Prevalence and determinants of Hyperpolypharmacy in adults with heart failure: an observational study from the National Health and Nutrition Examination Survey (NHANES)

Peter J. Kennel¹, Jerard Kneifati-Hayek², Joanna Bryan², Samprit Banerjee³, Irina Sobol⁴, Mark S. Lachs⁵, Monika M. Safford² and Parag Goyal²,⁵*

Abstract

Background: While an expanding armamentarium of pharmacologic therapies has contributed to improved outcomes among adults with heart failure (HF) over the past two decades, this has also been accompanied by an increase in the number of medications taken by adults with HF. The use of at least 10 medications, defined as hyperpolypharmacy, is particularly notable given its association with adverse outcomes. We aimed to assess the prevalence and identify determinants of hyperpolypharmacy among adults with HF.

Methods: We studied adults aged ≥50 years with self-reported HF from the National Health And Nutrition Examination Survey (NHANES) in 2003–2014. We calculated weighted means and percentages to describe patient characteristics. We conducted a multivariable Poisson regression analysis to identify factors independently associated with hyperpolypharmacy; we adjusted for survey sampling, socio-demographics, comorbidity, geriatric conditions, and health care utilization. We examined 947 participants, representing 4.6 million adults with HF.

Results: The prevalence of hyperpolypharmacy was 26%. In a multivariable regression analysis, comorbidity count, ≥10 ambulatory contacts, and ≥3 hospitalizations were independently associated with hyperpolypharmacy. Interestingly, functional impairment and cognitive impairment were not independently associated with hyperpolypharmacy; while low annual household income and low educational status were each associated with an almost 2-fold increase in hyperpolypharmacy.

Conclusion: Hyperpolypharmacy is a common condition among adults with HF. We additionally found that low household income and low educational status are independently associated with hyperpolypharmacy, suggesting that non-medical factors may be contributing to this potentially harmful condition.

Keywords: Polypharmacy, Heart failure, Healthcare disparity

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Background
While an expanding armamentarium of pharmaco
gic therapies has contributed to improved outcomes among
adults with heart failure (HF) over the past two decades, [1, 2] this has also been accompanied by an increase in the
number of medications taken by adults with HF. [3] Indeed, in addition to the many medications specifically indi-
cated for HF, adults with HF also frequently take medica-
tions for other common cardiovascular conditions like
coronary artery disease and atrial fibrillation, as well as for
non-cardiovascular conditions like lung disease and
musculoskeletal disease. [4, 5] Consequently, the number of
medications taken by some adults with HF could easily
surpass 10. [6]

The use of at least 10 medications is particularly notable,
representing a condition described in the Geriatrics and
Pharmacology literature as hyperpolypharmacy. [7, 8] Hyperpolypharmacy represents an extreme version of poly-
pharmacy—the condition of taking a high number of medi-
cations [9]—and is associated with a number of adverse
outcomes including disability, [10] hospitalizations, [11] and
mortality. [12] Despite the high burden of medication use
among adults with HF, the concept of hyperpolypharmacy
may be overlooked. This is potentially problematic, as
adults with HF represent a subgroup at particularly high
risk for medication-related adverse outcomes due to alte-
rations in pharmacokinetics and pharmacodynamics, [13]
changes in cardiovascular structure and function, [14] and
the coexistence of geriatric conditions like frailty [15] and
cognitive impairment. [16] Accordingly, we sought to
examine a nationally-representative cohort of adults with
HF using the National Health And Nutrition Examination
Survey (NHANES) data to better understand the preva-
ience of hyperpolypharmacy and identify its determinants
among this vulnerable population.

Methods
To conduct this cross-sectional population-based study of
data, we used publically available data from National
Health And Nutrition Examination Survey (NHANES). 
NHANES is a cross-sectional survey-based study with a
probability-based complex, stratified, multistage design.
[17] NHANES is designed to produce national estimates
representative of the total non-institutionalized civilian
United States population. Weighting produces estimates of
the data that would be obtained if the entire cohort that fits
inclusion criteria (civilian U.S. population) had been sur-
veyed. Health information is gathered biennially from a
sample of adult non-institutionalized civilians via an inter-
view and in-home examination.

