



Article

Primary Pulmonary Hypertension Mortality Trends and Demographic Disparities in the United States, 2018–2024

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Highlights

What are the main findings?

- Primary pulmonary hypertension mortality in the United States declined by 42.2% from 2018 to 2024 (344 to 199 annual deaths), with the age-adjusted mortality rate decreasing from 0.10 to 0.06 per 100,000 (estimated compound annual rate of change, −9.3%), representing the steepest decline reported in any U.S. PAH surveillance study.
- Women accounted for 69.5% of all PPH deaths, with a female-to-male age-adjusted mortality rate ratio of 2:1. Black individuals experienced a disproportionate per capita mortality burden (Black-to-White AAMR ratio, 1.67:1; AAMR 0.10 vs. 0.06 per 100,000). The U.S. South bore the highest geographic burden (43.1% of deaths; crude rate 0.09 per 100,000), while the Northeast had the lowest (12.3%; crude rate 0.06 per 100,000).

What are the implications of the main findings?

- The observed decline occurred during a period of substantial changes in PAH diagnosis and management. Although these developments provide important clinical context, the present study was not designed to determine their contribution to the observed mortality trend.
- The study also indicated the disproportionate response in the Black population and Southern US states, necessitating discussion about possible unequal access to therapy due to economic or geographic challenges.

Abstract

Background/Objectives: Prior U.S. surveillance studies described changes in pulmonary hypertension mortality through 2020, but contemporary national data focused specifically on deaths coded as primary pulmonary hypertension (PPH; ICD-10 I27.0) are limited. We examined temporal, sex, racial, and geographic patterns in I27.0-coded mortality in the United States from 2018 to 2024. **Methods:** CDC WONDER Underlying Cause of Death data were analyzed. Annual deaths and mortality rates were examined by year, sex, Single Race 6 category, and U.S. Census region. **Results:** A total of 1831 deaths were coded as I27.0. Annual deaths declined from 344 in 2018 to 199 in 2024, while the exact crude rate declined from 0.105 to 0.059 per 100,000. Women accounted for 69.5% of deaths. Black individuals had a higher age-adjusted mortality rate than White individuals (0.10 vs. 0.06 per 100,000). The South accounted for the largest share of deaths (43.1%), although the West had a marginally higher exact crude rate. **Conclusions:** Deaths assigned to I27.0 declined



Academic Editor: Tomoaki Ishigami

Received: 31 May 2026

Revised: 14 July 2026

Accepted: 17 July 2026

Published: 20 July 2026

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substantially during 2018–2024. This trend occurred during a period of major evolution in PAH care, but the ecological design cannot determine whether therapeutic advances caused the decline. Changes in coding, classification, and assignment of underlying cause may also have contributed. Persistent demographic disparities warrant further investigation.

Keywords: primary pulmonary hypertension; ICD-10 I27.0; mortality trends; health disparities; CDC WONDER; epidemiology

1. Introduction

Pulmonary hypertension (PH) comprises a heterogeneous group of disorders. Contemporary Group 1 pulmonary arterial hypertension (PAH) includes idiopathic, heritable, drug- and toxin-induced, and several associated forms. The present study evaluates deaths for which the underlying cause was coded as ICD-10 I27.0, “primary pulmonary hypertension.” Because I27.0 is a historical administrative and death-certificate category, we use “deaths coded as PPH (I27.0)” when referring to the study population and reserve “PAH” for the broader contemporary clinical entity [1–4].

During the study period, the hemodynamic definition of pre-capillary PH evolved. Earlier practice and the evidence base for most PAH therapies used a mean pulmonary artery pressure (mPAP) ≥ 25 mmHg and pulmonary vascular resistance (PVR) ≥ 3 Wood units, whereas the 2022 ESC/ERS guideline defined pre-capillary PH using mPAP > 20 mmHg, pulmonary arterial wedge pressure ≤ 15 mmHg, and PVR > 2 Wood units. These clinical criteria are not available in CDC WONDER and could not be applied to death-certificate case ascertainment [1–4].

The therapeutic landscape of pulmonary arterial hypertension also evolved substantially during the study period. Earlier management often relied on sequential escalation of therapy, whereas contemporary guidelines increasingly recommend initial combination therapy and structured, risk-based treatment strategies guided by multiparametric risk assessment. The evidence base supporting upfront ambrisentan–tadalafil combination therapy in appropriate patients and subsequent guideline updates incorporated these principles into routine clinical practice. More recently, additional therapeutic options became available, including the approval of sotatercept, the first novel-mechanism therapy for PAH in more than a decade, and the fixed-dose macitentan/tadalafil combination tablet. These developments represent important changes in the management of PAH during the study period and provide relevant clinical context for interpreting contemporary mortality trends.

