

# Current diagnosis and treatment of cryptococcal meningitis without acquired immunodeficiency syndrome

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## ABSTRACT

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Cryptococcal meningitis (CM) is a central nervous system infectious disease caused by *Cryptococcus*. It is the most common fungal infection in the central nervous system, accounting for about 48% of fungal infection. The disease occurs mainly in acquired immunodeficiency syndrome (AIDS) patients and concentrates in the immunocompromised people without AIDS. There are nearly one million new cases of CM each year, and about 70% of them died. In China, CM occurs mainly in people without AIDS and there is an increasing trend in recent years. Early diagnosis and treatment is the key to reducing morbidity and mortality associated with CM. The diagnosis mainly depends on laboratory examination such as morphological examination, fungal culture and antigen detection. History, clinical manifestation and imaging examination are the important parts of auxiliary examination. The initial combined antifungal treatment is emphasized, and the principle of fractional treatment including induction, consolidation and maintenance therapy should be followed. The high intracranial pressure must be reduced actively at the same time. In addition, it is proved that the novel immunotherapy combined with antifungal agents can improve the curative effect and limit the chance of antimicrobial resistance. Large-scale clinical trials are needed for further study.



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## INTRODUCTION

Cryptococcal meningitis (CM) is the most common cause of fungal meningitis worldwide. Globally, there are approximately 957,900 new cases of CM each year, and about 624,700 of them died.<sup>[1]</sup> CM occurs mainly in the acquired immunodeficiency syndrome (AIDS) crowd abroad. In China, CM is sporadic, mainly in people without AIDS. In recent years, there is an increasing trend for the incidence of CM as a result of the wide application of antibiotic, hormone and immune inhibitors, organ transplantation in China. In developing countries, up to 70% of CM lead to death eventually.<sup>[2]</sup> The severity of disease and limited access to diagnostics and medications results in the high mortality of CM in resource-limited settings (RLS).<sup>[1]</sup> Early diagnosis and treatment is the key to reduce the morbidity and mortality.

No symptoms, hardship to select pathogen or lack of awareness in the early stages of the disease make the diagnosis difficult, particularly in RLS. The clinical manifestations and part of cerebrospinal fluid parameters such as fever, headache, high intracranial pressure, high protein and low glucose in cerebrospinal fluid (CSF) which are easily confused with tuberculous meningitis. Substantial resources, such as hospitalization, intravenous antifungal therapy, access to lumbar punctures, and strict monitoring are required in the process of CM treatment.<sup>[3]</sup> In this review, we mainly describe the available diagnostic methods and management of CM without AIDS.

## DIAGNOSE OF CRYPTOCOCCAL MENINGITIS

The diagnosis of the CM is dependent on the medical history, clinical manifestations, imageological examination, cerebrospinal fluid parameters and laboratory tests. Among them, laboratory tests are the main methods to make a definite diagnosis. India ink staining and fungal cultures are regarded as the diagnostic gold standard. There is not much difference in diagnostic criteria of CM between patients with or without human immunodeficiency virus (HIV). Merely for patients with advanced HIV, World Health Organization (WHO) recommends early cryptococcal antigen (CrAg) screening and treatment in 2011.<sup>[4]</sup>

### Medical history and clinical manifestation

The medical history of CM includes environment (the contact history of pigeons) and susceptible population with risk factors including long term treatment of immunosuppressant, broad-spectrum antibiotics and glucocorticoids, HIV infection and patients with immunodeficiency is important for providing initial clues

and diagnostic evidence. The CM has a hidden onset and a slow course, mainly presenting the symptoms of increased intracranial pressure (headache, nausea, vomiting, and disturbance of consciousness), meningeal irritation sign (neck rigidity, Kernig sign and Brudzinski sign). Patients with altered mental status have high mortality.<sup>[5-7]</sup>

Patients with typical symptoms of the meningeal irritation are less than 20%.<sup>[6]</sup> Optic nerve damage is the most common among injury of cranial nerves caused by intracranial hypertension (optic nerve, oculomotor nerve, abducens nerve, facial nerve, vestibulocochlear nerve involvement). Forty percent of the patients with CM have visual involvement, including optic disc edema and uveitis.<sup>[8-10]</sup> Second is the vestibulocochlear nerve damage. If there is parenchymal involvement, it would appear epilepsy seizures, hemiplegia, mental disorder, ataxia, etc.

### Imaging examination

Computed tomography (CT) and magnetic resonance imaging (MRI) has limited effect on the diagnosis, but it is necessary to find the complications (intracranial mass and hydrocephalus).<sup>[11]</sup> Some professors divide the CM course into three periods.<sup>[12]</sup> Acute phase: cerebral edema is showed on CT or MRI. Brain parenchyma presents punctate low-density lesions and Long T1, long T2 signal area, it is similar to cerebral infarction, called "soap bubble damage"<sup>[12,13]</sup> which is caused by the expansion of the space (Robin Virchow) around the capillary. Subacute stage: Multifocal gelatinous pseudocysts formed in the deep white matter on both sides of the cerebral hemispheres, basal ganglia, thalamus and midbrain, etc. Chronic phase: intracranial single or multiple rounds, oval and sheet, etc., slightly higher or low density massive umbra, lesions surrounded by edema, may have mutual integration. Enhanced scan shows multiple small nodules ring, it is easy to be misdiagnosed as cerebral metastasis. Because of the correlation between CT/MRI and the disease progression or cerebrospinal fluid pressure, CT and MRI should be reviewed even if it was normal during the acute phase.

