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Demographic and Regional Disparities due to Peritonitis-Related Mortality in the US: A 21 Year Retrospective Analysis of the CDC WONDER Database

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1. Abstract

Background: Peritonitis is a critical surgical emergency with high mortality. Despite medical advances, disparities persist in outcomes across demographic and regional groups in the United States.

Methods: We conducted a retrospective analysis of the CDC WONDER Multiple Cause of Death database (1999 – 2020), identifying adults aged ≥ 25 years with peritonitis-related mortality using ICD-10 codes K65.0, K65.8, and K65.9. Crude mortality rates (CMRs) and age-adjusted mortality rates (AAMRs) per 100,000 population were calculated. Temporal trends were evaluated using Join point regression.

Results: Between 1999 and 2020, peritonitis accounted for 153,540 deaths. AAMR declined from 3.88 in 1999 to 3.31 in 2020 (AAPC – 0.96%, p<0.001), with a nadir in 2009, followed by a modest rise. Higher mortality was observed among men, American Indian/Alaska Native populations, rural residents, and older adults.

Conclusion: Peritonitis-related mortality has declined overall but persistent disparities demand targeted strategies to improve timely surgical access and reduce preventable deaths.

2. Keywords: Peritonitis, Cirrhosis, Emergency, CDC WONDER

3. Introduction

A severe inflammatory condition of the peritoneum, the thin membrane lining the abdominal cavity, is called peritonitis. It can result in several potentially fatal consequences, including sepsis, if treatment is not received [1]. Beyond its septic consequences, it can worsen peritoneal function by progressing to fibrosis and angiogenesis [2]. With a wide range of causes, including primary spontaneous bacterial peritonitis in patients with ascites [4], secondary peritonitis caused by duodenal perforation (26.2%), typhoid ileal perforation (24.2%), or ruptured appendix (16.8%) [4], peritonitis remains a major surgical emergency with severe consequences. Despite medical advances, reported mortality varies from 6% to 35% depending on severity and septic complications [5]. Antibiotherapy is a fundamental part of treatment [6]. The global pooled prevalence of spontaneous bacterial peritonitis (SBP) is estimated at 17.12%, with North America reporting the lowest rate at 10.81% [7]. The incidence and general prevalence of peritonitis in the United States vary by etiology. According to the United States Renal Data System (USRDS), hospitalization rates for peritonitis linked to peritoneal dialysis have dropped by more than 50% since 2009. However, there are concerns that national surveillance may understate the actual burden because other U.S. studies reveal higher rates of hospitalization for peritonitis than those recorded by USRDS [8]. The economic burden of hospitalizations for peritonitis is also considerable, with median treatment costs reported to be $13,655 USD (IQR $7,871-$28,434), particularly for Hispanic patients, children aged 3-12, cases requiring intensive care unit admission, and cases with fungal peritonitis [9].

Prior studies indicate that mortality in peritonitis varies widely by demographic and clinical factors. Reported mortality rates are 13.16% among patients younger than 50 years compared with 33.33% among those older than 50 years, with higher female mortality (55.56%) than male mortality (9.76%). The severity of the illness and the timing of hospital admission are also critical determinants of outcome. While localised peritonitis was not associated with mortality, but diffuse peritonitis was, and patients who arrived after 72 hours of the onset of symptoms had the highest mortality rate (66%) compared to those who arrived within 48 hours [10]. The results highlight variations in outcomes based on age, sex, and timeliness of care. However, despite these existing insights, a major gap persists; no study has comprehensively examined long-term trends in demographic and regional discrepancies in mortality from peritonitis in United States.

To fill this gap, a retrospective analysis using the CDC WONDER (Centres for Disease Control and Prevention Wide-Ranging Online Data for Epidemiological Research) database, examining peritonitis-related mortality outcomes in United States from 1999 to 2020 was conducted. Our analysis evaluated the impact of sex, race, age group, urbanization, state, and region on mortality outcomes. By looking at the national trends over many years, this study helps identify populations at high risks, emphasizes timely actions, and guide focused health policy and resource allocation. In the end, these findings may foster fair results for a disease that is largely preventable through early diagnosis and management.

4. Methods

4.1. Study Design and Setting

To assess regional and demographic variations in peritonitis-related mortality in the US between 1999 and 2020, we conducted a retrospective analysis. Information was obtained from the CDC Wide-Ranging Online Data for Epidemiologic Research (CDC WONDER), which compiles death certificate information supplied by the National Centre for Health Statistics (NCHS) [11]. The database provides information from all 50 states and the District of Columbia and includes both primary and contributing causes of death, along with demographic and geographic variables.

