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Disparities and drivers of early age at diagnosis of congestive heart failure in the USA

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ABSTRACT

Aim: Heart failure (HF) constitutes a major public health problem in the USA due to its high morbidity and mortality. Age at diagnosis of HF would refine burden quantification, budgeting, disease surveillance and assessment of interventions. We set out to determine the median age at diagnosis of HF and drivers of young age at diagnosis among patients 20 years or older in the USA.

Methods and results: We utilized NHANES data collected across five survey cycles (2007–2016). Included were individuals aged 20 to 80 years diagnosed of HF with valid entries for age at diagnosis. Differences in age at diagnosis between groups and major drivers for younger age at diagnosis were assessed using linear regression models with p-values <0.05 considered statistically significant. The prevalence of HF in the USA was 2.44% with a median age at diagnosis of 59 years (IQR 47–70). Non-Hispanic (NH) Blacks −4.94 years (95% CI −7.95 to −1.93), individuals living below the poverty line −5.79 years (95% CI −10.36 to −1.01), obese persons −5.63 years (95% CI −8.35 to −2.92), individuals without health insurance −4.31 years (95% CI −7.87 to −0.75) and those without hypertension −3.99 years (95% CI −7.19 to −0.78) were diagnosed at significantly younger ages than their respective counterparts.

Conclusion: The median age at diagnosis of HF in the USA is 59 years. NH Blacks, living in poverty, lack of health insurance and obesity are the main drivers of early age at diagnosis of HF in the USA.

1. Introduction

Congestive heart failure (HF) constitutes a major public health problem in the United States of America (USA) accounting for one in eight deaths [1]. Currently, there are about 6.5 million persons aged 20 years and older with HF in the USA, corresponding to a prevalence of 2.5% with an incidence of 550,000 cases/year [1,2]. Prevalence of HF has been projected to rise by 46% by the year 2030 [3], thanks to improved management of HF or heart disease in general [4,5]. Furthermore, the direct healthcare cost of HF is enormous; estimated at 31 billion USD in 2012, it is projected to rise by 127% by the year 2030 [3]. In addition to the huge financial burden of HF, persons with HF have a significantly poorer quality of life and low productivity compared to age-matched controls [6] resulting in huge losses.

Heart failure was highlighted as an epidemic in 1997 due to its rising incidence and prevalence and consequently, its huge economic burden to the society. To accurately quantify the burden of HF, in addition to measures of incidence, prevalence and survival, it is important to incorporate the age at diagnosis. Knowing the age at diagnosis of HF is important to plan and evaluate the effectiveness of both primary and secondary preventive measures against HF, and monitoring of HF epidemiology. Furthermore, the age at diagnosis is a major determinant of survival with younger patients surviving longer [4]. Therefore, a declining incidence of HF may not necessarily translate into decreased healthcare cost and societal burden if persons are increasingly being diagnosed at relatively younger ages. Also, documenting the age at diagnosis would help in monitoring and evaluating survival trends by making a difference between early aggressive diagnostic approaches at younger ages on the one hand and improved management on the other.

While there has been appreciable documentation on other measures of quantifying HF burden such as incidence, prevalence, survival and mortality, very little exists on the age at diagnosis in the general public.

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However, in a 20 years prospective study, Bibbins-Domingo *et al.* reported increased early diagnosis among blacks before age 50 years with hypertension and obesity reported as major risk factors [7]. Due to the importance of age at diagnosis in monitoring HF epidemiology, evaluating interventions and budgeting, we set out to determine the median age at diagnosis of HF in the general USA population and by categories of sex, poverty index ratio (PIR), educational level and ethnicity as well as to identify drivers of early age at diagnosis using data from the National Health and Nutrition Examination Survey (NHANES) collected from 2007 to 2016.

2. Methods

2.1. Survey design

The NHANES, conducted by the CDC NCHS (National Center for Health Statistics), collects nationally representative data on the health and nutritional status of non-institutionalized US population under 80 years of age. It utilizes a multistage probability sampling design and targets approximately 5000 persons in 15 counties per year. Detailed information on the survey design is available from the survey documentation [8]. We included records of participants aged 20–80 years, diagnosed with HF with valid entries for the age at diagnosis. Records with missing data on the age at diagnosis were excluded.