We conducted a cross-sectional observational study of
NHANES survey data. We included subjects aged ≥50
years old with self-reported HF from the 2003–2014 cycles
in our analysis. Self-reported HF is a reasonable approach
to identifying a nationally representative cohort of patients
with HF as statistics on self-reported HF derived from
NHANES are used in the annual report on heart disease
and stroke by the American Heart Association [15] and
self-report has previously demonstrated a high specificity
for HF. [15] We excluded subjects with missing data on
self-reported HF and/or medications. We examined several
variables routinely collected in NHANES. This included
socio-demographic variables (age, gender, race, payer sta-
tus, highest education attained, household income, marital
status, and living alone); comorbid conditions available
during each NHANES cycle included in the study period
(hypertension, diabetes, anemia, asthma, chronic bronchitis,
emphysema, coronary artery disease, prior myocardial in-
farction, prior stroke, thyroid disease, liver disease, cancer,
chronic kidney disease, dialysis, hypercholesterolemia,
arthritis); smoking (never, past, or current); self-reported
health compared to the prior year (same, worse, or better);
geriatric conditions (self-reported memory problems as a
proxy for cognitive impairment, and functional impairment
as characterized by impaired activities of daily living based
on “difficulty getting in and out of bed,” had “difficulty using
a fork, knife, drinking from cup” or difficulty “dressing them-
selves”); and healthcare utilization (number of contacts with
ambulatory healthcare services and emergency room visits
that did not result in an overnight hospitalization, and the
number of hospitalizations in the prior year).

During the in-home examination, participants were asked
to report prescription medications that they had taken
during the prior month, and show their medication con-
tainers to the examiner. We defined hyperpolypharmacy as
the condition of taking ≥10 medications. [7, 8] We clas-
sified medications according to the Multum Lexicon Drug
Database, [18] which then facilitated a broader classification
scheme of three major medication groups—HF medica-
tions, other (non-HF related) cardiovascular medications,
and non-cardiovascular medications.

For all analyses, we accounted for the complex survey
design of NHANES. In particular, we calculated weighted
percents and/or weighted means for all variables, and
accounted for clustering in all analyses. We assessed
significant differences between those with and without
hyperpolypharmacy by performing a Pearson’s chi square
test for categorical variables and a t-test for continuous
variables. Since the sample size is large, a simple application
of the Lyapunov or Lindeberg’s Central Limit Theorem
guarantees large sample convergence of the weighted mean
to a standard normal distribution, ensuring that the
t-statistic would have a limiting t-distribution.

To identify factors independently associated with
hyperpolypharmacy, we performed a Poisson regression
analysis with robust standard errors that incorporated
all candidate variables including socio-demographics,
Results

We studied 947 survey respondents, which represented 4.6 million non-institutionalized participants from the United States. Baseline characteristics are shown in Table 1. The cohort had a mean age of 70 years (±8.9), about half (49%) were women, and the majority were white (77%). Most participants were Medicare beneficiaries (66%), most had an educational level below a college degree (87%), and a substantial proportion reported an annual household income of under $20,000 (27%).