Deaths due to peritonitis in individuals aged 25 and older were determined using the Multiple Cause of Death Public Use Record alongside International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10) codes: K65.0 (acute peritonitis), K65.8 (other peritonitis), and K65.9 (peritonitis, unspecified). Our research is in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [12]. Institutional Review Board approval was not required as the analysis relied exclusively on publicly available, anonymous patient data.

4.2. Data extraction

Our research focused on individuals aged 25 years and older, grouped by standard age categories up to 85 years and above. Mortality rates were expressed per 100,000 population. In addition to the overall peritonitis-related AAMR, data were extracted for the following variables: age groups, sex (male and female), race/ethnicity (non-Hispanic White, non-Hispanic Black or African American, or Hispanic or Latino), and urbanization (metropolitan and nonmetropolitan) based on the National Center for Health Statistics Urban-Rural Classification Scheme (2013) [13] and geographic regions based on the U.S. Census Bureau definitions [14].

4.3. Statistical analysis

We analysed crude mortality rates (CMRs) and age-adjusted mortality rates (AAMRs) for peritonitis-related deaths per 100,000 population over the past 21 years. CMRs were derived by dividing the annual number of deaths by the corresponding U.S population. AAMRs, on the other hand, were standardised to the 2000 U.S. standard population with 95% confidence intervals (CIs) for comparisons across subgroups over time [15]. To assess the temporal trends, we used Joinpoint regression analysis (version 5.1.0, National Cancer Institute) to calculate annual percentage changes (APCs) with 95% Cis [16]. Statistically significant changes in mortality trends (expressed by a p-value < 0.05) were identified through log-linear regression models in which the slope represented the rate of change in mortality and any deviation from zero indicated an increase or decrease in mortality, as tested by 2-tailed t-tests. Sensitivity analyses were also performed to provide a more thorough understanding of peritonitis's effect on mortality by distinguishing cases where peritonitis was the underlying cause from a contributing cause of death, to get a better understanding of its role in mortality.

5. Results

From 1999 to 2020, Peritonitis accounted for 153,540 deaths among US individuals aged ≥25 years. Of these, most fatalities were recorded in medical facilities (82.56%) followed by the decedent's home (7.60%), nursing home/long term care (4.67%), and hospice facility (3.12%) respectively.

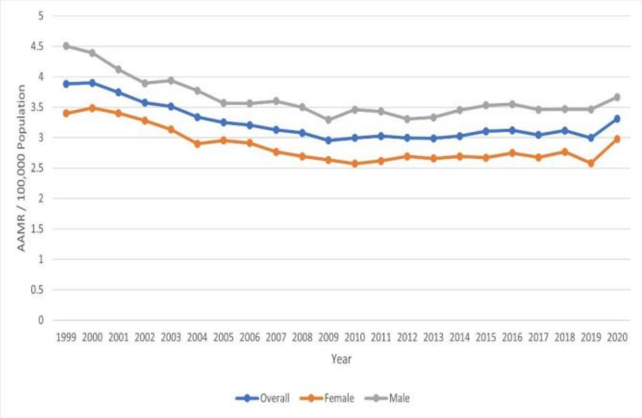
5.1. Annual trends

The overall Age adjusted mortality rate (AAMR) for Peritonitis showed a decline trend from 3.88 in 1999 to 3.31 in 2020 (AAPC -0.96; 95% CI: -1.47 to -0.41; p value <0.0008).

The AAMR showed a significant decline trend from 3.88 in 1999 to 2.95 in 2009 with an annual percentage change (APC) of -2.81 [95% Confidence interval (CI): -3.43 to -2.33); p value <0.000001], followed by a slight increase from 2.95 in 2009 to 3.31 in 2020 with an annual percentage change (APC) of 0.63 [95% Confidence interval (CI): 0.23 to

1.15); p value <0.002). **(Figure 1)**

Figure 1: AAMR-Related to Peritonitis in the US by Gender, 1999-2020.



5.2. Gender-wise analysis

From 1999 to 2020, Peritonitis accounted for 76,423 deaths among females and 77,117 among males aged ≥25 years. Throughout the study period, adult males exhibited slightly higher overall AAMR than adult females (overall AAMR males: 3.62; females 2.85).

