomyopathy. The reader is referred to any number of epidemiologic studies for evidence of this fact.
5. Systemic disease/Other organ systems: Aging-associated changes in other organ systems may affect cardiac structure-function and thereby contribute to HF development. This facet, however, is beyond the scope of the current review.

CARDIOVASCULAR CHANGES WITH AGING

Cardiac Changes at Rest and with Exercise

Cardiac structural changes

As described in **Table 1** and **Fig. 3**, there are structural and functional changes in the heart with

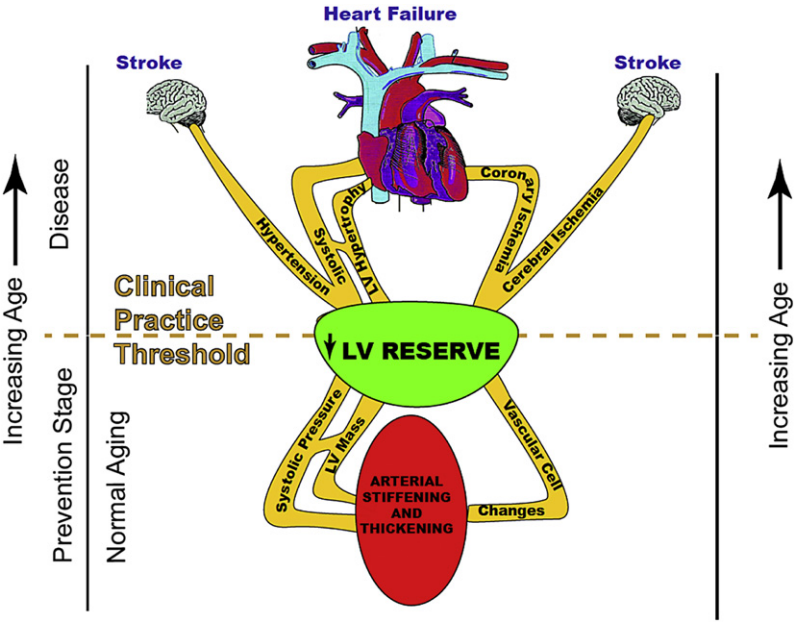

Fig. 2. Pathways linking aging to heart failure. (*Modified from* Lakatta EG. Age-associated cardiovascular changes in health: impact on cardiovascular disease in older persons. Heart Failure Rev 2002;7(1):1480; with permission.)