The prevalence of hyperpolypharmacy was 26%. Those with hyperpolypharmacy took a mean number of 11.9 (±2.0) medications, compared to 5.5 (±2.5) in individuals without hyperpolypharmacy. The mean number of HF medications, non-HF cardiovascular medications, and non-cardiovascular medications for those with hyperpolypharmacy were each higher compared to those without hyperpolypharmacy (Table 2). This difference was most striking among the non-cardiovascular medications—individuals with hyperpolypharmacy took a mean number of 6.6 (±2.4) non-cardiovascular medications, compared to a mean of 2.3 (±1.8) in those without hyperpolypharmacy (p < 0.001). Non-cardiovascular medications comprised 55% of medications in individuals with hyperpolypharmacy, compared to 42% in those without hyperpolypharmacy (p < 0.001). HF medications comprised 24% of medications among those with hyperpolypharmacy, compared to 34% among those without hyperpolypharmacy (Table 3). Notably, individuals with hyperpolypharmacy more frequently took opioid and non-opioid analgesics, psychotropic substances such as benzodiazepines and antidepressants, anti-diabetic agents, antacids, thyroid agents, bronchodilators, genitourinary tract agents, supplements, anti-infective agents, and topical agents (Table 2).

The mean number of comorbid conditions was 4.7 (±2.0) for the entire sample of individuals with HF. Those with hyperpolypharmacy had a higher comorbidity count than those without hyperpolypharmacy (Table 4). Of note, pulmonary disorders including asthma, chronic bronchitis and emphysema were each more than 2-fold more prevalent among individuals with hyperpolypharmacy compared to those without it (Table 4). Chronic ailments that frequently require multiple medications such as diabetes (p < 0.001), coronary artery disease (p < 0.001), and arthritis (p = 0.001) [20] were also significantly more prevalent in individuals with hyperpolypharmacy.

Table 5 shows a multivariable regression analysis of determinants for hyperpolypharmacy. Notably, comorbidity count (1.19, 95% CI [1.12–1.27], p < 0.001), ≥ 10 ambulatory contacts (3.01, 95% CI [1.73–5.21] p < 0.001) and ≥ 3 hospitalizations (1.70, 95% CI [1.27–2.30] p = 0.001) were strongly associated with hyperpolypharmacy. In addition, an educational level of below college (1.74, 95% CI [1.01–2.99] p = 0.04) and a household income below $20,000 (1.70, 95% CI [1.01–2.85] p = 0.04) were independently associated with hyperpolypharmacy. Meanwhile, advanced age, geriatric conditions including functional impairment and cognitive impairment, and declining health were not independently associated with the presence or absence of hyperpolypharmacy (Table 5).

Within this sample, 28% had a missing value for 1 covariate, and only 4% had a missing value for more than 1 covariate. Variables with the highest percent missing included primary payer (17%), comorbidity count (13%), and income (1%). All other variables were missing < 1% in the sample. Participants who were missing primary payer information were more likely to be white compared to the rest of the sample; and those missing comorbidity count were more likely to be female compared to the rest of the sample.

Discussion

There are two major findings from our analysis of NHANES data. First, hyperpolypharmacy was common among adults with HF. Second, non-medical factors including low income and low education were independently associated with hyperpolypharmacy. Our study found that one out of every four ambulatory HF patients take 10 or more medications. This is concerning because a high medication burden contributes to an increased risk for adverse drug reactions, and is associated with a number of adverse outcomes including disability, [10] hospitalizations, [11] and mortality. [12] The prevalence of hyperpolypharmacy did not vary even in the presence of factors associated with an increased risk for adverse drug events—advanced age, [21, 22] cognitive impairment, [16] and functional impairment. [10] This is consistent with a recent study of HF patients, where we showed that those with functional impairment take the same number of medications as those without functional impairment when adjusting for other factors like comorbidity burden, even when factors like cognitive impairment, low self-reported health, and recurrent hospitalizations are present. [23] This raises concern not only for drug-drug interactions, but also for drug-disease interactions, as HF is a
Table 1 Population Characteristics According to Hyperpolypharmacy