The Age adjusted mortality rate (AAMR) for Peritonitis in females showed an overall decline trend from 3.40 in 1999 to 2.98 in 2020 (AAPC -1.07; 95% CI: -1.62 to -0.49; p value <0.0004). The AAMR showed a clinically significant decline trend from 3.40 in 1999 to 2.63 in 2009 with an annual percentage change (APC) of -3.01 [95% Confidence interval (CI): -3.90 to -2.35); p value <0.000001] followed by a slight increase from 2.63 in 2009 to 2.98 in 2020 with an annual percentage change (APC) of 0.63 [95% Confidence interval (CI): 0.06 to 1.42); p value <0.0296].

The overall Age adjusted mortality rate (AAMR) for Peritonitis in males showed an overall decline trend from 4.51 in 1999 to 3.67 in 2020 (AAPC -0.89; 95% CI: -1.39 to -0.34; p value <0.002]. The AAMR showed a significant decline trend from 4.51 in 1999 to 3.29 in 2009 with an annual percentage change (APC) of -2.74 [95% Confidence interval (CI): -4.89 to -1.83); p value <0.000001], followed by a slight incline from 3.29 in 2009 to 3.67 in 2020 with an annual percentage change (APC) of 0.65 [95% Confidence interval (CI): -0.09 to 2.15); p value <0.0752] **(Figure 1).**

5.3. Race-wise analysis

Stratification by race and ethnicity revealed prominent disparities in AAMRs with the highest AAMR recorded among individuals with NH American Indian or Alaska Native [5.39] followed by NH Black or African American ancestry [3.86], Hispanics [3.23], NH Whites [3.13], and NH Asian OR Pacific Islander [2.05].

Among Hispanic or Latino populations, the overall AAMR declined from 4.32 in 1999 to 3.39 in 2020 with an AAPC of -0.79 [95% CI: -1.38 to -0.04, p value <0.0432]. The AAMR showed a significant decline trend from 4.32 in 1999 to 3.06 in 2005 with an annual percentage change (APC) of -5.13 [95% Confidence interval (CI): -11.07 to -2.50); p value <0.000001], followed by a slight incline from 3.06 in 2005 to 3.39 in 2020 with an annual percentage change (APC) of 0.18 [95% Confidence interval (CI): -0.36 to 1.09); p value <0.43).

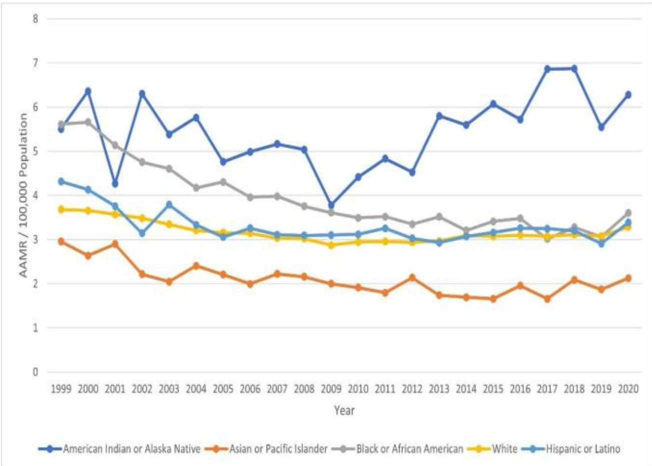
Among American Indian or Alaska Native populations, the overall AAMR inclined from 5.51 in 1999 to 6.28 in 2020 with an AAPC of 0.94 [95% CI: -0.08 to 2.31, p value <0.0744]. The AAMR showed a significant decline trend from 5.51 in 1999 to 3.78 in 2009 with an annual percentage change (APC) of -2.52 [95% Confidence interval (CI): -14.43 to 0.67); p value <0.11112], followed by a remarkable spike from 3.78 in 2009 to 6.28 in 2020 with an annual percentage change (APC) of 3.47 [95% Confidence interval (CI): 1.38 to 12.49); p value <0.0164].

Among Asian and Pacific Islander populations, the overall AAMR declined from 2.96 in 1999 to 2.13 in 2020 with an AAPC of -1.51 [95% CI: -2.36 to -0.40, p value <0.0088]. The AAMR showed a significant decline trend from 2.96 in 1999 to 1.66 in 2015 with an annual percentage change (APC) of -2.86 [95% Confidence interval (CI): -6.10 to -1.76); p value <0.0104], followed by a remarkable spike from 1.66 in 2015 to 2.13 in 2020 with an annual percentage change (APC) of 4.20 [95% Confidence interval (CI): -0.38 to 15.53); p value <0.0764].