French national registry and the U.S. REVEAL registry were assembled in different diagnostic and therapeutic eras and included different mixtures of idiopathic and associated PAH. More recent multinational data likewise show substantial geographic variation in phenotype and outcomes. Direct comparison of registry survival with death-certificate mortality therefore requires attention to case mix, hemodynamic entry criteria, race and ethnicity, and treatment availability [5–7].

The objective of this study was to characterize temporal and demographic patterns in U.S. deaths coded as I27.0 from 2018 through 2024. We sought to describe the national trajectory, quantify sex and racial disparities, and examine geographic distribution. Because CDC WONDER contains no patient-level treatment, hemodynamic, disease-severity, or access data, the study was designed to identify population-level patterns rather than determine the causes of those patterns.

2. Materials and Methods

2.1. Study Design and Data Source

This was a retrospective, population-based, cross-sectional study of deaths coded as primary pulmonary hypertension in the United States from 2018 through 2024 using the CDC WONDER Underlying Cause of Death database, Single Race series. The database compiles U.S. death-certificate data from the 50 states and the District of Columbia. The study population is defined by ICD-10 I27.0 and should not be interpreted as complete ascertainment of all contemporary Group 1 PAH phenotypes.

2.2. Case Identification

Deaths attributable to primary pulmonary hypertension were identified using the International Classification of Diseases, Tenth Revision (ICD-10) code I27.0 (Primary pulmonary hypertension) listed as the underlying cause of death. This code corresponds to WHO Group 1 (PAH) and was selected to maximize specificity for PAH-attributable mortality, consistent with prior CDC WONDER-based analyses of pulmonary hypertension.

2.3. Outcome Measures

The primary outcome was the age-adjusted mortality rate (AAMR) per 100,000 population, standardized to the 2000 U.S. standard population using the direct method. Secondary outcomes included absolute annual death counts, crude mortality rates per 100,000 population, and mortality rate ratios with 95% confidence intervals for demographic comparisons.

2.4. Demographic Variables

Deaths were stratified by the following variables as recorded on the death certificate:

- Sex: Female and male.
- Race: Deaths were classified using the Single Race 6 categories as recorded on the death certificate: White, Black or African American, Asian, Native Hawaiian or Other Pacific Islander, American Indian or Alaska Native, and More than one race. Race of the decedent was reported by the funeral director as provided by an informant, most often the surviving next of kin, or, in the absence of an informant, based on observation. Cells with fewer than 10 deaths were suppressed per CDC confidentiality standards; consequently, reliable rate estimates were limited to White and Black or African American decedents, with Asian subgroup rates flagged as unreliable per NCHS convention.
- Census Regions: Northeast (Region 1), Midwest (Region 2), South (Region 3), and West (Region 4), as defined by the U.S. Census Bureau.

2.5. Statistical Analysis

Analysis 1—Sex Disparities: Deaths grouped by sex, with aggregate AAMR comparison and female-to-male mortality rate ratio.

Analysis 2—Racial Disparities: Deaths grouped by Single Race 6 categories, with AAMR comparison across groups.

Analysis 3—Temporal Trend: Deaths were grouped by calendar year (2018–2024). The available study period contained seven annual observations. We therefore did not use formal Joinpoint regression to claim a statistically defined inflection point; instead, annual counts and mortality rates were used to characterize the temporal pattern. The previously reported compound annual growth rate estimate was removed.

Analysis 4—Geographic Disparities: Deaths grouped by U.S. Census Region.

Mortality rate ratios were interpreted only when supported by the available CDC WONDER age-adjusted rates. Exact crude rates were calculated as deaths divided by

population and multiplied by 100,000. Confidence intervals generated by CDC WONDER were retained where available; suppressed or unreliable estimates were not treated as precise effect estimates.

CDC WONDER suppresses cells with fewer than 10 deaths and flags selected estimates based on small counts as unreliable. These categories were retained descriptively when permitted by the source output but were not overinterpreted. Hispanic ethnicity was not included in the current query and is acknowledged as a limitation.

3. Results

From 2018 to 2024, a total of 1831 deaths were attributed to primary pulmonary hypertension (ICD-10 I27.0) as the underlying cause of death in the United States. This estimate represents deaths coded specifically as I27.0.

Women accounted for 69.5% of all I27.0-coded deaths (1272 deaths) and men for 30.5% (559 deaths). The aggregate AAMR was 0.08 per 100,000 for women and 0.04 per 100,000 for men, corresponding to an approximately 2:1 female-to-male rate ratio (Table 1).

Table 1. Mortality by Sex (2018–2024).

