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RESEARCH LETTER

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Association between income and likelihood of right heart catheterization in individuals with pulmonary hypertension: A US claims database analysis

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Abstract

We used a US-based administrative claims database to determine associations between annual household income and the likelihood of right heart catheterization (RHC) among individuals with pulmonary hypertension. Those with annual household income < $40,000 were 19% less likely to receive RHC compared to individuals with annual household income ≥ $100,000 ($p < 0.0001$).

KEYWORDS
health services research, pulmonary hypertension, social determinants

INTRODUCTION

Pulmonary hypertension (PH) encompasses multiple disease states, each with distinct pathophysiology, hemodynamic characteristics, and response to treatment.[1] The World Symposium on Pulmonary Hypertension (WSPH) classifies PH into pulmonary arterial hypertension (PAH, Group 1); PH due to left heart disease (Group 2); PH due to lung diseases and/or hypoxia (Group 3); PH due to pulmonary artery obstructions (Group 4); and PH with unclear and/or multifactorial mechanisms (Group 5).[2] Accurate classification is critical, as prognosis and treatment differ by WSPH Group.

Early diagnosis of PAH, specifically, has been associated with improved long-term survival.[3] However, the diagnosis is commonly delayed or missed.[4] In one study, the mean time from symptom onset to diagnosis was 47 ± 35 months.[5] For Groups 2 and 3 PH, accurate diagnosis is likewise essential due to harms associated with use of vasodilators.[6–8] Finally, a definitive diagnosis of Group 4 PH is important because thromboendarterectomy can be curative.[9]

Current guidelines provide a diagnostic algorithm for individuals with clinical history and echocardiographic findings consistent with PH.[10] Recommended tests include pulmonary function testing, chest computed tomography, and ventilation/perfusion scan, among others. Right heart catheterization (RHC) provides definitive hemodynamic measurements and is the gold standard for classifying PH by the WSPH Group.

Despite available guidelines, many individuals on vasodilators for PH have never received the requisite RHC.[1] The reasons for this gap in care are unclear. However, there is increasing evidence that social factors are associated with and may drive outcomes in PH. For example, lower annual household income correlates with a worse functional class at diagnosis, suggesting individuals with lower income are diagnosed with more severe disease.[11] Rural residence has also been linked with an elevated risk of mortality, independent of neighborhood poverty.[12] It is unknown whether socioeconomic factors relate to use of appropriate diagnostic testing, such as RHC.

We used a nationally representative database of deidentified, aggregated, commercial, and Medicare Advantage health claims to evaluate associations between annual household income and the likelihood of RHC among individuals with PH. Specialist follow-up was included as a secondary outcome.

METHODS

Data were obtained from Optum's De-identified Clinformatics® Data Mart Database, a US–based database containing inpatient, outpatient, emergency department, and pharmacy claims from individuals with commercial insurance and Medicare Advantage. Informed consent is waived because data are deidentified. Claims data include ICD-9 and ICD-10 diagnosis and procedure codes; Current Procedural Terminology (CPT), Version 4 procedure codes; Healthcare Common Procedure Coding System procedure codes; and site of service codes.

Individuals were identified as having PH by ≥1 inpatient or outpatient medical claim containing an ICD-9 or ICD-10 code for PH (Supporting Information: Table 1) from January 1, 2015 to December 31, 2019. Individuals were included if they had continuous health plan enrollment with medical benefits for ≥6 months before the index diagnosis of PH. To capture incident disease, we excluded anyone with a diagnosis of PH in the calendar year before the index diagnosis of PH. This process yielded a sample of 404,389 individuals. We excluded those who underwent RHC ≤ 12 months before diagnosis ($n = 1085$), were under age 18 ($n = 809$), had missing/unknown income ($n = 82{,}269$) or sex ($n = 55$), or had <30 days continuous enrollment ($n = 12{,}658$).

Annual household income was acquired through Optum, which sources income data from AmeriLINK Consumer Marketing Database. AmeriLINK data is based on monthly surveys of >30,000 households considered to be a representative cross-section of the US population as previously described.[13] Data are informed by 130 variables including ZIP + 4, Internal Revenue Service data, home value at the address level, aggregated credit, and short-term loans. Annual household income is categorized as < $40,000, $40–$49,999, $50–$59,999, $60–$74,999, $75–$99,999, and ≥ $100,000.

We identified RHC (CPT code 93451, ICD-9 code 37.21, ICD-10 code 4A023N6) performed after the index diagnosis of PH. Procedure codes were limited to those that describe RHC without left heart catheterization. Specialist visits were defined by outpatient encounters with pulmonologists or cardiologists identified using Optum-specified provider codes.