Among Black or African American, the overall AAMR declined from 5.61 in 1999 to 3.61 in 2020 with an AAPC of -2.54 [95% CI: -3.22 to -1.83, p value <0.000001]. The AAMR showed a significant decline trend from 5.61 in 1999 to 5.57 in 2009 with an annual percentage change (APC) of -4.64 [95% Confidence interval (CI): -6.52 to -3.62); p value <0.000001], followed by a slight increase from 3.61 in 2009 to 3.61 in 2020 with an annual percentage change (APC) of -0.66 [95% Confidence interval (CI): -1.57 to 0.99); p value <0.314].

Among NH White populations, the overall AAMR declined from 3.68 in 1999 to 3.29 in 2020 with an AAPC of -0.67 [95% CI: -1.15 to -0.16, p value <0.0132]. The AAMR showed a significant decline trend from 3.68 in 1999 to 2.87 in 2009 with an annual percentage change (APC) of -2.46 [95% Confidence interval (CI): -2.94 to -2.08); p value <0.000001], followed by a slight increase from 2.87 in 2009 to 3.29 in 2020 with an annual percentage change (APC) of 0.90 [95% Confidence interval (CI): 0.58 to 1.31); p value <0.000001] **(Figure 2).**

Figure 2: AAMR-Related to Peritonitis in the US by Race, 1999-2020.



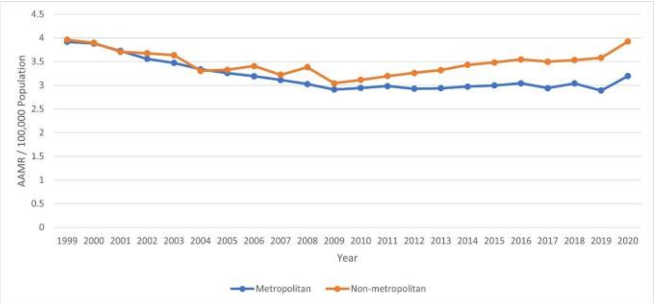
5.4. Urbanization-wise analysis

From 1999 to 2020, Peritonitis related to AAMR was slightly higher in non-metropolitan areas [3.46; 95% CI: 3.42 to 3.50] than metropolitan areas [3.18; 95% CI: 3.16 to 3.19].

Among non-metropolitan areas, the overall AAMR slightly declined from 3.96 in 1999 to 3.93 in 2020 with an AAPC of -0.16 [95% CI: -0.71 to 0.44, p value <0.60]. The AAMR showed a significant decline trend from 3.96 in 1999 to 3.04 in 2009 with an annual percentage change (APC) of -2.35 [95% Confidence interval (CI): -3.20 to -1.70); p value <0.000001], followed by a slight increase from 3.04 in 2009 to 3.93 in 2020 with an annual percentage change (APC) of 1.76 [95% Confidence interval (CI): 1.21 to 2.51); p value <0.000001] .

Among Metropolitan areas, the overall AAMR declined from 3.92 in 1999 to 3.20 in 2020 with an AAPC of -1.14 [95% CI: -1.60 to -0.64, p value <0.000001]. The AAMR showed a significant decline trend from 3.92 in 1999 to 2.91 in 2009 with an annual percentage change (APC) of -2.96 [95% Confidence interval (CI): -3.54 to -2.49) ; p value <0.000001] , followed by a slight increase from 2.91 in 2009 to 3.20 in 2020 with an annual percentage change (APC) of 0.42 [95% Confidence interval (CI): 0.04 to 0.92) ; p value <0.0352] **(Figure 3).**

Figure 3: AAMR-Related to Peritonitis in the US by Urbanization, 1999-2020.



5.5. Region-wise analysis

Stratification by region revealed prominent disparities in AAMRs with the highest AAMR recorded among individuals in West [3.62], followed by Mid-West [3.37], South [3.02], and Northeast [2.96]. All regions exhibited a decline in AAMR from 1999 to 2020.