Sex	Deaths	Population	Crude Rate (per 100,000)	Age-Adjusted Rate	% of Total
Female	1272	1,176,300,483	0.11	0.08	69.5%
Male	559	1,148,797,782	0.05	0.04	30.5%
Total	1831	2,325,098,265	0.08	0.06	100%

Analysis 2—Racial Disparities

Among racial groups (Table 2), White individuals accounted for 1527 deaths (83.4%), followed by Black or African American individuals (235 deaths; 12.8%), Asian individuals (47 deaths; 2.6%), and individuals reporting more than one race (11 deaths; 0.6%); other categories were suppressed. The CDC WONDER AAMR was 0.10 per 100,000 among Black individuals and 0.06 among White individuals. The Asian age-adjusted estimate was flagged as unreliable in the source output and was not interpreted as a precise rate.

Table 2. Mortality by Race (2018–2024).

Race	Deaths	Crude Rate	Age-Adjusted Rate	% of Total
White	1527	0.09	0.06	83.4%
Black or African American	235	0.07	0.10	12.8%
Asian	47	0.03	Unreliable	2.6%
Native Hawaiian or Other Pacific Islander	Suppressed	—	—	—
American Indian or Alaska Native	Suppressed	—	—	—
More than one race	11	0.02	Unreliable	0.6%
Total	1831	0.08	0.06	100%

Analysis 3—Temporal Trend

Annual I27.0-coded deaths declined from 344 in 2018 to 199 in 2024 (Table 3), a 42.2% reduction in absolute counts. Exact crude rates calculated from the supplied annual denominators declined from 0.105 per 100,000 in 2018 to 0.059 per 100,000 in 2024. The decline was sustained across most of the study period, with little additional change between 2023 and 2024. Because only seven annual observations were available, we did not claim a statistically defined inflection point.

Table 3. Mortality by Year, 2018–2024.

Year	Deaths	Population	Exact Crude Rate	AAMR
2018	344	327,167,434	0.105	0.10
2019	314	328,239,523	0.096	0.10
2020	276	329,484,123	0.084	0.08
2021	254	331,893,745	0.077	0.07
2022	244	333,287,557	0.073	0.07
2023	200	334,914,895	0.060	0.06
2024	199	340,110,988	0.059	0.06

Analysis 4: Geographic Disparities

The South accounted for the largest number and share of deaths (790; 43.1%), followed by the West (497; 27.1%), the Midwest (319; 17.4%), and the Northeast (225; 12.3%). Exact crude rates calculated from the supplied denominators were 0.088 per 100,000 in the South, 0.090 in the West, 0.066 in the Midwest, and 0.057 in the Northeast. Thus, the South had the largest absolute burden, whereas the West had a marginally higher exact crude rate (Table 4). These crude regional comparisons should not be interpreted as age-adjusted geographic risk.

Table 4. Regional Disparities.

Census Region	Female Deaths	Male Deaths	Total Deaths	Exact Crude Rate (per 100,000)	% of Total
Northeast	158	67	225	0.057	12.3%
Midwest	230	89	319	0.066	17.4%
South	513	277	790	0.088	43.1%
West	371	126	497	0.090	27.1%
Total	1272	559	1831	0.079	100%

4. Discussion

This national analysis identified a substantial decline in deaths between 2018 and 2024, accompanied by persistent differences by sex and race and marked variation in absolute geographic burden.

The magnitude of the observed decline is directionally consistent with the longer evolution of PAH outcomes reported in U.S. and international cohorts. Earlier U.S. surveillance studies by Kang et al. and Singh et al. described changing pulmonary hypertension mortality over longer periods, although their coding strategies, populations, and time windows were not identical to ours and therefore do not permit direct numerical comparison [8,9]. Registry data provide complementary rather than equivalent evidence. The French national registry characterized PAH in an earlier treatment era, while REVEAL established the contemporary U.S. phenotype and prognostic framework in a large, clinically adjudicated cohort [5,6]. COMPERA subsequently demonstrated how patient characteristics, risk assessment, and treatment patterns evolved across Europe [10].

The study period followed the transition from predominantly sequential monotherapy toward earlier multidrug treatment and risk-based escalation. The AMBITION trial established the benefit of initial ambrisentan–tadalafil combination therapy, and contemporary guidelines increasingly emphasized multiparametric risk assessment and treatment intensification [2,11]. These changes could plausibly contribute to better outcomes at the population level through earlier recognition of inadequate response and broader use of

combination therapy. However, our data contain no treatment exposure, prescribing, adherence, or disease-severity information, so this remains a contextual hypothesis rather than a causal finding. The timing is particularly important for newer therapies: sotatercept and fixed-dose macitentan/tadalafil were approved in March 2024, after most of the decline observed in this study had already occurred [12–15]. They therefore cannot explain the preceding trend, and the present analysis should not be used as evidence of their population-level mortality effect.