2.2. Data collection

Survey participants were interviewed in their homes to ascertain demographic characteristics (age, gender, level of education, ethnicity, marital status, place of birth, health insurance and smoking status) and disease conditions of interest (diabetes, hypertension, coronary heart disease, dyslipidemia, HF and age at diagnosis) using a Computer-Assisted Personal Interviewing (CAPI) system (i.e., interviewer-administered). Questions on disease conditions were generally followed by four categorical response options ("Yes" "No" "Refuse" "Don't know"). Persons who responded "Yes" were classified as "Yes" and all other responses were classified as "No". Persons who reported having smoked >100 cigarettes in their lifetime were classified as smokers. The body mass index (BMI) was calculated from measured weight and height at subsequent follow up visits in the Mobile Examination Center (MEC) by trained health technicians using standardized protocols. BMI (kg/m^2) was grouped into three categories: <25.00, 25.00–29.99, ≥30.00, representing normal, overweight and obesity, respectively. The family PIR was computed by dividing the total family income by the poverty threshold income, as defined by the US Census bureau, with adjustment for family size at the time of the interview [9]. Family PIR of <1 and ≥1 were defined as living "below poverty line" and "at or above poverty line", respectively. Family PIR was grouped into 3 categories (PIR < 1.00, PIR 1.00–2.99 and PIR ≥ 3.00).

The diagnosis of HF and age at diagnosis was determined by the response to the questions; (a) "Has a doctor or other health professional ever told {you/SP} that {you/s/he} … had congestive heart failure?; and (b) "How old {were you/was SP} when {you were/s/he was} first told {you/s/he} … had congestive heart failure?", respectively, to individuals aged 20–80 years. All study questionnaires, exact question wording, response options and data are available to the entire public at no cost [10].

2.3. Statistical analysis

Relevant questionnaire data files with variables of interest from five survey cycles (2007–2016) were combined with demographic information. Appropriate survey weights for the combined dataset were then computed to ensure estimates are representative of the entire non-institutionalized US population in keeping with stipulated analytical guidelines [8]. Included in our analysis were persons 20 years or older with diagnosis of HF and valid entries for age at diagnosis. Cases with missing variables were excluded from respective analyses. The age at diagnosis of HF is reported as median (IQR) and categorical variables as percentages. Equality and drivers of age at diagnosis of HF across different groups was assessed using both bivariate and multivariate linear regression with age as the outcome variable, respectively. Analysis was done using STATA 13 and two-tailed p values <0.05 were considered statistically significant.

3. Results

3.1. General characteristics

Of the 50,588 individuals who participated in the NHANES surveys from 2007 to 2016, 29,201 (57.7%) persons were in the age range 20 to 80 years, with a median age of 49 years (IQR 34–64). In all, there were 974 cases of HF among persons 20 years and older with valid entries for age at diagnosis, corresponding to a prevalence of 2.44%. About 52% of the study population were women. Most of our study participants were married Non-Hispanic (NH) Whites with at least some college level of education. About 17.1% lived below the poverty line and about 70% were at least overweight. The prevalence of smoking, diabetes, hypertension, dyslipidemia and coronary heart disease (CHD) were 44.5%, 9.45%, 31.86%, 36.17% and 3.31%, respectively. Table 1 shows the general characteristics of our study participants.

The median age at diagnosis of HF was 59 years (47–70) in the entire USA population. NH Blacks and Hispanics, never married, obese individuals, participants without health insurance and participants never diagnosed of hypertension were diagnosed at statistically significant younger ages compared to their respective counterparts (Table 2). Specifically, the median age at diagnosis was 53 years (IQR 43–63) and 53 years (IQR 41–63) in NH Blacks and Hispanics, respectively, compared to 62 years (IQR 52–71) in NH Whites with $p < 0.001$. Furthermore, people without hypertension were diagnosed at a statistically significantly younger ages compared with those hypertension (60 versus 57 years, $p = 0.007$). There was no statistically significant difference between age at diagnosis across different categories of diabetes, CHD, educational level and country of birth as shown on Table 2. Widow (er)s had a median age at diagnosis of at least 10 years older compared to all other marital categories.

After controlling for confounders using multivariate linear regression models, NH Blacks were diagnosed on average 5 years younger than NH Whites, (Coefficient [b] = −4.94 [−7.95 to −1.93]; $p = 0.002$), Table 3. Similarly, participants living below the poverty line (b = −5.79 [−10.36 to −1.01]; $p < 0.001$) and those with BMI above 30 kg/m^2 (b = −5.63 [−8.35 to −2.92]; $p < 0.001$), were diagnosed on average 6 years and 5 years younger, respectively. In addition, those without health insurance (b = −4.31 [− 7.87 to −0.75]; $p = 0.018$) and never diagnosed of hypertension (b = −3.99 [−7.19 to −0.78]; $p = 0.015$) were diagnosed on average 4 years younger. On the other hand, widowed individuals were diagnosed on average 10 years older (b = 9.72 [5.49 to 13.95]; $p < 0.001$) compared to married individuals.