### CSF parameter

The typical characteristic of cerebrospinal fluid for CM is high intracranial pressure (HICP) which is more than 350 mmH<sub>2</sub>O or up to more than 900 mmH<sub>2</sub>O. The reason for HICP is that *Cryptococcus* hinder the CSF to pass through the arachnoid villi which obstructs the CSF circulation channel.<sup>[14]</sup> Furthermore, the accumulation of capsular polysaccharide in arachnoid villi and subarachnoid spaces contributes to fluid retention by increasing the osmolarity of the CSF and

interstitial fluid.<sup>[15,16]</sup> The appearance of CSF is clear and transparent generally, and it can be slightly turbid if there is a large amount of *Cryptococcus*. Leukocyte count in CSF is increased (about  $100\text{--}500 \times 10^6/\text{L}$ ) in the majority of people, or normal in the minority. In addition, the protein level rises (no more than 2 g/L usually), and the glucose and chloride decreases in CSF as the result of infection. The degree of decrease in glucose levels is significantly lower than that of other central nervous system infection.<sup>[17]</sup>

The characteristics of cerebrospinal fluid cytology: the total number of cells increases to different degrees, presenting mixed cell reaction or lymphocyte dominated mixed cell reaction. Monocyte constitutes the main ingredients in the most of the cerebrospinal fluid cytology of CM patients, the total number of cells decreases and the proportion of small lymphocytes also increases with the improvement of the disease. Therefore, cerebrospinal fluid cytology has also certain significance to the monitoring of the efficacy.

However, cerebrospinal fluid examination is normal in 10-17% other patients, especially in the patients with HIV.<sup>[18,19]</sup>

### Other laboratory examination

The common laboratory examination for diagnosing of CM mainly includes morphological examination, fungal culture, and antigen detection.

*Cryptococcus neoformans* (*C. neoformans*) is a single-celled organism with a polysaccharide capsule. It exists in the blood, CSF, and tissues.<sup>[20]</sup> Morphological diagnosis depends on dyeing technology. India ink staining is considered to be one of the gold standards for diagnosis. It is a traditional method of identification of *C. neoformans*, especially in areas with limited resources because of its simple and rapid operation. Characteristic “starry night” phenomenon<sup>[20]</sup> would be observed by India ink staining: capsule is not shaded but surrounded dyed blue. Yet the sensitivity of india ink staining is only < 86%.<sup>[21,22]</sup> In addition, due to low fungal loads, India ink is insensitive for patients who presenting early after symptoms appear or being on initiating antiretroviral therapy (ART).<sup>[23]</sup> The detection rate of *C. neoformans* in the CSF is only 66% at first time, about 17.8% at second time, and others remain 3 to 20 times smear test under microscope to find positive.<sup>[24]</sup> May-Grunwald-Giemsa (MGG) staining has a relatively high positive detection rate, a small amount of *C. neoformans* can be detected after centrifugal precipitation, applying to patients with low amount of fungi. But the morphological characteristics of the fungi are not clear, it is easy to be confused with small lymph cells in CSF when the *C. neoformans* scattered in the

distribution. Therefore, the detection method requires high skill levels from observers. Alcian blue staining is a special dye for the *C. neoformans*<sup>[25]</sup> and could dye the capsule to be deep blue, and the cell light blue, without the peripheral inflammatory cells being dyed. Therefore, the sensitivity of alcain blue staining is high and the fungi can be easily observed.<sup>[26]</sup> The combination of the above methods can improve the detection rate. Culture is considered the gold standard for diagnosis of cryptococcal meningitis.<sup>[27]</sup> But it is limited by culture conditions, culture time and the amount of cerebrospinal fluid and fungi, thus making the early diagnosis hampered. But it has important value for further drug sensitivity test and species classification.

The most reliable diagnostic method for cryptococcosis is to detect capsular polysaccharide antigen<sup>[20]</sup> which can be find in serum, CSF, and urine specimens. Serum CrAg is taken as an early biologic marker which is far more sensitive and rapid than direct detection of the pathogen, it highly predicts of the development of CM within one year.<sup>[28]</sup> Retrospective data suggests that CrAg screening in patients with late-stage human HIV ART may reduce cryptococcal disease and deaths.<sup>[29]</sup> However, presence of CrAg in CSF is more valuable for diagnosis of CM and serum CrAg assay can help to assist the diagnosis.

