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Climate Change and Coccidioidomycosis

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In 2023, the California Department of Public Health recorded 9210 cases of coccidioidomycosis, or *valley fever*, which is the highest of any year on record. During the winter of 2022-2023, California experienced a prolonged sequence of very wet storms (or *atmospheric rivers*) that brought more than 1 year's worth of precipitation in less than a month and record-breaking seasonal accumulation across central portions of the state. These storms caused major flooding and largely ended a severe drought that began in 2020.¹ California's record-high numbers of coccidioidomycosis in 2023 thus followed an established pattern of higher rates of infections when wet conditions follow multiyear droughts.²

Coccidioidomycosis is a fungal infection secondary to *Coccidioides* species that is endemic to semiarid portions of the Western hemisphere. In the US, this includes southern/interior portions of California, Arizona, and Utah, as well as New Mexico and west Texas. A noncontiguous region of endemicity has been described in Washington. Outside the US, *Coccidioides* species have been identified in western and central Mexico as well as Central America and South America.

Coccidioides species reside in soil and infect humans via inhalation of airborne arthroconidia (fungal spores). In the environment, *Coccidioides* have high tolerance for extremes of temperature and soil pH, which may facilitate fungal survival because there are few competing microorganisms.² *Coccidioides* growth in soil is understood to increase with heavy precipitation, while dispersion of arthroconidia is facilitated when soil dries. This "grow and blow" pattern that occurs during rapid changes from dry and wet conditions promotes ideal conditions for fungal growth and infection transmission.²

Climate change may expand the geographic regions at risk for coccidioidomycosis. Climate change has already increased temperatures and evaporative demand (ie, the propensity of air to drive evaporation from the land surface and bodies of water) in the US. These changes have increased drought severity and soil dryness in the American West, with further increases anticipated depending on future global warming trajectory.³ Decreases in soil moisture and/or increasingly wide or frequent swings between dry and wet conditions may promote environmental settings increasingly favorable to *Coccidioides* growth and dispersion. Modeling a rapidly warming climate change scenario estimates that by 2100, *Coccidioides* endemicity in the US will spread to Idaho, Wyoming, Montana, Nebraska, North Dakota, and South Dakota.⁴

Coccidioidomycosis is currently underdiagnosed. Approximately 10 000 to 20 000 coccidioidomycosis cases are reported to the Centers for Disease Control and Prevention (CDC) annually. However, CDC modeling accounting for underdiagnosis, underreporting, and endemicity suggests that the number of actual coccidioidomycosis cases is 10 to 18 times higher than reported cases.⁵ Even in highly endemic areas, coccidioidomycosis diagnosis is fre-

quently missed or delayed. There is a clear need to improve clinician education regarding coccidioidomycosis. Increased coccidioidomycosis reporting and public health messaging are also required.

Coccidioidomycosis Presentation, Diagnosis, and Treatment

Approximately 40% of patients infected with *Coccidioides* develop symptoms. Patients with pulmonary *Coccidioides* infection frequently experience fever, cough, and shortness of breath. Chest radiographic imaging may demonstrate lobar, segmental, or multifocal consolidations; cavitory lesions; and lung nodules. Given these non-specific findings, patients with coccidioidomycosis are often treated for community-acquired pneumonia. Coccidioidomycosis should be considered in patients not improving with antibiotic treatment or in those who have exposure to or reside in endemic areas. Up to 50% of patients with pulmonary coccidioidomycosis have erythema nodosum, approximately 25% to 30% have peripheral eosinophilia, and approximately 25% have arthralgias (particularly symmetric knee and ankle arthralgia). Up to 10% of patients diagnosed with coccidioidomycosis develop disseminated disease, including skin, central nervous system, and bone and joint infection. Coccidioidal meningitis affects less than 1% of patients infected with *Coccidioides* but has a 2-year mortality rate of 100% without treatment.⁶ Pregnant and immunocompromised patients are at higher risk of coccidioidal meningitis. Patients with known or suspected coccidioidomycosis who have headaches or other neurologic symptoms lasting longer than 2 weeks should be evaluated for central nervous system *Coccidioides* infection. Cerebrospinal fluid analysis results in coccidioidal meningitis typically show a lymphocytic pleocytosis, high protein, low glucose, and positive *Coccidioides* antibodies.