| Variable                                | All       | No HPP (n = 705) | HPP (n = 242) | P-value |
|-----------------------------------------|-----------|-----------------|---------------|---------|
| Mean age (SD)                           | 70.0 (8.9)| 70.1 (9.1)      | 69.7 (8.2)    | 0.67    |
| Age, %                                  |           |                 |               |         |
| 50–74                                    | 61        | 60              | 65            |         |
| ≥75                                      | 40        | 41              | 35            |         |
| Women, %                                | 49        | 48              | 54            | 0.07    |
| Race, %                                 |           |                 |               |         |
| White                                   | 77        | 76              | 81            |         |
| Black                                   | 13        | 13              | 13            |         |
| Other                                   | 10        | 12              | 6             |         |
| Primary Payer, %                        |           |                 |               | 0.30    |
| Medicare without Medicaid               | 66        | 64              | 72            |         |
| Medicaid without Medicare               | 6         | 6               | 6             |         |
| Dual Medicare and Medicaid              | 7         | 7               | 8             |         |
| Other insurance                         | 15        | 16              | 12            |         |
| Uninsured                               | 6         | 7               | 3             |         |
| Education, %                            |           |                 |               | 0.01    |
| High school or below                    | 87        | 8               | 93            |         |
| College degree and above                | 13        | 15              | 7             |         |
| Household Income (%)                    |           |                 |               | 0.36    |
| ≥$75,000                                | 14        | 16              | 10            |         |
| $35,000–$74,000                         | 28        | 28              | 28            |         |
| $20,000–$34,000                         | 27        | 27              | 28            |         |
| <$20,000                                | 27        | 26              | 32            |         |
| Refused to answer                       | 3         | 4               | 2             |         |
| Married, %                              | 53        | 52              | 56            | 0.38    |
| Living alone, %                         | 26        | 27              | 24            | 0.42    |
| Count of comorbidities, mean (95% CI)  | 4.7 (4.5–4.8) | 4.3 (4.1–4.4)   | 5.9 (5.5–6.3) | <0.001  |
| Smoking status, %                       |           |                 |               | 0.34    |
| Never                                   | 40        | 40              | 39            |         |
| Past                                    | 43        | 42              | 48            |         |
| Current                                 | 16        | 18              | 13            |         |
| Change in self-reported health, %       |           |                 |               | 0.27    |
| Better                                  | 22        | 22              | 23            |         |
| Worse                                   | 22        | 21              | 27            |         |
| Same                                    | 55        | 57              | 50            |         |
| Cognitive impairment, %                 | 24        | 23              | 26            | 0.52    |
| Functional impairment, %                | 12        | 10              | 16            | 0.04    |
| Number of contacts with ambulatory healthcare services, past year | | | | <0.001 |
| 0–3                                     | 20        | 25              | 7             |         |
| 4–9                                     | 41        | 42              | 38            |         |
| ≥10                                     | 39        | 33              | 56            |         |
| Number of hospitalizations, past year   |           |                 |               | <0.001  |
| <3                                      | 91        | 95              | 82            |         |
| ≥3                                      | 9         | 5               | 18            |         |
### Table 1: Population Characteristics According to Hyperpolypharmacy (Continued)

| Variable          | All | No HPP (n = 705) | HPP (n = 242) | P-value |
|-------------------|-----|-----------------|---------------|---------|
| Cycle Year        |     |                 |               |         |
| 2003–2004         | 17  | 18              | 16            | 0.78    |
| 2005–2006         | 17  | 18              | 14            |         |
| 2007–2008         | 16  | 15              | 16            |         |
| 2009–2010         | 14  | 14              | 14            |         |
| 2011–2012         | 19  | 19              | 20            |         |
| 2013–2014         | 18  | 17              | 21            |         |

Abbreviations: HPP Hyperpolypharmacy, CI Confidence Interval, SD standard deviation