Age, sex, and insurance type were available at the individual level based on insurance enrollment. Race and ethnicity were imputed based on a validated algorithm using the individual name and nine-digit ZIP codes. Racial categories included Asian, Black, Hispanic, and White. Education level was determined from US Census data at the nine-digit-ZIP + four-code level, classified as <12th grade, high school diploma, some college, or ≥bachelor's degree. Comorbidities were identified by ICD-9 and ICD-10 codes (Supporting Information: Table 1) from inpatient and outpatient claims before the index diagnosis of PH. These included Elixhauser comorbidities,[14] hyperlipidemia, interstitial lung disease, and tobacco use.

Data set enrollment was the date of the first diagnostic code for PH. We calculated incidence of RHC from index diagnosis to the end of continuous enrollment. Individuals were censored at RHC or end of continuous enrollment, whichever came first.

Multivariable-adjusted Cox proportional hazards models were used to calculate hazard ratios (HR) for RHC by annual household income relative to ≥ $100,000. We employed stepwise multivariable adjustment to determine associations between annual household income and RHC using three models adjusting for age, sex, and race and ethnicity (Model 1); Model 1 plus comorbidities (Model 2); and Model 2 plus educational attainment and insurance type (Model 3). Relevant Elixhauser comorbidities were determined by stepwise model selection with a p value of 0.2 for entry and removal.

Statistical analyses were performed using SAS software version 9.4 (SAS Institute). The threshold for statistical significance was $p < 0.05$.

RESULTS

The final cohort included 307,513 individuals (mean age 74.5 ± 11.5 years, 57.3% women). Race was predominantly White (71.9%), followed by Black (13.5%),

TABLE 1 Hazard ratio and 95% confidence intervals for right heart catheterization with three models adjusting for covariates

	<$40,000 ($n = 111,438$)	$40,000–$49,999 ($n = 29,223$)	$50,000–$59,999 ($n = 30,230$)	$60,000–$74,999 ($n = 36,955$)	$75,000-$99,999 ($n = 44,840$)	≥ $100,000 ($n = 54,827$)
Right heart catheterization						
Model 1	0.86 (0.81–0.92), $p < 0.0001$	0.92 (0.84–1.0), $p = 0.04$	0.88 (0.81–0.96), $p = 0.003$	0.97 (0.90–1.05), $p = 0.49$	1.05 (0.98–1.12), $p = 0.20$	Ref
Model 2	0.76 (0.71–0.81), $p < 0.0001$	0.84 (0.77–0.91), $p < 0.0001$	0.82 (0.75–0.89), $p < 0.0001$	0.91 (0.85–0.99), $p = 0.02$	1.00 (0.93–1.07), $p = 0.98$	Ref
Model 3	0.81 (0.76–0.87), $p < 0.0001$	0.89 (0.81–0.97), $p = 0.007$	0.86 (0.79–0.94), $p = 0.001$	0.95 (0.88–1.03), $p = 0.24$	1.03 (0.96–1.11), $p = 0.38$	Ref
Pulmonologist follow-up						
Model 1	0.98 (0.96–0.99), $p = 0.01$	0.99 (0.96–1.01), $p = 0.36$	0.98 (0.96–1.01), $p = 0.20$	1.01 (0.99–1.04), $p = 0.38$	1.05 (1.03–1.08), $p < 0.0001$	Ref
Model 2	0.85 (0.84–0.87), $p < 0.0001$	0.90 (0.87–0.92), $p < 0.0001$	0.91 (0.88–0.93), $p < 0.0001$	0.95 (0.92–0.97), $p < 0.0001$	1.01 (0.99–1.03), $p = 0.46$	Ref
Model 3	0.86 (0.85–0.88), $p < 0.0001$	0.91 (0.88–0.93), $p < 0.0001$	0.91 (0.89–0.94), $p < 0.0001$	0.95 (0.93–0.98), $p = 0.0001$	1.01 (0.99–1.04), $p = 0.32$	Ref
Cardiologist follow-up						
Model 1	0.98 (0.97–0.99), $p = 0.001$	0.98 (0.963–1.00), $p = 0.01$	0.98 (0.96–1.00), $p = 0.01$	1.03 (1.02–1.05), $p < 0.0001$	1.03 (1.02–1.05), $p < 0.0001$	Ref
Model 2	0.96 (0.95–0.97), $p < 0.0001$	0.97 (0.95–0.98), $p < 0.0001$	0.97 (0.96–0.99), $p = 0.0007$	1.02 (1.00–1.04), $p = 0.01$	1.02 (1.01–1.04), $p = 0.001$	Ref
Model 3	0.96 (0.95–0.97), $p < 0.0001$	0.96 (0.95–0.98), $p < 0.0001$	0.97 (0.95–0.99), $p = 0.0006$	1.02 (1.00–1.03), $p = 0.03$	1.02 (1.01–1.04), $p = 0.004$	Ref

Hispanic (10.1%), and Asian (2.4%). Most individuals had <bachelor degree (55.5%), followed by high school diploma (30.9%), ≥bachelor degree (13%), and <12th grade (0.5%). A majority were Medicare beneficiaries (85.4%). The lowest income bracket contained a greater proportion of women (Supporting Information: Table 2). Median follow-up was 21 months (interquartile range 10–36 months), and the incidence of RHC was 2.9%. Supporting Information: Table 3 summarizes rates of RHC and specialist visits by income.