Diagnosis of coccidioidomycosis should begin with serologic testing. Common serologic tests for *Coccidioides* include immunodiffusion, which detects *Coccidioides* IgM and IgG antibodies, with IgM detectable beginning at approximately 3 weeks after infection, and complement fixation, which detects only IgG and results are typically positive by 5 weeks after infection. Both immunodiffusion and complement fixation should be ordered for initial diagnosis of coccidioidomycosis. Positive serologic test results and corresponding symptoms are diagnostic of coccidioidomycosis. However, not all patients with coccidioidomycosis have positive serologic test results. For example, immunodiffusion sensitivity in immunocompromised patients may be as low as 53%.⁷ Therefore negative serologic test results do not exclude coccidioidomycosis, particularly in immunocompromised patients. Other serologic tests used for coccidioidomycosis are enzyme immunoassays (EIAs), which provide results within 1 day, compared with 5 to 7 days for immunodiffusion and complement fixation. However, because EIAs have false-positive result rates of up to 18%,⁸ positive EIA test results should be confirmed by immunodiffusion and complement fixation testing.

More than 90% of patients with pulmonary coccidioidomycosis recover without antifungals.⁹ Current US guidelines recommend

that patients with pulmonary *Coccidioides* infection who have severe disease or comorbidities, including diabetes, should be treated with oral fluconazole, 400 mg daily for at least 3 months.⁹ Patients with disseminated infection should typically be treated with oral azoles, such as fluconazole, and should be referred to an infectious disease specialist.

Reporting and Prevention

Challenges associated with climate change include changes in infectious disease epidemiology. For coccidioidomycosis, a multifaceted strategy of intensive surveillance and public education about infection prevention may reduce health harms from anticipated changes in infection rates and locations. In addition to *Coccidioides*, climate change is anticipated to affect the range, transmissibility, and/or pathogenicity of multiple other endemic fungal pathogens, including the causative organisms of histoplasmosis and blastomycosis—suggesting that similar surveillance and education strategies could be implemented for other fungal infections and in other regions.¹⁰

According to the CDC, coccidioidomycosis is currently a reportable disease in 29 US states. However, Texas, in which *Coccidioides* is already endemic, does not require coccidioidomycosis to be reported. Idaho, a state anticipated to have increasing coccidioidomycosis cases in association with climate change, does not mandate coccidioidomycosis reporting. Required reporting in states with

coccidioidomycosis outbreaks would augment current data on disease incidence and location, especially given the potential for expansion of the geographic range in which *Coccidioides* is endemic due to expected intensification of both precipitation and droughts and subsequent alternating wet and dry soil moisture conditions.

Preventing coccidioidomycosis is challenging, because even a small number of fungal particles in the air can transmit infection. Keeping car windows closed when driving through endemic areas and staying inside on windy days may reduce infection risk, but these measures are not feasible for many at-risk individuals, such as those working in agriculture or construction. Well-fitted N95 respirators and wetting dirt to prevent dust aerosolization may prevent disease acquisition. Improved public health education and enhanced personal protective measures during high-risk periods, based on short-term weather (ie, windy/dry days) and longer-term climate (ie, months to years of exceptional wetness followed by exceptional heat and/or dryness), could also be useful.

Conclusions

Climate change may substantially increase the number of individuals with *Coccidioides* infection, which is currently an underdiagnosed disease. To ensure accurate identification of and optimal care for patients with coccidioidomycosis, clinicians, patients, and health systems should be educated about this disease and be aware of the increased risk of coccidioidomycosis due to climate change.

ARTICLE INFORMATION

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