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Economic Burden of Fungal Diseases in the United States

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Abstract

We conservatively estimated the annual US fungal disease-related economic burden as \$19.4 billion, including direct medical costs (\$13.4 billion) of hospitalizations (n=133,555) and outpatient visits (n=13.4 million), \$1.7 billion from absenteeism, and \$4.3 billion from deaths (n=7,288). These findings underscore the need for fungal disease surveillance, treatment, and prevention efforts.

Lay summary:

We estimate that fungal diseases cost about \$19.4 billion each year in the United States. This includes \$13.4 billion for medical care, like hospital stays and doctor visits. It also includes costs from people missing work, which adds up to \$1.7 billion, and \$4.3 billion from deaths.

Keywords

mycoses; costs and cost analysis; outpatients; hospitalization; death

INTRODUCTION

Fungal diseases range from relatively mild superficial infections to potentially life-threatening conditions including pneumonia, sepsis, and meningitis. Symptoms often resemble those of other diseases, frequently resulting in delays in diagnosis and treatment and incurring excess costs.

Previous studies to measure the US fungal disease burden have relied on administrative data to estimate hospitalizations, outpatient visits, and costs.^{1–3} Yearly direct costs of fungal diseases exceeded \$7 billion before the COVID-19 pandemic,^{1,3} However, COVID-19

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led to an increase in fungal disease-associated hospitalization and deaths,^{4,5} and updated burden estimates based on more recent data could help inform public health planning and guide prevention efforts. We present updated estimates of total national outpatient visits, hospitalizations, direct medical costs, and indirect costs associated with fungal diseases.

METHODS

Data sources

We used the 2021 Healthcare Cost and Utilization Project (HCUP) National Inpatient Survey (NIS) (<https://hcup-us.ahrq.gov/nisoverview.jsp>) to estimate total numbers of fungal disease-associated hospitalizations in the United States. The NIS is the largest publicly available all-payer US hospitalization database, representing a ~20% stratified sample of all discharges from community hospitals and covering >97% of the population. Discharge weights allow calculation of national estimates; the weighted NIS estimates ~35 million total hospitalizations annually.

We used the 2022 Merative™ MarketScan® Commercial, Medicare, and Multi-State Medicaid Databases (<https://www.merative.com/documents/merative-marketscan-research-databases>) to obtain numbers of fungal disease-associated outpatient visits and mean costs per outpatient visit and per hospitalization. The MarketScan® databases are among the largest US health insurance claims-based databases and are widely used for public health and health services research. The 2022 Commercial and Medicare Databases represent a convenience sample of ~20 million employees, dependents, and retirees covered by employer-sponsored insurance including Medicare Supplemental and Medicare Advantage plans. The databases enable calculations of weights to project the convenience sample to the entire US population with employer-sponsored insurance; the weights are based on Census division, age group, sex, and policy holder status from the US Census Bureau's American Community Survey. The Multi-State Medicaid Database is structured similarly to the Commercial/Medicare Database and represents a convenience sample of ~8 million patients from several geographically dispersed states.

We used 2023 Final Multiple Cause of Death data from the National Vital Statistics System (NVSS) using the Centers for Disease Control and Prevention's Wide-ranging Online Data for Epidemiologic Research (CDC-WONDER) platform (<https://wonder.cdc.gov/mcd.html>) to identify fungal disease-associated deaths. These mortality data for all US residents are based on death certificates.

For each data source, we used the most recent year of finalized data available and International Classification of Diseases, Tenth Revision, Clinical Modification codes to identify fungal diseases (Table S1).

Direct medical cost calculations

We estimated total national direct medical costs of fungal disease-associated hospitalizations and outpatient visits from a healthcare payer perspective. These costs represent the sum of payments to insurers and patient out-of-pocket costs. All costs incurred at a hospitalization or outpatient visit were included, even if fungal disease was not the main diagnosis. For

each setting (hospital and outpatient), we calculated disease-specific costs by insurance type: Medicare, Medicaid, private insurance, and “other,” which includes self-pay and other government programs. We used the privately-insured mean cost per hospitalization and outpatient visit for “other” insurance types.¹

To calculate total national hospitalization costs, we multiplied national hospitalization numbers from HCUP by mean hospitalization costs. We used numbers of outpatient visits among the entire US population with employer-sponsored insurance from the weighted MarketScan® estimates combined with proportions of the US population with each insurance type,⁶ to extrapolate to total outpatient visits among persons without employer-sponsored insurance. To calculate total national outpatient visit costs, we multiplied national outpatient visits by mean outpatient costs.

