

# Persistent Headaches in an Avid Hiker: A Case of Chronic Coccidioidal Meningitis

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## Abstract

The clinical presentation, diagnosis, treatment, and complications of coccidioidal meningitis caused by the dimorphic pathogenic fungus *Coccidioides* (*Coccidioides immitis* and *Coccidioides posadasii*) have been well documented in the literature. Despite the abundance of literature concerning this disease manifestation, it is not very commonly seen in clinical practice, delaying its diagnosis and treatment and leading to devastating neurological sequelae. Therefore, considering this disease process as a potential diagnosis in endemic areas is important for appropriate and timely treatment.

We present the case of a 26-year-old male who was found to have chronic coccidioidal meningitis on further investigation. The patient presented as a transfer for an abnormal head MRI with a three-month history of progressive occipital headaches and shortness of breath. Associated symptoms included transit vision loss, upper extremity numbness, night sweats, decreased appetite, and weight loss. Relevant risk factors were being a hiker and living in the southwest of Texas. The patient was started on empiric ceftriaxone and vancomycin. A repeat MRI showed leptomeningeal enhancement and acute infarcts in the left temporal lobe and lentiform nucleus. Cerebrospinal fluid (CSF) analysis showed pleocytosis with lymphocytic predominance, the presence of eosinophils, elevated protein level, and an extremely low glucose level. Further workup ruled out syphilis and tuberculosis.

Therefore, considering his clinical presentation, risk factors, and workup results, ceftriaxone and vancomycin were discontinued, and high-dose oral fluconazole was started, which produced a marked clinical response within the next 48 hours. A CT thorax showed findings suggestive of pulmonary coccidioidomycosis, and *Coccidioides* serology in both serum and CSF specimens returned positive.

**Categories:** Internal Medicine, Infectious Disease, Public Health

**Keywords:** lentiform nucleus infarct, left temporal lobe infarct, fluconazole, leptomeningeal enhancement, coccidioidal meningitis, coccidiomycosis, disseminated coccidiomycosis, pulmonary coccidiomycosis, disseminated coccidioides, coccidioides immitis

## Introduction

A systemic fungal infection with *Coccidioides* spp. is typically acquired via inhalation of its arthroconidia found in soil [1]. It is endemic to the southwestern United States, northern Mexico, and Central and South America [2]. Coccidioidomycosis refers to the spectrum of diseases caused by the dimorphic fungus *Coccidioides*. It has been reported to involve almost all organ systems; however, pulmonary disease is the most common clinical manifestation [1]. It is often a benign self-limited illness; nonetheless, it can disseminate outside of the lungs.

Coccidioidal meningitis (CM) is a relatively uncommon and severe form of coccidioidomycosis with complications if left untreated [2]. It is a condition that affects between 200 to 300 persons annually within the endemic areas of the United States [3]. Affected individuals may solely complain of a headache without any other symptoms, which challenges a clinician with a low index of suspicion. CM is more likely to occur in immunocompromised individuals, for example, those with HIV infection, but it can also manifest in immunocompetent individuals [4,5].

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## Case Presentation

A 26-year-old male with glucose-6-phosphate dehydrogenase (G6PD) deficiency, attention deficit hyperactivity disorder (ADHD), and depression presented as a hospital transfer after an abnormal outpatient head MRI showed findings concerning for a pituitary adenoma and an area of restriction on diffusion-weighted imaging on the left temporal area (Figure 1).

### How to cite this article

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**FIGURE 1: MRI Sella (pituitary with + without contrast)**

Three months prior to this, the patient presented to a local emergency department for chest pain and shortness of breath. After a negative work-up in the emergency department, the patient was discharged home. Following discharge, the patient reported having continued shortness of breath with the development of night sweats and an occipital headache that radiated to bilateral temporal areas of his head. The patient stated that his headache was exacerbated by neck flexion. The patient's primary care provider (PCP) attributed these symptoms to the patient's home medications, dextroamphetamine/amphetamine and duloxetine, so they were discontinued. Despite discontinuing dextroamphetamine/amphetamine and duloxetine, the patient's symptoms persisted and progressed with the development of intermittent blurry vision with occipital/bitemporal headaches.