We observed a direct association between income and the likelihood of RHC (Table 1). After full multivariable adjustment (Model 3), incidence of RHC was 19% lower for individuals with annual household income < $40,000 relative to ≥ $100,000 (HR 0.81, 95% confidence interval [CI] 0.76–0.87, $p < 0.0001$). In this model, individuals with annual household income < $40,000 relative to ≥ $100,000 were 14% less likely to have outpatient pulmonology follow-up (HR 0.86, 95% CI 0.85–0.88, $p < 0.0001$) and 4% less likely to have outpatient cardiology follow-up (HR 0.96, 95% CI 0.95–0.97, $p < 0.0001$).

We performed a subgroup analysis evaluating the incidence of RHC by race and ethnicity and found that Hispanic and White individuals with annual household income < $40,000 relative to ≥ $100,000 were significantly less likely to undergo RHC (Supporting Information: Table 4).

DISCUSSION

Using a large, nationally representative claims database, we observed direct associations between annual household income and the likelihood of RHC among individuals with PH. After multivariable adjustment, individuals with annual household income < $40,000 were significantly less likely to receive RHC and specialist follow-up compared to those with annual household income ≥ $100,000.

Our findings are consistent with a robust body of literature demonstrating associations between socioeconomic status, access to care, and cardiovascular outcomes.[13,15–19] One study demonstrated that, among individuals with PH, lower income was associated with increased disease severity at diagnosis; however, these individuals had all undergone RHC.[11] The study did not include those who may have needed but did not receive, RHC. The authors hypothesized that access to primary and subspecialty care underlay differences in disease severity by income level, consistent with our finding that individuals in the lowest versus highest income group were less likely to receive specialist follow-up.

There are several potential explanations for the association between annual household income and RHC. Lower-income has been linked with reduced access to preventive and specialty care.[20–22] Additionally, low income might force individuals to prioritize other necessities over healthcare, particularly when facing structural barriers like limited transportation or inability to take time off work. Finally, low socioeconomic status has been associated with negative perceptions and provider biases,[23] which could contribute to providers' decisions about whether to pursue RHC.

We describe access to diagnostic testing at a time when new treatments have demonstrated benefit for multiple clinical endpoints in PH.[10,24] For example, a recent trial demonstrated that among individuals with Group 3 PH confirmed by RHC, treatment with inhaled treprostinil was related to improved exercise capacity and reduced likelihood of clinical worsening.[25] In addition, experts recently recommended expanding indications for RHC to improve the early detection of PAH.[4] Thus, while the incidence of RHC was low, we anticipate RHC will be used more frequently in the coming years.

Additional strengths include the use of a nationally representative database with a geographically and racially diverse composition. Our data are an important addition to literature from single-center studies, which may be affected by geographical differences and referral center selection bias.

Our study has several limitations. First, the claims database does not include those who are uninsured or covered by Medicaid. Thus, our study likely underestimates associations between annual household income and receipt of specialist care and RHC. Second, there are inherent limitations to using diagnostic coding for cohort selection, which can lead to misclassification.[26] Additionally, the claims database does not supply the clinical data needed to determine how someone was diagnosed with PH. Finally, we recognize that, in practice, many clinicians do not pursue invasive testing if it is not expected to change management. However, our study was not designed to describe the process by which clinicians decide to order RHC.

In conclusion, for individuals with PH, those with the lowest annual household income were significantly less likely to receive RHC and specialist follow-up compared to those with the highest annual household income. Our findings suggest that, among individuals with low annual household incomes, there are missed opportunities for diagnosis and treatment.

AUTHOR CONTRIBUTIONS

Erin M. Schikowski, Jared W. Magnani, and Stephen Y. Chan conceived of the study. Erin M. Schikowski, Gretchen Swabe, Jared W. Magnani, and Stephen Y. Chan contributed to conducting and reporting the study.

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CONFLICTS OF INTEREST

S. Y. C. has served as a consultant for United Therapeutics and Acceleron Pharma; S. Y. C. is a director, officer, and shareholder in Synhale Therapeutics; S. Y. C. has held research grants from Actelion, Bayer, and Pfizer. S. Y. C. has filed patent applications regarding the targeting of metabolism in pulmonary hypertension. The remaining authors declare no conflict of interest.

ETHICS STATEMENT

Not applicable.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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