Indirect cost calculations

We calculated indirect costs due to absenteeism and premature deaths using a human capital approach.² Productivity loss from absenteeism was calculated for patients <65 years old by multiplying missed workdays from a) nonfatal hospitalizations (Table S1) and b) outpatient visits by the 2023 mean hourly wage of \$31.48, doubled to account for overhead and benefits.⁷ We used a conservative assumption of 2 missed workdays per outpatient visit for coccidioidomycosis, histoplasmosis, and blastomycosis and 0.25 missed workdays per visit for all other diseases.^{2,8} To calculate productivity loss from premature deaths, we multiplied numbers of deaths by future market and nonmarket productivity (3% discount rate and a 0.5% productivity growth rate) for the average age at fungal disease-associated death.⁹ We assumed all deaths occurred during hospitalization. All costs were adjusted to 2024 dollars using the medical Consumer Price Index.¹⁰

RESULTS

We estimated 133,555 yearly fungal disease-associated hospitalizations and 13,369,951 outpatient visits (Table S2), resulting in total national direct medical costs of \$13.4 billion. Invasive/severe candidiasis (61,120 hospitalizations, \$3.3 billion) and “other and unspecified mycoses” (23,530 hospitalizations, \$3.0 billion) accounted for the most hospitalizations and the highest total hospitalization costs by disease. Mean cost per hospitalization was highest for mucormycosis, “other and unspecified mycoses,” and aspergillosis (Table S3).

Dermatophytosis and other superficial mycoses (9,046,811 outpatient visits, \$1.3 billion) and non-invasive/unspecified candidiasis (3,780,841 outpatient visits, \$892 million) accounted for the most outpatient visits and the highest total outpatient visit costs (Table 1). Mean cost per outpatient visit was highest for mucormycosis and lowest for dermatophytosis and non-invasive/unspecified candidiasis.

Productivity loss costs were \$1.7 billion for absenteeism and \$4.3 billion for premature deaths (Table 2). Among 7,288 total fungal disease-associated deaths, most were from “other and unspecified mycoses” (n=2,352), invasive/severe candidiasis (n=1,132), and aspergillosis (n=1,060) (Supplemental content). Direct and indirect costs summed to \$19.4 billion.

Nearly 30% of the total economic burden was from invasive/severe candidiasis (\$5.3 billion), another 23% was from “other and unspecified mycoses” (\$4.5 billion), and nearly 20% was from dermatophytosis and non-invasive/unspecified candidiasis combined (\$3.6 billion).

DISCUSSION

We estimate that fungal diseases in the United States impose an annual economic burden of \$19.4 billion (2024 dollars). Although our study might have captured potentially unrelated costs associated with concurrent medical conditions, the results likely underestimate the true total costs of fungal diseases for several reasons. We did not account for costs of over-the-counter antifungal medications (valued at \$1.3 billion in 2022);¹¹ medical care and treatment before a fungal disease diagnosis is established; longer-term follow-up care and medication; long-term care facility or home healthcare; or indirect costs associated with non-medically attended cases. Further, the analysis did not quantify costs such as pain, psychosocial distress, and indirect effects to families.^{1,2}

Total national direct medical costs (\$13.4 billion) increased compared with our previous estimate (\$7.2 billion [2017 dollars], equivalent to ~\$8.5 billion in 2024), although results might not be directly comparable because of methodological differences.¹ We previously required “other and unspecified mycoses” to be listed as a primary diagnosis on hospitalization records. However, we removed this requirement because a subsequent analysis revealed that many “unspecified mycosis” hospitalizations likely involve invasive candidiasis.¹²

Indirect costs (\$6 billion), primarily driven by premature deaths, also increased compared with the previous estimate (\$4 billion [2019 dollars], or ~\$4.5 billion in 2024) despite similar methodology. Fungal disease-associated deaths increased by >50% during 2019–2023, and as with prior analyses, under detection (and misclassification) is a concern with hospitalization, outpatient, and death certificate records.² This updated conservative estimate of the economic burden of fungal diseases shows that continued efforts to improve prevention, diagnosis, and treatment are needed.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1: Total direct medical costs* of fungal disease-associated hospitalizations and outpatient visits by payer, United States