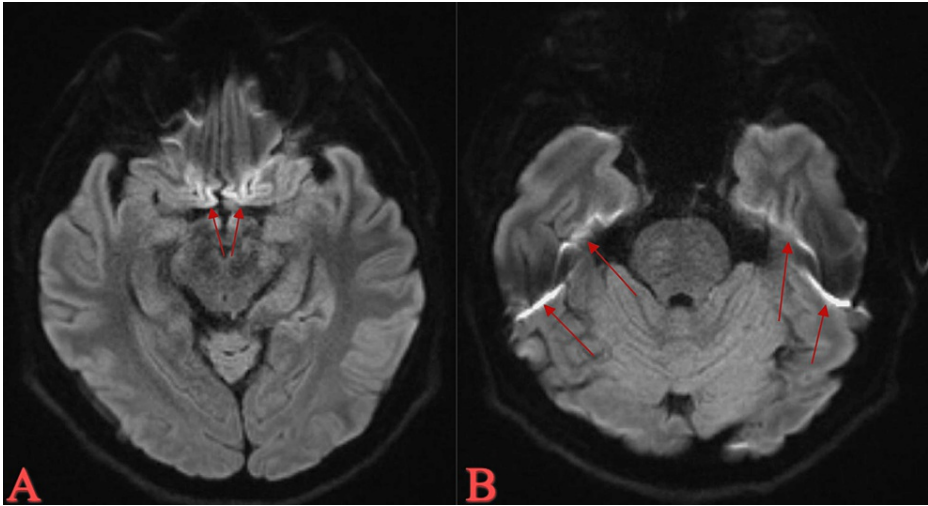
The patient stated that he also had two episodes of numbness on his right upper and lower extremities that only lasted a few seconds and self-resolved. In association with these symptoms, the patient also claimed to have lost 20 pounds in a month, secondary to having a low appetite. Due to his progressive symptoms, his PCP ordered labs to work up possible causes of his symptoms. Lab work returned with an elevated prolactin and testosterone level. This prompted his PCP to order an MRI of the head regarding high suspicion for a potential prolactinoma. The findings were concerning for potential pituitary adenoma and abnormalities of the left temporal lobe. Concerning significant social history, the patient stated that he worked in a military base located in Southwest Texas and was an avid hiker. On initial presentation, the patient was vitally stable. The only positive finding on examination was pain on neck flexion. The patient was started on empiric ceftriaxone and vancomycin. The initial laboratory workup revealed the following (Table 1).

	Normal Range	Results
Serum Tests		
White blood cells	4.5-11.0 x 10 <sup>3</sup> /μL	11.01 x 10 <sup>3</sup> /μL
Red blood cells	3.5-5.5 x 10 <sup>6</sup> /μL	4.50 x 10 <sup>6</sup> /μL
Hemoglobin	12.0-15.0 g/dL	14.2 g/dL
Hematocrit	38.0-47.0%	42.5%
Platelets	150-450 x 10 <sup>3</sup> /μL	282 x 10 <sup>3</sup> /μL
Sodium	135-145 mmol/L	135 mmol/L
Potassium	3.5-5.1 mmol/L	4.2 mmol/L
Chloride	98-107 mmol/L	103 mmol/L
Bicarbonate	22-30 mmol/L	26 mmol/L
Glucose	74-106 mg/dL	110 mg/dL
Blood urea nitrogen	7-20 mg/dL	17 mg/dL
Creatinine	0.52-1.04 mg/dL	1.10 mg/dL
AST	17-59 IU/L	31 IU/L
Alkaline Phosphate	38-126 IU/L	71 IU/L
ALT	0-50 IU/L	33 IU/L
PT	11.8-14.8 sec	13.6 sec
PT-INR	0.9-1.1 sec	1.0 sec
APTT	23.3-38.6 sec	30.5 sec
SED Rate	0-14 mm/hr	57 mm/hr
CRP	0-1 mg/dL	0.65 mg/dL
LDH	120-246 IU/L	151 IU/L