Table 1
General characteristics of study participants.

Variable	Categories	Percentage (%)
Age (in years)	Median (IQR)	47.32 (46.8–47.83)
Gender	Male	48.1
	Female	51.9
Educational status	Less than high school	17.17
	High school or GED	22.17
	Some college or Associate degree	31.36
	College degree and above	29.34
Ethnicity	Hispanic	14.25
	Non-Hispanic black	11.39
	Non-Hispanic white	66.63
	Others	7.73
Marital status	Never married	18.6
	Married or living with partner	62.82
	Divorced or separated	12.64
	Widowed	5.94
Place of birth	USA	81.95
	Non-USA	18.05
Health insurance	Yes	81.8
	No	18.2
Poverty index ratio	Below 1	17.64
	1 to 3	40.22
	3 and above	42.14
Body mass index (in kg/m^2)	<25	30.21
	25 to <30	33.21
	30 and above	36.57
Smoking	Yes	44.5
Coronary heart disease	Yes	3.31
Dyslipidemia	Yes	36.17
Diabetes	Yes	9.45
Hypertension	Yes	31.86

GED = General Education Diploma; USA = United States of America.

Table 2
Age at diagnosis of congestive heart failure by subpopulation categories.

Variable	Category	Median age in years (IQR)	*p* value
Gender	Male	57 (48–67)	0.041
	Female	61 (47–71)	
Educational status	Less than high school	59 (47–70)	0.588
	High school or GED	58 (46–69)	
	Some college or associate degree	61 (48–70)	
	College degree and above	57 (45–70)	
Ethnicity	Hispanic	53 (41–63)	<0.0001
	Non-Hispanic black	53 (43–63)	
	Non-Hispanic white	62 (50–71)	
	Others	60 (45–71)	
Marital status	Never married	48 (35–58)	<0.001
	Married or living with partner	57 (47–69)	
	Divorced or separated	53 (43–60)	
	Widowed	70 (60–79)	
Place of birth	USA	60 (48–70)	0.408
	Non-USA	57 (43–70)	
Health insurance	Yes	60 (49–70)	<0.001
	No	48 (41–55)	
Poverty index ratio	Below 1	52 (40–62)	<0.001
	1 to 3	62 (49–61)	
	3 and above	60 (52–70)	
Body mass index	<25	64 (40–62)	0.006
	25 to <30	62 (49–61)	
	30 and above	55 (45–66)	
Smoking	Yes	57 (46–68)	0.011
	No	60 (50–71)	
Coronary heart disease	Yes	58 (48–68)	0.725
	No	60 (46–70)	
Dyslipidemia	Yes	60 (49–70)	0.075
	No	58 (44–70)	
Diabetes	Yes	56 (47–68)	0.332
	No	60 (48–71)	
Hypertension	Yes	60 (49–70)	0.007
	No	57 (42–67)	

GED = General Education Diploma; USA = United States of America.

Table 3
Multivariate linear regression analysis showing relationship between various factors and age at diagnosis.

Variable	Category	[a]Coefficient in years (95% CI)	*p* value
Gender	Male	–	–
	Female	0.63 (−2.99 to 4.24)	0.731
Ethnicity	NH Whites	–	
	Hispanics	−4.40 (−9.14 to 1.35)	0.069
	NH Blacks	−4.94 (−7.95 to −1.93)	0.002
	Others	−1.09 (−7.49 to 5.31)	0.735
Marital status	Married or living with partner	–	
	Never married	−3.17 (−8.97 to 2.64)	0.281
	Divorce or separated	−1.17 (−4.71 to 2.37)	0.513
	widowed	9.72 (5.49 to 13.95)	<0.001
Health insurance	Yes	–	
	No	−4.31 (−7.87 to −0.75)	0.018
Poverty index ratio	Greater or equal to 3	–	
	1 to <3	1.42 (−2.39 to 5.23)	0.461
	Below poverty	−5.69 (−10.36 to −1.01)	0.018
Body mass index	<25	–	
	25 to <30	−0.81(−4.61 to 2.99)	0.673
	30 and above	−5.63 (−8.35 to −2.92)	<0.001
Smoking status	Yes	–	
	No	−1.35 (−1.35 to 4.06)	0.322
Hypertension	Yes	–	
	No	−3.99 (−7.19 to −0.78)	0.015
Dyslipidemia	Yes	–	
	No	−1.72 (−4.18 to 0.74)	0.167