### Table 2: Medication Profile According to Hyperpolypharmacy

| Variable                                      | All       | No HPP     | HPP        | P-value |
|-----------------------------------------------|-----------|------------|------------|---------|
| Prevalence of Hyperpolypharmacy               | 26%       | –          | –          | –       |
| Total Medication Count, mean (SD)             | 7.2 (3.7) | 5.5 (2.5)  | 11.9 (2.0) | <0.001  |
| Heart Failure Medications, mean (SD)          | 2.1 (1.3) | 1.9 (1.3)  | 2.8 (1.2)  | <0.001  |
| Beta blockers, %                              | 61        | 56         | 77         | <0.001  |
| ACEI or ARB, %                                | 58        | 55         | 66         | 0.02    |
| Aldosterone antagonist, %                     | 11        | 9          | 16         | 0.01    |
| Vasodilators, %                               | 10        | 7          | 18         | 0.001   |
| Diuretics, %                                  | 60        | 53         | 78         | <0.001  |
| Digoxin, %                                    | 13        | 12         | 17         | 0.08    |
| Other Cardiovascular Agents, mean (SD)        | 1.6 (1.3) | 1.3 (1.1)  | 2.5 (1.3)  | <0.001  |
| Lipid Lowering, %                             | 60        | 53         | 80         | <0.001  |
| Anti-platelet agents, %                       | 21        | 14         | 40         | <0.001  |
| Anti-coagulation agents, %                    | 21        | 19         | 26         | 0.06    |
| Anti-arrhythmic agents, %                     | 26        | 23         | 32         | 0.02    |
| Calcium-channel blockers, %                   | 22        | 19         | 31         | 0.001   |
| Anti-anginal agents, %                        | 12        | 7          | 27         | <0.001  |
| Other anti-hypertensive agents, %             | 14        | 10         | 24         | <0.001  |
| Non-cardiovascular medications, mean (SD)     | 3.4 (2.7) | 2.3 (1.8)  | 6.6 (2.4)  | <0.001  |
| Opioids, %                                    | 15        | 9          | 30         | <0.001  |
| Non-opioid analgesic, %                       | 11        | 8          | 19         | 0.004   |
| Benzodiazepines, %                            | 9         | 6          | 18         | <0.001  |
| Anti-depressants, %                           | 23        | 17         | 41         | <0.001  |
| Anti-psychotics, %                            | 3         | 2          | 3          | 0.6     |
| Anti-diabetic agents, %                       | 34        | 27         | 55         | <0.001  |
| Antacids, %                                   | 32        | 23         | 60         | <0.001  |
| Thyroid agents, %                             | 20        | 16         | 30         | <0.001  |
| Bronchodilators, %                            | 15        | 9          | 29         | <0.001  |
| GU Tract agents, %                            | 4         | 2          | 8          | 0.001   |
| Minerals/Vitamins, %                          | 24        | 17         | 45         | <0.001  |
| Anti-infective agents, %                      | 9         | 6          | 17         | 0.001   |
| Anti-neoplastic agents, %                     | 2         | 1          | 5          | 0.003   |
| Topical agents, %                             | 9         | 5          | 17         | <0.001  |

Abbreviations: HPP Hyperpolypharmacy, CI Confidence Interval, ACEI Angiotensin Converting Enzyme Inhibitor, ARB Angiotensin II Receptor Blocker, PPI Proton Pump Inhibitor, GU Genitourinary, SD standard deviation
condition that can be exacerbated by several common medications. [24, 25] High medication burden has also been linked to medication non-adherence, [26] a particularly relevant issue in HF, as self-care and medication adherence are key components of chronic disease management. Consequently, while hyperpolypharmacy may be a reflection of guideline-concordant therapy for multiple co-occurring conditions (comorbidity count was independently associated with hyperpolypharmacy), it is important to consider the potential risks of a high number of medications when prescribing medications, as adverse drug events and non-adherence can undermine the efficacy and safety of HF therapy.