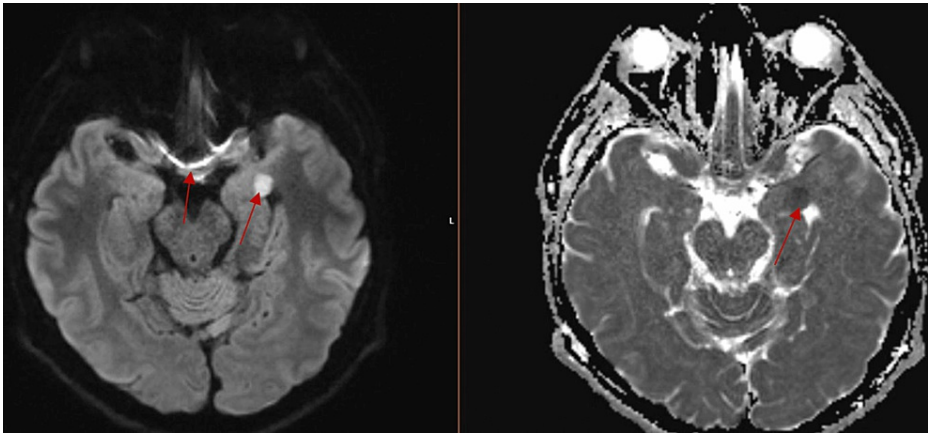
TABLE 1: Initial laboratory workup.

AST: Aspartate Transaminase, ALT: Alanine Transaminase, PT: Prothrombin Time, PT-INR: Prothrombin Time-International Normalized Ratio, APTT: Activated Partial Thromboplastin Time, SED Rate: Erythrocyte Sedimentation Rate, CRP: C-Reactive Protein, LDH: Lactate Dehydrogenase.

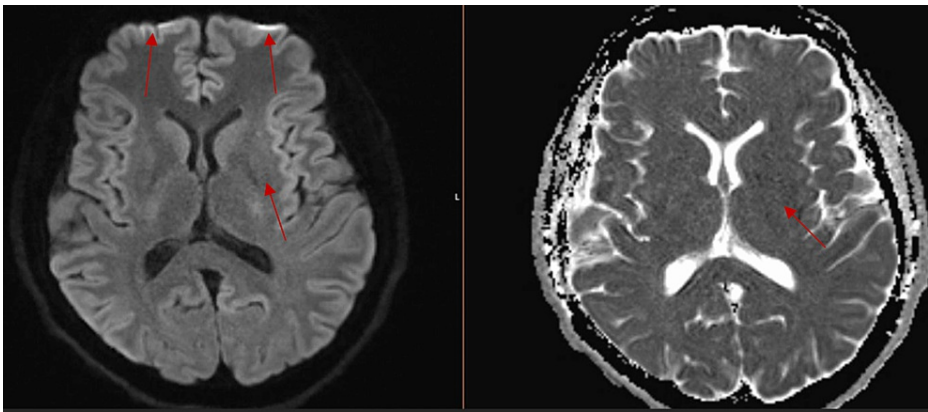
On admission, MRI head showed leptomeningeal enhancement of temporal lobes with basilar predominance, acute infarcts in the left temporal lobe and lentiform nucleus, and faint intertriginous hypo-enhancing area in the pituitary (Figures 2-5).



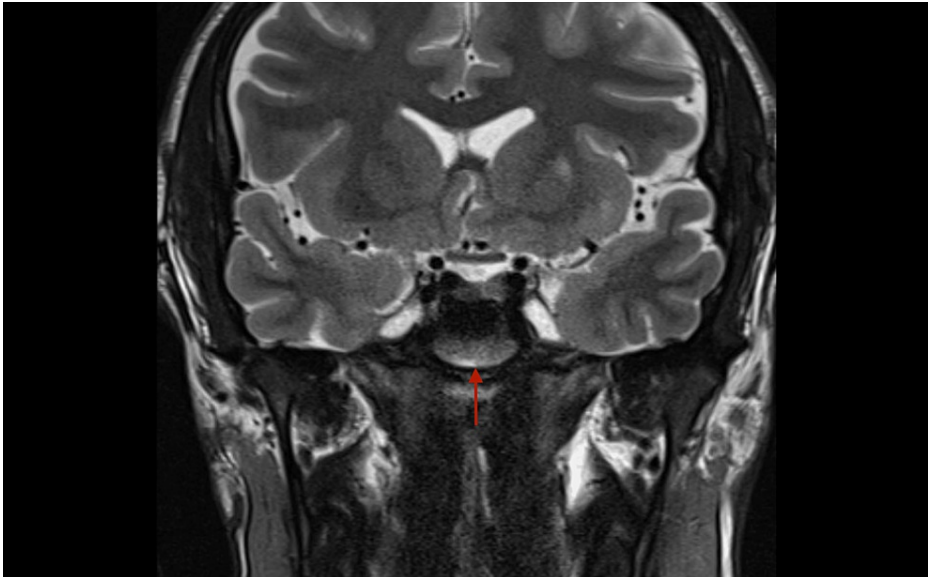
**FIGURE 2: MRI T1 Leptomeningeal enhancement with basilar predominance (A) and of temporal lobes (B).**