GED = General Education Diploma; USA = United States of America.
[a] Negative coefficients represent the number of years younger while positive coefficients represent the number of years older than the reference category. Using health insurance as an example, the coefficient of −4.31 means that persons without health insurance are diagnosed on average 4.31 years younger than those with health insurance.

4. Discussion

Using cumulative nationally representative data of non-institutionalized US residents, the median age at diagnosis of HF is 59 years. Individuals without health insurance, never diagnosed of hypertension, obese, NH Blacks and individuals living below the poverty line were diagnosed with HF at statistically significant younger ages.

Though there are no prior studies on the age at diagnosis of HF in the general USA, higher incidence of HF with older age has been firmly established. Incident HF rates have been reported to double and triple with each 10 year increase from age 65–85 years in men and women, respectively [11], reflective of advancing age as an indisputable HF risk factor. With a 5 years HF survival rate <50%, theoretically, almost all HF patients would be dead by the age of 70 years [5]. Bearing in mind that the average life expectancy at 20 years in USA is 60 years, this equates to at least 10 years of life lost [12]. Furthermore, poor quality of life and increased dependence of persons with HF constitutes a huge burden on the limited health resources [6]. Though the strain on the health system is enormous, costly innovation and improved management of HF with resultant increased survival is projected to further aggravate its burden on the health system [3]. It is therefore imperative to devise and implement interdisciplinary interventions which focus both on reducing the incidence and the age at onset of HF through timely diagnosis and management of modifiable risk factors.

We observed a significant disparity between the age at diagnosis of HF and ethnicity. NH Whites were diagnosed at significantly older ages compared to other ethnic groups, consistent with previous reports [7,13]. Race has traditionally served as a marker for populations at high risk through the lack of health insurance, poverty, increased prevalence of smoking and obesity. These prevalent sociodemographic constraints lead to poor prevention and management of risk factors such as CHD, hypertension, diabetes and dyslipidemia [14] with resultant increased incident HF as opposed to genotypic differences. HF burden in NH Blacks and Hispanics is further compounded by the fact that NH Blacks and Hispanics experience lower 5-years survival rates compared to NH Whites [15]. With the 5-years survival rate of HF of <50% [15], most Hispanics and NH Blacks would develop and die from HF before their NH Whites age mates ever get diagnosed with HF. These disparities in the burden of HF among different ethnicities must serve as a wakeup call to policy makers who genuinely aspire to curb the burden of HF in the USA to pay specific attention to these groups.

People with health insurance and those with incomes above the poverty threshold were diagnosed with HF at significantly older ages compared to those without health insurance and incomes below the poverty threshold, respectively. Indeed, there exists a significant health disparity in access to chronic disease care between NH Blacks and NH Whites, and Hispanics and NH Whites [16–18]. With most risk factors for HF being chronic such as hypertension, diabetes and dyslipidemia among others, poor persons with limited access to affordable care, follow up and control, are more likely to develop HF at an earlier age [19,20]. The significant difference in median age at diagnosis of HF warrants specific interventions aimed at reducing the prevalence and management of risk factors in these subpopulations. To further compound this discrepancy, poor persons with no health insurance also have a poorer 5-years survival [5]. These findings suggest that better control of HF risk factors in the general population with emphasis on groups with limited socioeconomic resources through improved access to

quality care could play an important role in reducing the burden of HF in the USA.

The fact that widowed persons were diagnosed with HF at a later age compared with other marital status categories could be a biased finding as most widow(er)s are more likely to be elderly subjects. This bias could not be accounted for as we did not control for age in the multivariable linear regression analysis as age could not both serve as outcome and an independent variable.