The evolving hemodynamic definition of PH provides a second potential influence on the observed pattern. The threshold for PH changed from $\text{mPAP} \geq 25 \text{ mmHg}$ to $>20 \text{ mmHg}$, and the 2022 ESC/ERS guideline lowered the PVR threshold for pre-capillary PH to >2 Wood units [1–4]. In principle, broader diagnostic criteria could increase recognition of earlier or milder disease and alter the clinical population labeled as PAH. Whether this affected death-certificate coding is uncertain. CDC WONDER does not contain right-heart catheterization data, and a clinical change in diagnostic criteria does not necessarily translate directly into a change in the ICD-10 code selected as the underlying cause of death. Thus, the new definition is relevant in context, but it cannot by itself explain the decline in I27.0-coded mortality.

Sex differences remained prominent. Women accounted for 69.5% of deaths and had an approximately twofold higher AAMR than men. Female predominance is a well-established feature of PAH epidemiology and has been described in REVEAL and other major registries [6,16–19]. At the same time, registry studies have described a male survival disadvantage after disease develops, creating the familiar epidemiologic paradox of greater disease prevalence among women but poorer prognosis among men in some cohorts [20]. Our death-certificate analysis cannot disentangle incidence, prevalence, disease duration, or case fatality. The female predominance in deaths should therefore be interpreted primarily as reflecting the sex distribution of the coded disease burden rather than as evidence that women have worse survival.

The racial findings are clinically important. Black individuals represented a smaller absolute number of deaths than White individuals but had a higher age-adjusted mortality rate in the CDC WONDER output. This pattern is consistent with prior U.S. literature describing racial differences in PAH outcomes and treatment patterns [17,21–23]. The present study cannot identify the mechanism. Potential contributors include differences in associated disease burden, diagnostic delay, referral to specialty care, insurance structure, treatment exposure, and social determinants of health, but none were measured here. Race categories in death-certificate data are social and administrative classifications rather than biological explanations. The appropriate interpretation is therefore that the disparity is a reproducible epidemiologic signal that requires mechanistic study, not that the current dataset proves a particular access-to-care pathway.

The geographic results require similar care. The South contributed the largest absolute number of deaths, but the West had a marginally higher exact crude rate. Absolute death share is strongly influenced by population size, whereas crude regional rates remain sensitive to age structure. Differences in specialty-center distribution, referral networks, insurance coverage, rurality, and treatment access are plausible hypotheses, and prior work has demonstrated geographic variation in where PAH care is delivered [23,24]. However, annual state-level center counts, reimbursement policies, and patient-level access were not available in CDC WONDER. The regional analysis should therefore be viewed as hypothesis-generating rather than explanatory.

Several limitations should be acknowledged. The analysis is based on death certificates and is vulnerable to diagnostic and coding misclassification. The I27.0 case definition limits generalizability to the full contemporary Group 1 PAH population. Multiple-cause and broader-code sensitivity analyses were not available in the current extract and would help determine whether the decline is specific to I27.0 or part of a broader pulmonary hypertension pattern. No patient-level clinical, hemodynamic, treatment, insurance, or specialty-center data were available. Hispanic ethnicity and age-stratified analyses were not included in the current query, and small counts limited interpretation of several racial categories. Regional results were crude rather than fully age adjusted. Finally, the seven-year observation period is short and limits reliable assessment of inflection points. Despite these limitations, the study provides a focused contemporary national description of I27.0-coded mortality through 2024 and identifies demographic patterns that remain relevant for future clinical and population-based investigation.

5. Conclusions

Deaths coded as primary pulmonary hypertension (ICD-10 I27.0) declined substantially in the United States from 2018 to 2024. The finding is compatible with a period of major improvement in PAH recognition, risk assessment, and treatment, but the present ecological data cannot determine whether those advances caused the decline. Persistent sex and racial differences and geographic variation in burden warrant further study using multiple-cause mortality, broader coding strategies, age and ethnicity analyses, and patient-level measures of treatment and access.

Author Contributions: Conceptualization, N.R., P.G. and R.J.; methodology, B.S.; software, B.S.; formal analysis, B.S.; investigation, G.K.; resources, G.K.; data curation, P.G.; writing—original draft preparation, R.J.; writing—review and editing, B.S.; supervision, P.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Ethical review and approval were not required because the study used publicly available, de-identified, aggregate data.

Informed Consent Statement: Not applicable.

Data Availability Statement: The mortality data analyzed in this study are publicly available through the Centers for Disease Control and Prevention's Wide-Ranging Online Data for Epidemiologic Research (CDC WONDER) Underlying Cause of Death database.

Acknowledgments: Generative AI, ChatGPT Plus-5.5, was used to generate the graphical abstract. The authors have reviewed and edited the output and take full responsibility for the content of this publication.

Conflicts of Interest: The authors declare no conflicts of interest.

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