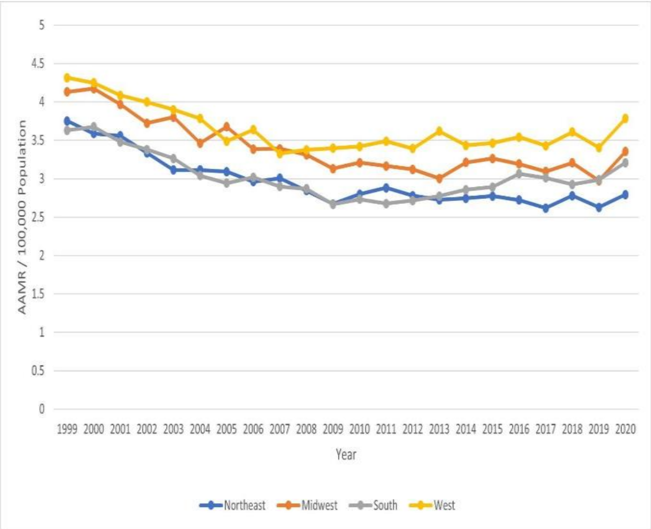
For individuals in the Northeast, a downward trend was observed with AAMR declining from 3.75 in 1999 to 2.79 in 2020 [AAPC -1.42; 95% CI: -1.81 to -1.03, p value <0.000001] indicating a decrease in mortality burden. The AAMR showed a significant decline trend from 3.75 in 1999 to 2.67 in 2009 with an annual percentage change (APC) of -2.82 [95% Confidence interval (CI): -3.96 to -2.18) ; p value <0.000001] , followed by a slight increase from 2.67 in 2009 to 2.79 in 2020 with an annual percentage change (APC) of -0.15 [95% Confidence interval (CI): -0.71 to 0.82) ; p value <0.7131].

For individuals in the Midwest, a downward trend was observed with AAMR declining from 4.13 in 1999 to 3.35 in 2020 [AAPC -1.28; 95% CI: -1.80 to -0.73, p value <0.000001] indicating a decrease in mortality burden. The AAMR showed a significant decline trend from 4.13 in 1999 to 3.13 in 2009 with an annual percentage change (APC) of -2.76 [95% Confidence interval (CI): -3.95 to -2.06) ; p value <0.000001] , followed by a slight increase from 3.13 in 2009 to 3.35 in 2020 with an annual percentage change (APC) of 0.05 [95% Confidence interval (CI): -0.55 to 1.06) ; p value <0.799].

For individuals in the South, a downward trend was observed with AAMR declining from 3.63 in 1999 to 3.21 in 2020 [AAPC -0.71; 95% CI: -1.49 to 0.15, p value <0.104] indicating a decrease in mortality burden. The AAMR showed a significant decline trend from 3.63 in 1999 to 2.73 in 2010 with an annual percentage change (APC) of -0.71 [95% Confidence interval (CI): -1.49 to 0.15) ; p value <0.104], followed by a slight increase from 2.73 in 2010 to 3.21 in 2020 with an annual percentage change (APC) of -2.90 [95% Confidence interval (CI): -3.45 to -2.42) ; p value <0.000001]

For individuals in the West, a downward trend was observed with AAMR declining from 4.31 in 1999 to 3.78 in 2020 [AAPC -0.71; 95% CI: -1.21 to -0.14, p value <0.0196] indicating a decrease in mortality burden. The AAMR showed a significant decline trend from 4.31 in 1999 to 3.33 in 2007 with an annual percentage change (APC) of -3.16 [95% Confidence interval (CI): -4.46 to -2.29) ; p value <0.000001] , followed by a slight increase from 3.33 in 2007 to 3.78 in 2020 with an annual percentage change (APC) of 0.46 [95% Confidence interval (CI): 0.06 to 1.00) ; p value <0.0304] **(Figure 4).**

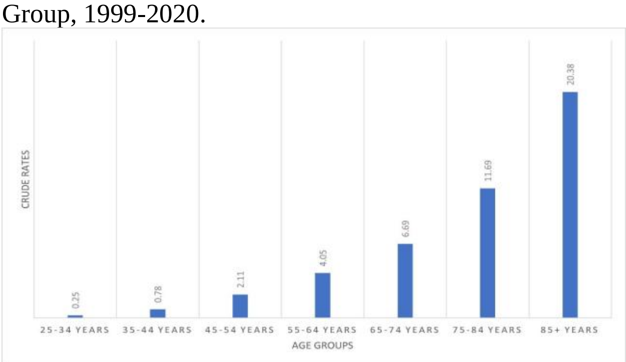
Figure 4: AAMR-Related to Peritonitis in the US by Region, 1999-2020.