When examining determinants of hyperpolypharmacy, our study revealed that non-medical factors including low income and low education were independently associated with hyperpolypharmacy, even after controlling for other socio-demographic factors including receipt of Medicaid, comorbid conditions, and healthcare utilization. This was a surprising and concerning finding that warrants additional investigation. Disparities in the outcomes of individuals with HF and low socioeconomic status (SES) are well-described—individuals with low SES are at increased risk for hospitalization and death. [27, 28] This may in part relate to suboptimal care, for which low SES is a known risk factor. For example, those with low SES are less likely to undergo an evaluation of left ventricular systolic function during a hospitalization, [29] and are less likely to receive devices like implantable cardioverter-defibrillator (ICD) [30] or undergo coronary revascularization. [31] Whether specific medication prescribing patterns such as hyperpolypharmacy, which is associated with adverse outcomes, can help explain these health disparities is unknown. Indeed, while medication underutilization represents an important form of suboptimal care in HF, medication overutilization may represent an overlooked form of suboptimal care as well. Thus, in light of our finding that low SES is associated with hyperpolypharmacy, there is a need to further explore whether SES-related health disparities in HF can at least in part be explained by hyperpolypharmacy.

There are several strengths to this study. NHANES is a nationally representative sample, and thus has high degree of generalizability to the United States population. Another strength is the detailed list of medications routinely collected from NHANES participants, which are then verified by an in-home visit. There are also some important limitations to our study. This study was observational in nature and thus precluded establishing a causal relationship between variables. Data in NHANES were based on self-report, which can introduce recall bias and social desirability bias. Because details of medication dosing and indications were not available, we were unable to determine whether medications were actually indicated; we also did not have data on the chronicity of medications. Future studies based on medical record abstraction would be useful to better understand this dimension. Also, the number of medications obtained during the in-home visit reflects only prescription medications; accordingly, the prevalence of hyperpolypharmacy may be even greater when accounting for non-prescription medications and dietary supplements. The number of medications did not account for multiple pharmacologically-active ingredients in a single pill (e.g., combination pills), and did not account for pill burden (multiple pills of the same medication); these aspects of medication burden may warrant further investigation. Lastly, details regarding the etiology, subtype (HF with reduced ejection fraction versus HF with preserved ejection fraction), and severity of HF were not available, and could have affected our findings. In particular, given limitations in the sensitivity [32] of self-reported HF, individuals with less severe HF may have been excluded.

### Table 3 Composition of Medication Regimens According to Hyperpolypharmacy

| Variable                        | All       | No HPP | HPP | P-value |
|---------------------------------|-----------|--------|-----|---------|
| HF medications, %               | 30        | 34     | 24  | <0.001  |
| Non-HF, Cardiovascular medications, % | 23        | 24     | 21  | <0.001  |
| Non-cardiovascular medications, % | 48        | 42     | 55  | <0.001  |

Abbreviations: HPP Hyperpolypharmacy, HF Heart Failure

### Table 4 Comorbid Conditions According to Hyperpolypharmacy

| Variable                  | All       | No HPP | HPP | P-value |
|---------------------------|-----------|--------|-----|---------|
| Comorbidity Count, mean (SD) | 4.7 (2.0) | 4.3 (1.8) | 5.9 (2.1) | <0.001  |
| Hypertension, %           | 76        | 74     | 83  | 0.04    |
| Hypercholesterolemia, %   | 66        | 63     | 73  | 0.03    |
| Myocardial Infarction, %  | 46        | 43     | 52  | 0.07    |
| Coronary Artery Disease, %| 40        | 35     | 54  | <0.001  |
| Stroke, %                 | 22        | 20     | 27  | 0.05    |
| Diabetes, %               | 39        | 32     | 59  | <0.001  |
| Asthma, %                 | 17        | 13     | 28  | 0.001   |
| Chronic Bronchitis, %     | 12        | 9      | 20  | 0.003   |
| Emphysema, %              | 13        | 10     | 22  | <0.001  |
| Cancer, %                 | 27        | 27     | 25  | 0.70    |
| Anemia, %                 | 12        | 11     | 15  | 0.20    |
| CKD, %                    | 14        | 10     | 24  | <0.001  |
| Dialysis, %               | 2         | 2      | 3   | 0.60    |
| Thyroid disease, %        | 18        | 15     | 26  | 0.002   |
| Arthritis, %              | 63        | 58     | 76  | 0.001   |
| Liver disease, %          | 4         | 4      | 5   | 0.42    |