**FIGURE 3: MRI T1/T2 Leptomeningeal enhancement with basilar predominance. Acute infarct in the left temporal lobe.**



**FIGURE 4: MRI T1/T2 Leptomeningeal enhancement of frontal lobes. Acute infarct in the left lentiform nucleus.**



**FIGURE 5: MRI head showing faint intertriginous hypo-enhancing area in the pituitary.**

Cerebrospinal fluid (CSF) analysis showed pleocytosis with lymphocytic predominance and the presence of atypical lymphocytes and eosinophils. Protein level was elevated, and glucose level was extremely low (Table 2).

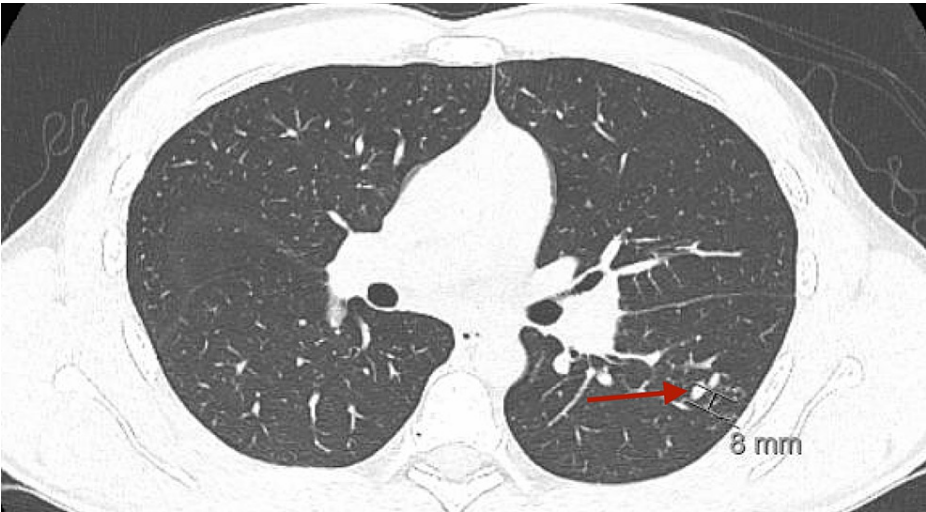
	Normal Range	Results
Cerebrospinal Fluid		
Color	Colorless	Colorless
Appearance	Clear	Clear
Red blood cells	<5 / $\mu$ L	10 / $\mu$ L
White blood cells	<5 / $\mu$ L	440 / $\mu$ L
Neutrophils	0%	5%
Lymphocytes	0%	58%
Eosinophils	0%	2%
Macrophages	3-37%	14%
Atypical Lymphocytes	0%	21%
Glucose	40-70 mg/dL	<20 mg/dL
Protein	12-60 mg/dL	202 mg/dL