Disease	Direct medical costs of hospitalizations				Total
	Medicaid	Medicare	Private insurance	Other	
Aspergillosis	\$125,486,041	\$558,480,078	\$1,140,148,041	\$141,507,736	\$1,965,621,895
Blastomycosis	\$8,187,442	\$13,529,191	\$50,930,290	\$5,093,029	\$77,739,952
<i>Candida</i> infection	\$332,776,255	\$1,306,088,075	\$1,499,736,036	\$155,724,203	\$3,294,324,568
Invasive or severe candidiasis	\$421,712,709	\$1,707,767,031	\$1,904,536,553	\$199,631,338	\$4,233,647,630
Non-invasive/unspecified candidiasis	\$12,375,103	\$44,612,841	\$54,613,536	\$4,509,375	\$116,110,854
Coccidioidomycosis	\$323,567,552	\$90,386,553	\$167,993,574	\$27,340,131	\$609,287,810
Cryptococcosis	\$79,250,107	\$96,990,171	\$167,072,314	\$15,379,041	\$358,691,633
Dermatophytosis (ringworm) and other superficial mycoses	\$2,830,429	\$8,760,140	\$6,325,950	\$632,595	\$18,549,114
Histoplasmosis	\$21,721,750	\$63,591,040	\$170,905,688	\$15,214,156	\$271,432,634
<i>Pneumocystis</i> pneumonia	\$85,740,988	\$93,977,953	\$446,117,875	\$37,818,470	\$663,655,286
Mucormycosis	\$117,732,734	\$65,816,862	\$373,201,429	\$48,328,243	\$605,079,269
Other and unspecified mycoses	\$316,415,443	\$982,433,221	\$1,566,979,167	\$168,257,599	\$3,034,085,430
Any fungal disease [†]	\$755,184,095	\$2,547,540,306	\$3,664,074,806	\$398,029,595	\$7,364,828,803
Total	\$1,413,708,740	\$3,280,053,285	\$5,589,410,363	\$615,295,203	\$10,898,467,590
	Direct medical costs of outpatient visits				Total
	Medicaid	Medicare	Private insurance	Other	
Aspergillosis	\$5,155,358	\$10,608,389	\$41,033,342	\$6,023,243	\$62,820,333
Blastomycosis	\$750,580	\$891,315	\$3,133,354	\$459,942	\$5,235,191
<i>Candida</i> infection	\$72,745,074	\$288,442,322	\$526,815,325	\$77,330,690	\$965,333,411
Invasive or severe candidiasis	\$14,730,787	\$14,460,998	\$57,736,515	\$8,475,085	\$95,403,384
Non-invasive/unspecified candidiasis	\$69,147,577	\$260,790,328	\$490,590,734	\$72,013,319	\$892,541,958
Coccidioidomycosis	\$3,571,392	\$7,998,670	\$21,853,988	\$3,207,925	\$36,631,974
Cryptococcosis	\$1,475,778	\$787,269	\$8,314,398	\$1,220,462	\$11,797,907
Dermatophytosis (ringworm) and other superficial mycoses	\$121,749,889	\$293,779,044	\$729,566,821	\$107,092,377	\$1,252,188,132
Histoplasmosis	\$4,509,114	\$3,821,820	\$17,641,149	\$2,589,526	\$28,561,608
<i>Pneumocystis</i> pneumonia	\$706,768	\$1,174,389	\$12,096,192	\$1,775,588	\$15,752,938

Mucormycosis	\$123,351	\$2,114,322	\$12,840,833	\$1,884,893	\$16,963,398
Other and unspecified mycoses	\$5,598,796	\$18,681,704	\$42,683,819	\$6,265,515	\$73,229,825
Any fungal disease [†]	\$230,265,101	\$616,709,531	\$1,535,096,124	\$225,335,211	\$2,607,405,966
Total	\$216,386,092	\$628,299,243	\$1,415,979,221	\$207,850,161	\$2,468,514,717

* In 2024 dollars.

[†] Each hospitalization or outpatient visit record could have more than one fungal disease listed.

Table 2:

Total economic burden* of fungal diseases, United States

Disease	Total direct medical costs	Indirect costs due to productivity loss			From premature deaths	Total economic burden
		From workdays lost due to hospitalizations	From workdays lost due to outpatient visits			
Aspergillosis	\$2,028,442,227	\$101,596,045	\$3,568,606		\$615,165,702	\$2,748,772,580
Blastomycosis	\$82,975,143	\$5,918,846	\$4,398,263		\$49,777,981	\$143,070,232
Candida infection	\$4,259,657,979	\$291,966,352	\$235,022,700		\$1,104,396,539	\$5,891,043,570
Invasive or severe candidiasis	\$4,329,051,014	\$284,760,493	\$6,466,774		\$656,950,542	\$5,277,228,824
Non-invasive/unspecified candidiasis	\$1,008,652,811	\$3,917,419	\$260,796,154		\$376,100,073	\$1,649,466,457
Coccidioidomycosis	\$645,919,784	\$46,493,269	\$54,023,590		\$141,941,614	\$888,378,257
Cryptococcosis	\$370,489,540	\$33,590,311	\$983,997		\$304,575,033	\$709,638,882
Dermatophytosis (ringworm) and other superficial mycoses	\$1,270,737,246	\$629,810	\$653,414,214		†	\$1,924,781,270
Histoplasmosis	\$299,994,242	\$22,080,742	\$49,253,393		\$132,505,839	\$503,834,216
Pneumocystis pneumonia	\$679,408,224	\$55,481,945	\$1,124,735		\$482,296,135	\$1,218,311,039
Mucormycosis	\$622,042,667	\$16,075,282	\$563,981		\$197,982,608	\$836,664,537
Other and unspecified mycoses	\$3,107,315,255	\$130,654,240	\$5,601,278		\$1,257,746,774	\$4,501,317,546
Total	\$13,366,982,307	\$704,486,842	\$1,007,954,756		\$4,286,388,225	\$19,365,812,130

* In 2024 dollars.

† Not calculated because no in-hospital deaths due to dermatophytosis occurred.