Abbreviations: HPP Hyperpolypharmacy, CI Confidence Interval, CKD Chronic Kidney Disease, SD standard deviation
Table 5 Prevalence Ratios for the Determinants of Hyperpolypharmacy

| Variable                                      | Univariate Model | Multivariable Model |
|-----------------------------------------------|------------------|---------------------|
|                                               | PR (95% CI)      | P-value             | PR (95% CI)      | P-value             |
| Age ≥ 75                                       | 0.84 (0.62–1.14) | 0.26                | 0.83 (0.63–1.11) | 0.21                |
| Women                                         | 1.22 (0.98–1.52) | 0.07                | 1.15 (0.92–1.43) | 0.23                |
| Race                                          |                  |                     |                    |                     |
| White Referent Group                          |                  |                     |                    |                     |
| Black                                         | 0.96 (0.70–1.32) | 0.81                | 0.98 (0.71–1.35) | 0.91                |
| Other                                         | 0.56 (0.34–0.93) | 0.03                | 0.59 (0.38–0.91) | 0.02                |
| Primary Payer                                 |                  |                     |                    |                     |
| Medicare without Medicaid Referent Group       |                  |                     |                    |                     |
| Medicaid without Medicare 1.03 (0.60–1.76)     | 0.91             |                     | 0.76 (0.48–1.21) | 0.25                |
| Dual Medicare and Medicaid 1.03 (0.67–1.59)    | 0.88             |                     | 0.82 (0.53–1.27) | 0.37                |
| Other insurance                               | 0.76 (0.39–1.48) | 0.42                | 0.85 (0.50–1.45) | 0.55                |
| Uninsured                                     | 0.40 (0.15–1.12) | 0.08                | 0.66 (0.25–1.73) | 0.40                |
| Education, High school or below                | 1.95 (1.12–3.38) | 0.02                | 1.74 (1.01–2.99) | 0.04                |
| Household income                              |                  |                     |                    |                     |
| ≥$75,000                                      | 1.40 (0.80–2.45) | 0.24                | 1.52 (0.89–2.59) | 0.12                |
| $35,000–$74,000                               | 1.46 (0.85–2.65) | 0.17                | 1.42 (0.86–2.35) | 0.16                |
| $20,000–$34,000                               | 1.65 (1.00–2.70) | 0.05                | 1.70 (1.01–2.85) | 0.04                |
| <$20,000                                      | 0.87 (0.64–1.19) | 0.38                | 0.82 (0.56–1.21) | 0.32                |
| Not Married                                   | 0.89 (0.66–1.19) | 0.43                | 0.95 (0.65–1.40) | 0.81                |
| Count of comorbidities                        | 1.28 (1.21–1.36) | <0.001              | 1.19 (1.12–1.27) | <0.001              |
| Smoking status                                |                  |                     |                    |                     |
| Never Referent Group                          |                  |                     |                    |                     |
| Past                                          | 1.13 (0.85–1.50) | 0.39                | 0.96 (0.72–1.28) | 0.80                |
| Current                                       | 0.78 (0.42–1.46) | 0.44                | 0.69 (0.41–1.16) | 0.16                |
| Change in self-reported health                 |                  |                     |                    |                     |
| Better Referent Group                         |                  |                     |                    |                     |
| Same                                          | 0.86 (0.61–1.21) | 0.39                | 1.08 (0.78–1.50) | 0.64                |
| Worse                                         | 1.14 (0.76–1.70) | 0.53                | 1.05 (0.72–1.53) | 0.80                |
| Cognitive impairment                          | 1.10 (0.83–1.46) | 0.52                | 0.92 (0.68–1.24) | 0.57                |
| Functional impairment                         | 1.46 (1.03–2.06) | 0.04                | 1.02 (0.72–1.45) | 0.90                |
| Number of contacts with ambulatory healthcare services, past year | | | | |
| 0–3 Referent Group                            |                  |                     |                    |                     |
| 4–9                                           | 2.78 (1.52–5.08) | 0.001               | 2.20 (1.23–3.96) | 0.01                |
| >10                                           | 4.31 (2.50–7.42) | <0.001              | 3.01 (1.73–5.21) | <0.001              |
| Number of hospitalizations, past year          |                  |                     |                    |                     |
| <3 Referent Group                             |                  |                     |                    |                     |
| ≥3                                            | 2.35 (1.75–3.14) | <0.001              | 1.70 (1.27–2.30) | 0.001               |
| Cycle Year                                    |                  |                     |                    |                     |
| 2003–2004 Referent Group                      |                  |                     |                    |                     |
| 2005–2006                                     | 0.88 (0.55–1.40) | 0.58                | 0.81 (0.50–1.33) | 0.41                |
| 2007–2008                                     | 1.15 (0.66–2.00) | 0.63                | 1.16 (0.67–2.01) | 0.60                |
| 2009–2010                                     | 1.12 (1.72–1.76) | 0.63                | 1.16 (0.79–1.71) | 0.44                |
| 2011–2012                                     | 1.13 (0.74–1.73) | 0.57                | 1.16 (0.83–1.63) | 0.38                |
| 2013–2014                                     | 1.27 (0.70–2.31) | 0.42                | 1.35 (0.88–2.06) | 0.16                |