**TABLE 2: Cerebrospinal fluid analysis.**

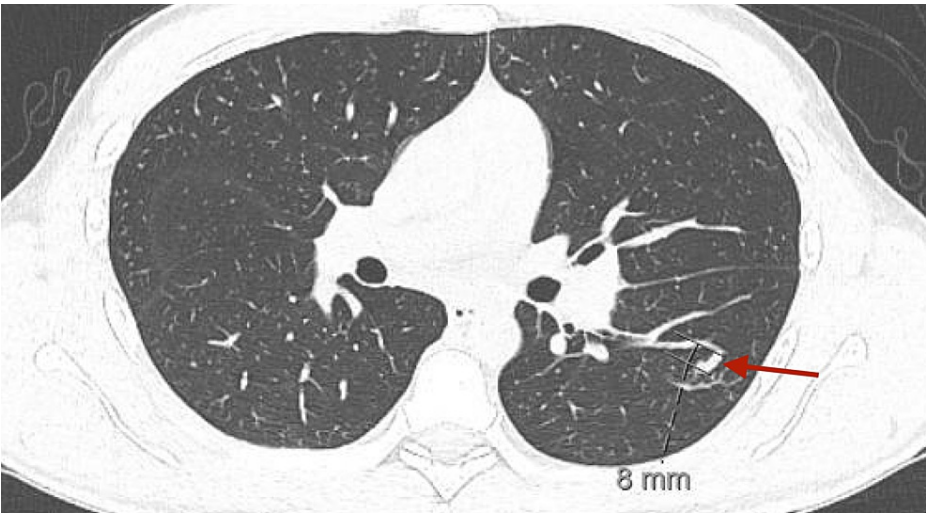
These findings were concerning for coccidioidomycosis, tuberculosis, and syphilis. Serum rapid plasma reagin (RPR), cerebrospinal fluid (CSF) venereal disease research laboratory (VDRL) test, CSF acid-fast stain and culture, CSF meningitis panel, CSF mycobacterium tuberculosis (MTB) complex polymerase chain reaction (PCR), and serum QuantiFERON-TB serum test were all negative, ruling out syphilis and tuberculosis. Due to high suspicion for coccidioidomycosis given the patient’s clinical presentation and work-up results, ceftriaxone and vancomycin were discontinued, and the patient was started on empiric high dose fluconazole 1 gram orally daily.

A CT thorax without contrast was significant for two nodular lesions in the apical segment of the left lower

lobe with adjacent tree-in-bud opacities and mediastinal adenopathy with the largest lymph node measuring 19 mm, suggestive of pulmonary coccidioidomycosis (Figures 6-8).



**FIGURE 6: CT Thorax without contrast: elongated nodular lesion in the apical segment of the left lower lobe.**



**FIGURE 7: CT Thorax without contrast: elongated nodular lesion in the apical segment of the left lower lobe.**





**FIGURE 8: CT Thorax without contrast: mediastinal adenopathy with largest lymph node measuring 19 mm.**

These findings have been well-documented to be suggestive of pulmonary coccidioidomycosis [1,6]. *Coccidioides* serology in both serum and CSF returned positive (Table 3).

	Complement Fixation Titer	Immunodiffusion
Serum	1:64	Positive
CSF	1:4	Positive

**TABLE 3: Serum and cerebrospinal fluid (CSF) *Coccidioides* serology by immunodiffusion and complement fixation.**

The patient’s headache gradually resolved while being on the fluconazole trial within 48 hours. The patient was recommended to continue fluconazole 1 gram orally daily for 4-6 months, then decrease to 400 mg daily for lifelong treatment. The patient was also advised for periodic monitoring of *Coccidioides* serology and imaging studies. It was also recommended to obtain an immunodeficiency workup as a possible contributing risk factor for the underlying infection. Immunodeficiency workup completed prior to discharge showed elevation in immunoglobulin E, while all other workup results were normal (Table 4).

	Normal Range	Results
Serum Tests		
C3	88-165 mg/dL	137 mg/dL
C4	14-44 mg/dL	27 mg/dL
Immunoglobulin A	47-310 mg/dL	131 mg/dL
Immunoglobulin E	<=114 kU/L	1391 kU/L
Immunoglobulin G	600-1640 mg/dL	1328 mg/dL
Immunoglobulin M	50-300 mg/dL	143 mg/dL
HIV ½ 4 <sup>th</sup> Generation	Negative	Negative

TABLE 4: Immunodeficiency workup.

Discussion

CM is an extrapulmonary manifestation of coccidioidomycosis that occurs when *Coccidioides* spherules migrate to the central nervous system (CNS). A persistent headache is the most common complaint [2]. Affected individuals can also have cranial nerve deficits, gait disturbances, or changes in mental status [7]. MRI results vary substantially, but basilar leptomeningeal enhancement is a classic finding [8]. Lymphocytic pleocytosis, eosinophilia, hypoglycorrhachia, and elevated protein level are seen in CSF analysis [7]. The diagnosis can be made by microscopic identification of *Coccidioides* spherules, fungal isolation in culture, or serologic testing [9]. Interestingly, our patient’s presentation, workup results, and strong suspicion of CM allowed a prompt initiation of antifungal therapy and prevented catastrophic CNS sequelae that are generally implicated throughout virtually accessible literature.