Unsurprisingly, age at diagnosis of HF was significantly lower in normal weight individuals compared to overweight and obese individuals. Obesity serves a central marker for the agglomeration of cardiovascular risk factors such as diabetes, hypertension, dyslipidemia and CHD and metabolic syndrome [21] which explains this observation. Increased basal sympathetic tone leading to cardiac remodeling; increased prevalence of obstructive sleep apnea/obesity hypoventilation subsequently leading to right heart failure, elevated left ventricular end diastolic pressure at rest and increased total and central blood volume leading to alterations in cardiac hemodynamics in severely obese individuals [22] serve as plausible explanations for this observation. If no effective and meaningful weight control interventions are implemented in the near future, the surging prevalence of obesity in the USA [23] would be mirrored by a significantly increased incident HF at younger ages with ensuing consequences.

We equally observed that participants with hypertension reported being diagnosed with HF at significantly older ages compared to those never diagnosed of hypertension. This difference could be explained by the fact that hypertensive heart disease, a significant cause of HF, is predominantly a disease of the elderly resulting from a longstanding hypertension [24]. Another possibility is that those without hypertension might have developed HF secondary to other causes which might have occurred at significantly younger ages. Unfortunately, our data did not capture the leading causes of HF to have allowed for further analyses.

On the other hand, there were no statistically significant differences between the age at diagnosis of HF with diabetes, dyslipidemia, smoking and CHD status. This highlights the fact that while these are established risk factors for HF, they might not necessarily affect to the same extent the age at disease onset as much as the incidence and prevalence. Also, these disease conditions markedly contribute to HF through chronicity and not their mere presence. The fact that our data did not capture the duration of these conditions prevented us from appropriately assessing their impact on the age at diagnosis of HF. We suggest that future researchers incorporate the duration of these conditions to adequately assess their impact. While there are many persons with undiagnosed hypertension, diabetes and dyslipidemia in the society which often leads to misclassification that might explain this observation, it is highly unlikely that these conditions could go undiagnosed and underreported in persons with a major CVD condition such as HF whose management hinges on meticulous control of prevailing risk factors.

4.1. Strengths and limitations

To the best of our knowledge, this is the first comprehensive study on the median age at diagnosis of HF in the USA and across subpopulations. Using cumulative data spanning a decade with a large sample size, our estimates are both stable and reliable. The diagnosis of HF and age at diagnosis were self-reported and, therefore, liable to recall bias. However, patients with HF are more likely to accurately recall the age at diagnosis with this chronic and life-changing condition. Self-reporting without access to clinical data also made it impossible to further subclassify by causes (Ischemic vs Non-ischemic), type (Diastolic vs Systolic), etc. Also, because the age at diagnosis was reported, it made it impossible to compute and compare trends in the age at diagnosis which would have served as a great tool in assessing efforts geared at reducing the burden of HF in the population, in addition to measures of incidence, prevalence, survival and mortality over this time period. Furthermore, the cross-sectional study design made it impossible to investigate the impact of these drivers on outcomes such as survival and quality of life among others. Finally, our survey designed failed to capture institutionalized persons though a non-negligible proportion of persons with HF end up in care facilities due to dependence. Notwithstanding these shortcomings, our findings are reliable and representative of the non-institutionalized USA population 20 years and older from 2007 to 2016 and serve to inform policy makers on major drivers of early age at diagnosis of HF in the USA.

5. Conclusion

We report that majority of HF patients in the USA are diagnosed by the sixth decade of life, with significant disparities across various socioeconomic groups. Persons living below the poverty threshold, obese persons, NH Blacks and those without health insurance constitute the main determinants of early age at diagnosis. Efforts aimed at reducing the burden of HF must pay specific attention to these high-risk groups for meaningful and impactful results.

5.1. Clinical perspectives

We have established a baseline value for median age at diagnosis of HF in the USA and subpopulations, highlighting disparities and identifying major drivers of early age at diagnosis. This information would serve as a monitoring parameter for epidemiologist in monitoring of HF epidemiology; valuable information to alert clinicians on high risk groups for aggressive evaluation and management; vital for public health practitioners in designing high impact intervention and finally guiding for policy makers for prioritization of limited resources.

Authorship

Chobufo Muchi Ditah (MD, MPH), **Rahman Ebad** (MD), **Valirie Ndip Agbor** (MD): conception, data collection and analysis.

Foryoung Joyce Bei (MD), **Shahzad Moazzam** (MD), **Birendra Amgai** (MD), **Paritosh Kafle** (MD), **Jonnadula Saikiran** (MD): drafting and review of manuscript.

Tonga K. Nfor (MD, MSPH, FACC, FSCAI), **Dufresne Alix** (MD, FACC, FESC): final Approval of manuscript for submission.

Declaration of Competing Interest

The authors report no relationships that could be construed as a conflict of interest.

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