5.6. Age group-wise analysis

Stratification by age groups revealed prominent disparities in crude mortality rates with the highest crude mortality rate recorded among individuals in age group >85 [20.38], followed by age group 75-84 [11.69], age group 65-74 [6.69], age group 55-64 [4.05], age group 45-54 [2.11], age group 35-44 [0.78], and age group 25-34 [0.25]. **(Figure 5).**

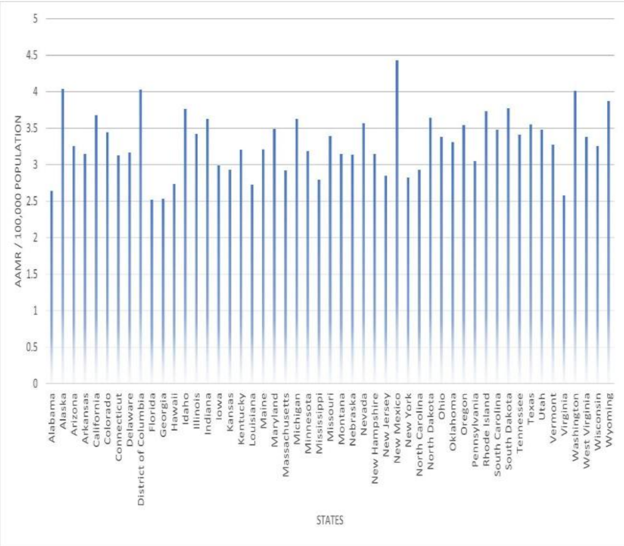
Figure 5: AAMR-Related to Peritonitis in the US by Age Group, 1999-2020.



5.7. State-wise analysis

Significant disparities in AAMR were recorded among different states with the highest AAMR observed in New Mexico (4.43) and the lowest AAMR observed in Florida (2.52). States in top 90th percentile Peritonitis related mortality included Alaska, District of Columbia and Washington. These states had AAMRs that were roughly twice as high as those in the lower 10th percentile which included Virginia, Hawaii, Georgia and Alabama. **(Figure 6).**

Figure 6: AAMR-Related to Peritonitis in the US by States, 1999-2020.



6. Discussion

Mortality from peritonitis in U.S. adults aged 25 years and older recorded a steady decline across the first decade, until 2009, followed by a small rise through 2020. Higher AAMRs were recorded among males, NH American Indians/Alaskan Natives (AI/AN), rural regions, and the West Region. Furthermore, crude mortality rates were the highest in the oldest age group of 85+, with mortality rates progressively declining with decreasing age.

The steep decline in peritonitis-related mortality observed between 1999 and 2009 likely reflects the development of evidence-based early identification and management of intra-abdominal infections (IAIs). The shift from open to laparoscopic surgery for complicated conditions like perforated appendicitis or peptic ulcer has been shown to have lower risks of mortality, thereby improving survivability in patients with surgical emergencies like peritonitis as well [17,18]. Furthermore, the increasing use of imaging modalities, such as CT scans, has allowed for the rapid assessment of patients with an acute abdomen and identification of primary etiological causes [19].

Standardized antibiotic coverage and development of empiric regimens may have also reduced the risk of peritonitis [20]. Following this, a slight incline in mortality was noted till 2020. The rising incidence of antimicrobial resistance may have contributed to the burden, resulting in increasing treatment failures [21]. Higher burden of comorbidities may have also contributed to the rise; peritonitis associated with malignancies, chronic kidney diseases, and diabetes mellitus has been shown to have a poorer prognosis [22,23]. The COVID-19 pandemic, albeit contributing to only the 2020 period of our study, may have caused a slight rise in mortality due to delayed accessibility of emergency operative services [24].

Further, our analysis noted that mortality was consistently higher among men than women. Studies indicate that women are predisposed to lower risks of sepsis or systemic inflammation, possibly due to differences in inflammatory responses [25]. In addition, contributing causes to peritonitis, including perforated peptic ulcers, are more commonly seen among males [26]. Social factors like higher alcohol and tobacco use may have also contributed to the higher mortality risk [27,28]. Additionally, certain studies have reported higher survival of women following abdominal surgeries, possibly due to better receipt of post-surgical care [29]. Gender disparities and their underlying causes remain inconclusive and warrant further investigation.