Prompt diagnosis of CM is critical, considering that meningitis represents the most severe and frequent manifestation of disseminated disease following initial pulmonary infection [3]. The complications of undiagnosed CM can lead to deleterious consequences, such as aneurysm formation in the CNS [10]. The progression of this complication can result in aneurysm rupture and consequent subarachnoid hemorrhage with clinical manifestations of altered mental status and hydrocephalus [11]. The pathogenesis of fungal aneurysm rupture is via migration of mast cells at the wall of the arterial vessel in response to the fungus causing a vast inflammatory response. CM can also lead to intracranial vasospasm due to vasculitic or subacute fibrotic changes requiring percutaneous transluminal angioplasty [12]. In rare cases, there can be co-infection with other pathogens, such as *Treponema pallidum*, which can cause severe brain damage and neurologic disability [13]. CM can present with relatively benign symptoms that can be misdiagnosed as chronic migraines or cognitive impairment and lead to mistreatment for years.

Before introducing azole therapy, CM was treated with intrathecal (IT) amphotericin B. However, it was associated with many severe side effects. High-dose fluconazole is now considered first-line therapy [2]. Fluconazole therapy appears to suppress rather than cure coccidioidomycosis meningeal disease, and evidence demonstrates a high relapse rate when azoles are reduced in dose or discontinued in CM patients [2]. Therefore, it is recommended to continue azole therapy for life in patients with CM who achieve remission and do not deteriorate on treatment [2]. IT amphotericin B, itraconazole, voriconazole, posaconazole, or isavuconazole are considered in patients who develop a refractory infection after fluconazole therapy. In a single-center retrospective chart review study, a high failure rate of initial fluconazole therapy for CM was found, supporting the need for further research of alternative treatments [14]. A case series of three patients with refractory CM showed clinical improvement with isavuconazole, used as salvage therapy [15]. Prompt serologic CM diagnosis through *Coccidioides* antigen testing, serum and CSF antibodies by immunodiffusion and complement fixation, and a promising new coccidioidal chitinase-1 (CTSI) inhibition enzyme-linked immunosorbent assay (ELISA) can aid in timely treatment to prevent clinical deterioration [16].

Predisposing risk factors for disseminated coccidioidomycosis in the immunocompromised include HIV infection and the use of corticosteroids and immunotherapy, as reported in the retrospective study of 71 cases of CM and brain abscesses by Drake and Adam [17]. HIV-infected individuals are susceptible to developing CM in non-endemic areas during antiretroviral therapy as a manifestation of immune reconstitution inflammatory syndrome [18]. On the contrary, immunocompetent individuals having disseminated coccidioidomycosis in the form of CM are rare. Few reports demonstrate rapidly disseminated infections in immunocompetent patients. Fatima et al. reported an immunocompetent individual with early manifestations of CM who received early treatment that prevented neurological sequelae [19].



Having high suspicion for coccidioidomycosis in endemic areas is important. However, in non-endemic areas, clinical suspicion should also be present. Most of these cases occur in individuals or groups who visit or temporarily relocate to endemic areas and seek medical care after returning to their permanent residence [20]. Thus, it is important to educate travelers and healthcare providers in non-endemic areas about coccidioidomycosis so that the diagnosis and treatment will not be delayed [20].

Imaging findings in acute/chronic CM show areas of focal enhancement in the cervical subarachnoid space, basilar, Sylvian, and interhemispheric cisterns representing focal collections of the organism [8]. Deep infarcts and communicating hydrocephalus are also associated findings. The neuroimaging of CM also shows hydrocephalus, periventricular edema, meningeal enhancement abnormalities, leptomeningitis, pachymeningitis, cranial nerve enhancement, and vasculitic abnormalities [21]. Intense enhancement regions tend to decrease during therapy. Decompensated patients with severe presentations of CM often present with hydrocephalus and require placement of a ventriculoperitoneal shunt [22]. A case series of five children showed hydrocephalus as a common complication of severe disseminated CM [23]. This complication can be associated with or a result of cerebral vasculitis caused by the inflammatory component of the CM infection.

Our patient presented with a known G6PD deficiency in correspondence to additional potential undiagnosed immunodeficiencies, which ultimately could have served as a significant risk factor for disseminated coccidioidomycosis in the form of CM. G6PD deficiency can lead to reduced nicotinamide adenine dinucleotide phosphate oxidase activity in phagocytes, resulting in immunodeficiency, and can lead to bacterial, viral, and fungal infections [24,25].