Abbreviations: CI Confidence Interval, PR Prevalence Ratio
Conclusion
In conclusion, our study showed that hyperpolypharmacy is common in adults with HF and that its prevalence does not vary according to advanced age, functional impairment, or cognitive impairment. Conversely, low household income and low educational status were independently associated with hyperpolypharmacy, even after accounting for influences such as receipt of Medicaid, suggesting that non-medical factors may be contributing to this potentially harmful practice. Future research is warranted to explore the mechanisms underlying this finding and whether hyperpolypharmacy could be contributing to worse health outcomes in this population.

Abbreviations
HF: Heart failure; NHANES: National Health and Nutrition Examination Survey; SES: Socioeconomic status

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Availability of data and materials
Data that support the findings of this study are available NHANES, https://www.cdc.gov/nchs/nhanes/index.htm

Authors’ contributions
PK: study concept and design; acquisition, analysis, or interpretation of data; drafting of the manuscript. JH: study concept and design; acquisition, analysis, or interpretation of data; statistical analysis. JB: acquisition, analysis, or interpretation of data; statistical analysis. IS: critical revision of the manuscript for important intellectual content; administrative, technical, or material support; study supervision. MM: study concept and design; critical revision of the manuscript for important intellectual content; administrative, technical, or material support; study supervision. ML: critical revision of the manuscript; critical revision of the manuscript for important intellectual content; statistical analysis. PB: acquisition, analysis, or interpretation of data; statistical analysis. PG: study concept and design; critical revision of the manuscript for important intellectual content; statistical analysis. All authors read and approved the final manuscript.

Ethics approval and consent to participate
This study was reviewed and approved by the National Center for Health Statistics research ethics review board, and written informed consent was obtained from all NHANES participants.

Consent for publication
Not applicable.

Competing interests
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Author details
1Department of Healthcare Policy & Research, Weill Cornell Medicine, New York, NY, USA. 2Division of Geriatrics/Department of Medicine, Weill Cornell Medical College, New York, NY, USA. 3Division of Internal Medicine/Department of Medicine, Weill Cornell Medical College, New York, NY, USA. 4Division of Geriatrics/Department of Medicine, Weill Cornell Medical College, New York, NY, USA. 5Division of Cardiology/Department of Medicine, Weill Cornell Medical College, New York, NY, USA.

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