Across races, AI/AN individuals recorded the highest peritonitis-related mortality, followed by Black individuals and Hispanic populations, while Asian/Pacific Islanders consistently had the lowest rates. AI/AN populations often reside in regions with long transport times and limited surgical or critical-care availability [30,31]. Underfunding of Indian Health Service facilities, along with shortages in the workforce and availability of hospitals, may contribute to delayed administration of care [32,33]. High burdens of diabetes, cirrhosis, and chronic kidney disease in AI/AN communities may further amplify susceptibility to both spontaneous and secondary peritonitis [34,35]. For Black and Hispanic populations, mortality declined more rapidly in the early 2000s but plateaued after 2009, reflecting improved access to emergency health care services [36,37]. Despite this, Black individuals continue to have disparity in receipt of surgical treatment [38]. Persistent barriers linked to insurance coverage gaps and disparities in healthcare provision still exist in these populations, warranting further investigation [39,40].

Further, non-metropolitan regions noted higher mortality trends than urban regions. This finding is consistent with widespread rural hospital closures, resulting in diminished local access to emergency general surgeons and intensive care units [41,42]. Delays in transfer and prolonged transport times, particularly in trauma or perforation-related peritonitis, compromise timely access to care [43]. Moreover, rural hospitals often lack advanced imaging modalities and 24/7 operative coverage, further exacerbating diagnostic delays [44]. Urban regions, due to broader ICU capacity and effective adoption of sepsis protocols, may have had lower mortality rates [45].

Region-wise analysis revealed the highest mortality in the West, followed by the Midwest and the Southern regions. The West has larger concentrations of rural regions and limited critical care facilities [46]. On the other hand, the Midwest has a high burden of obesity, diabetes, and alcohol-related cirrhosis, all strong risk factors for peritonitis [47]. Medicaid expansion in most Northeastern states has improved access to emergency care, which may have contributed to the lower burden [48].

Lastly, mortality proportionately increased with age, with those above 85 experiencing the highest mortality rates due to peritonitis. Geriatric patients often present with atypical symptoms, leading to delayed diagnosis and progression to severe peritonitis before intervention [49]. High prevalence of cirrhosis, cancer, immunosuppressive therapy, and chronic renal failure in older adults predisposes them to spontaneous bacterial peritonitis and, further, septic shock [50].

Our analysis includes a detailed stratification of peritonitis-related mortality across 22-years. One of our limitations includes reliance on death-certificate coding, which is susceptible to misclassification between primary and secondary peritonitis or sepsis listed as the underlying cause. Further, a lack of etiology behind peritonitis limited further exploration of causative factors. Future studies must attempt to link mortality to factors such as accessibility to emergency medical services. Microbiological correlations will further help quantify peritonitis complicated with antimicrobial resistance.

7. Conclusion

Peritonitis-related mortality in U.S. adults declined until 2009 but has since risen modestly, reflecting the balance between advances in surgical care, diagnostics, and empiric therapy, and the growing impact of antimicrobial resistance and comorbidities. Disparities persist, with higher mortality among men, AI/AN populations, rural residents, the West region, and the oldest age groups. Addressing gaps in emergency surgical access, strengthening infection management, and focusing on high-risk groups will be critical to reducing preventable deaths and narrowing inequities in peritonitis outcomes.

8. Declarations

8.1. Funding

No funding/ grants were received for the completion of this manuscript.

8.2. Consent for publication

Not Applicable

8.3. Competing interests

The authors have no relevant financial or non-financial interests to disclose.

8.4. Ethics approval and consent to participate

Ethics approval is deemed unnecessary according to national regulations as our study did not involve any human/ animal test subject (http://nbcpakistan.org.pk/nbc-r.html). The need for consent to participate is deemed unnecessary according to national regulations as our study did not involve any human/ animal test subject (http://nbcpakistan.org.pk/nbc-r.html). We ensured adherence to the ethical principles outlined in the Declaration of Helsinki. This has been clearly stated under the Declarations section in the manuscript.

8.5. Availability of data and materials

Data is provided within the manuscript or supplementary information files. Any extra data required will be provided on further request to the author.

8.6. Author's contributions

Conception & Design: A.N
Data Extraction: A.N and M.A
Analysis: M.A,
Main Manuscript Writing: S.R, N.Q, M.F.I
Manuscript - editing and revision: A.N
Final review and supervision: A.R.S

8.9. Clinical trial number

not applicable.

8.10. Acknowledgments

Not applicable

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