This case presents an indolent course of CM in a young immunocompetent individual with timely treatment that prevented severe neurological deterioration. The patient had benign symptoms for 3 months which prompted further workup. MRI head showed leptomeningeal enhancement with basilar predominance and acute infarcts in the left temporal lobe and lentiform nucleus, consistent with documented findings of CM. CSF analysis was consistent with findings of a fungal infection. High-dose fluconazole was started per Infectious Diseases Society of America (IDSA) guidelines with clinical improvement [2]. Serum and CSF antibodies by immunodiffusion and complement fixation were positive for *Coccidioides*, supporting the diagnosis.

## Conclusions

It is imperative to place CM on the differential list for even a seemingly innocuous complaint, such as a headache, in regions where *Coccidioides* is native. A retrospective study of the patient's findings helps identify our own limitations in providing appropriate care. Clinicians are encouraged to acquaint themselves with the epidemiology, symptomatology, and relevant laboratory values that commonly accompany this condition with the potential for detrimental consequences.

## Additional Information

### Disclosures

**Human subjects:** Consent was obtained or waived by all participants in this study. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

## References

1. Thompson GR 3rd: Pulmonary coccidioidomycosis. *Semin Respir Crit Care Med*. 2011, 32:754-63. [10.1055/s-0031-1295723](#)
2. Galgiani JN, Ampel NM, Blair JE, et al.: 2016 Infectious Diseases Society of America (IDSA) clinical practice guideline for the treatment of coccidioidomycosis. *Clin Infect Dis*. 2016, 63:e112-46. [10.1093/cid/ciw360](#)
3. Williams PL: Coccidioidal meningitis. *Ann N Y Acad Sci*. 2007, 1111:377-84. [10.1196/annals.1406.037](#)
4. Mathisen G, Shelub A, Truong J, Wigen C: Coccidioidal meningitis: clinical presentation and management in the fluconazole era. *Medicine (Baltimore)*. 2010, 89:251-84. [10.1097/MD.0b013e3181f378a8](#)
5. Vinh DC: Coccidioidal meningitis: disseminated disease in patients without HIV/AIDS. *Medicine (Baltimore)*. 2011, 90:87. [10.1097/MD.0b013e3182073ae3](#)
6. Mayer AP, Morris MF, Panse PM, Ko MG, Files JA, Ruddy BE, Blair JE: Does the presence of mediastinal adenopathy confer a risk for disseminated infection in immunocompetent persons with pulmonary coccidioidomycosis?. *Mycoses*. 2013, 56:145-9. [10.1111/j.1439-0507.2012.02224.x](#)
7. Jackson NR, Blair JE, Ampel NM: Central nervous system infections due to coccidioidomycosis. *J Fungi (Basel)*. 2019, 5:[10.3390/jof5030054](#)
8. Wrobel CJ, Meyer S, Johnson RH, Hesselink JR: MR findings in acute and chronic coccidioidomycosis meningitis. *AJNR Am J Neuroradiol*. 1992, 13:1241-5.
9. Parish JM, Blair JE: Coccidioidomycosis. *Mayo Clin Proc*. 2008, 83:343-48; quiz 348-9. [10.4065/83.3.343](#)

10. Buchanan IA, Ravina K, Strickland B, et al.: Multiple intracranial aneurysms from Coccidioidal meningitis: case report featuring aneurysm formation and spontaneous thrombosis with literature review. *World Neurosurg.* 2019, 121:117-23. [10.1016/j.wneu.2018.08.220](https://doi.org/10.1016/j.wneu.2018.08.220)
11. Singh R, Srinivasan VM, Catapano JS, DiDomenico JD, Baranoski JF, Lawton MT: Coccidioidal meningitis with multiple aneurysms presenting with pseudo-subarachnoid hemorrhage: illustrative case. *J Neurosurg Case Lessons.* 2021, 2:CASE21424. [10.3171/CASE21424](https://doi.org/10.3171/CASE21424)
12. Hu YC, Newman CB, Bristol R, McDougall CG, Albuquerque FC: Percutaneous transluminal angioplasty in a patient with vasospasm secondary to coccidioidal meningitis: case report and review of the literature. *J Neurointerv Surg.* 2011, 3:62-5. [10.1136/jnis.2010.002386](https://doi.org/10.1136/jnis.2010.002386)
13. Kim JM, Sivasubramanian G: Coccidioidal meningitis and neurosyphilis co-infection in a non-HIV patient. *Med Mycol Case Rep.* 2021, 34:5-7. [10.1016/j.mmcr.2021.08.002](https://doi.org/10.1016/j.mmcr.2021.08.002)
14. Gupta S, Ampel NM, Klanderman M, Grill MF, Blair JE: Fluconazole failure in the treatment of Coccidioidal meningitis. *J Fungi (Basel).* 2022, 8:[10.3390/jof8111157](https://doi.org/10.3390/jof8111157)
15. Davis MR, Chang S, Gaynor P, McCreary EK, Allyn P: Isavuconazole for treatment of refractory coccidioidal meningitis with concomitant cerebrospinal fluid and plasma therapeutic drug monitoring. *Med Mycol.* 2021, 59:939-42. [10.1093/mmy/myab035](https://doi.org/10.1093/mmy/myab035)
16. Grill FJ, Grys TE, Grill MF, Roeder A, Blair JE, Lake DF: Development of a quantitative antigen assay to detect Coccidioidal Chitinase-1 (CTS1) in human serum. *Open Forum Infect Dis.* 2021, 8:ofab344. [10.1093/ofid/ofab344](https://doi.org/10.1093/ofid/ofab344)
17. Drake KW, Adam RD: Coccidioidal meningitis and brain abscesses: analysis of 71 cases at a referral center. *Neurology.* 2009, 73:1780-6. [10.1212/WNL.0b013e3181c34b69](https://doi.org/10.1212/WNL.0b013e3181c34b69)
18. Tribble R, Edgerton N, Hayek S, Winkel D, Anderson AM: Antiretroviral therapy-associated coccidioidal meningitis. *Emerg Infect Dis.* 2013, 19:163-5. [10.3201/eid1901.120889](https://doi.org/10.3201/eid1901.120889)
19. Fatima M, Patel RS, Brunworth JR, et al.: A case of rapidly progressive coccidioidal meningitis in an immunocompetent patient. *Cureus.* 2022, 14:e28643. [10.7759/cureus.28643](https://doi.org/10.7759/cureus.28643)
20. Brown J, Benedict K, Park BJ, Thompson GR 3rd: Coccidioidomycosis: epidemiology. *Clin Epidemiol.* 2013, 5:185-97. [10.2147/CLEP.S34434](https://doi.org/10.2147/CLEP.S34434)
21. Cárdenas G, Aristizábal S, Salinas C, et al.: Coccidioidal meningitis in non-AIDS patients. A case series at a Mexican neurological referral center. *Clin Neurol Neurosurg.* 2020, 196:106011. [10.1016/j.clineuro.2020.106011](https://doi.org/10.1016/j.clineuro.2020.106011)
22. Shi J, Wong M, Xu Y: Coccidioidal meningitis with hyphal forms detected in cerebrospinal fluid in a patient with ventriculoperitoneal shunt: a case report. *J Cent Nerv Syst Dis.* 2021, 13:11795735211053446. [10.1177/11795735211053446](https://doi.org/10.1177/11795735211053446)
23. De la Cerda-Vargas MF, Sandoval-Bonilla BA, McCarty JM, et al.: Hydrocephalus in Mexican children with Coccidioidal meningitis: clinical, serological, and neuroimaging findings. *Surg Neurol Int.* 2021, 12:119. [10.25259/SNI\\_895\\_2020](https://doi.org/10.25259/SNI_895_2020)
24. Sun B, Li Q, Dong X, et al.: Severe G6PD deficiency leads to recurrent infections and defects in ROS production: case report and literature review. *Front Genet.* 2022, 13:1035673. [10.3389/fgene.2022.1035673](https://doi.org/10.3389/fgene.2022.1035673)
25. Alrahmany D, Omar AF, Al-Maqbali SR, Harb G, Ghazi IM: Infections in G6PD-deficient hospitalized patients-prevalence, risk factors, and related mortality. *Antibiotics (Basel).* 2022, 11:[10.3390/antibiotics11070934](https://doi.org/10.3390/antibiotics11070934)