Main methods are consist of latex agglutination (LA) assays, enzyme immunoassays (EIAs), or the novel lateral flow assay (LFA).<sup>[20]</sup> LA or EIAs has been used for detecting CrAg for several years.<sup>[30]</sup> The sensitivity and specificity of the LA test for CSF is high. The sensitivity ranges from 93% to 100%, while the specificity ranges from 93% to 98%, which is significantly better than India ink staining and CSF cytology in the early diagnosis of CM. And the severity of the disease in patients with cryptococcal meningitis is correlated with the antigen titer of capsular polysaccharide, therefore, LA test also has the value of evaluating the severity of illness and the prognosis.<sup>[31]</sup> Although this method has high sensitivity, but may appear false positive results in patients with immunological diseases, such as rheumatoid.<sup>[32,33]</sup> Tedious manual operation and subjective intervention is the main weakness, in addition, this method needs equipment and refrigeration which restricts its application in resource limited area.<sup>[20]</sup> The sensitivity and specificity of EIAs test for capsular polysaccharide antigen is high which is 100% and 98% respectively for CSF samples.<sup>[34,35]</sup> However, EIAs test cannot be widely used because of the expensive detection kits.

The lateral flow assay (LFA) is developed in 2009, it could detect cryptococcal polysaccharide capsule

quickly by using gold-conjugated anti-cryptococcal monoclonal antibodies directed at *C. neoformans*.<sup>[30]</sup> It has higher sensitivity than LA and EIAs, and it is more sensitive for detecting the lower antigen in CSF.<sup>[22,30]</sup> The CrAg LFA which is low cost can be carried out at room temperature without refrigeration or complicate experimental equipment, takes just 10 min to get the results. Therefore, it is expected to reform the diagnosis of cryptococcosis in the restricted area.<sup>[36]</sup>

Recently, molecular biological detection comprised of chromosome pulse electrophoresis, nucleic acid probe, DNA fingerprinting technique and polymerase chain reaction (PCR) has been carried out in some laboratories. PCR are often used at present. PCR which applicates specific primer aimed at conservative sequence of *C. neoformans* to the detection of fungi is rapidly and pecifically.<sup>[31]</sup> The primer used for multi-locus sequence typing of *C. neoformans* includes CAP59, GPD1, IGS1, LAC1, PLB1, SOD1, URA5.<sup>[37]</sup> The pathogenic fungi are identified as *C. neoformans* var. *grubii*, *C. neoformans* var. *neoformans* and hybrid strains by PCR. However, the requirements for the experimental technique of PCR is so high that this kind of test is not widely carried out in clinical practice at present.<sup>[31]</sup>

## TREATMENT OF CRYPTOCOCCAL MENINGITIS

Cryptococcal meningitis without treatment is fatal in most cases. It is critical to diagnose early and treat promptly for the improvement of survival.<sup>[38]</sup>

### Antifungal agents therapy

Antifungal drugs used commonly include amphotericin B (AmB), 5-Flurocytosine (5-FC) and fluconazole (FCZ).

AmB is a broad-spectrum antifungal agent. The mechanism of AmB is to combine with fungal cells membrane of ergosterol and interfere with cell metabolism and increase the cell membrane permeability aimed to bring about cell death. AmB is the first choice for the treatment of CM, and it has the best early fungicidal activity (EFA).

5-FC is a pyrimidine analogues, and its mechanism of action is to inhibit cell division by interfering with

the synthesis of fungal DNA. Single drug treatment is easy to produce drug resistance. 5-FC is usually used incombination with AmB and is superior to the combination of AmB and FCZ.<sup>[39]</sup> The reason is that AmB has the ability to make the cell membrane permeability to increase, thus 5-FC is more susceptible to enter the fungus and appear synergistic fungicidal effect. Without use of 5-FC in induction therapy will lead to increased mortality, treatment failure<sup>[40]</sup> or recurrence.<sup>[41]</sup>

FCZ is one of the triazole antifungal agents and its mechanism of action is to destroy the cell membrane and promotes cell death by inhibiting the activity of cytochrome P450 by inhibiting the synthesis of ergosterol in fungal cell membrane.<sup>[42]</sup> FCZ is easy to go through the blood brain barrier (BBB) to reach a high concentration in CSF. However, it belongs to fungistat that the effect of killing *Cryptococcus* is weaker than that of AmB. Therefore, it can be used for sequential therapy after induction therapy. New drugs such as voriconazole and posaconazole have obvious anti-*Cryptococcus* activity *in vitro*.

Fractional treatment of the CM is recommended at present, consists of AmB plus 5-FC induction therapy, FCZ consolidation and maintenance therapy.<sup>[43]</sup>

Expert consensus of the diagnose and treatment of cryptococcal infection in China recommended combination therapy with AmB 0.5-1 mg/kg per day and 5-FC 100 mg/kg per day as induction treatment for non-HIV associated patients which earned widespread approval from experts.<sup>[44]</sup> The induction phase lasts at least 8 weeks which is different from the project of Infectious Diseases Society of America (IDSA), and this may be related to the use of the method in our country, namely it takes a period of time to begin with small dose to effective maintenance dose gradually. However, large-scale clinical trials are needed to demonstrate their validity. Then followed by consolidation therapy with FCZ or itraconazole 200-400 mg/day at least 12 weeks,<sup>[24]</sup> and maintenance therapy has not been mentioned in the Consensus [Table 1].

At present, there is a difference in the treatment of non-HIV associated patients, and its management is based on the characteristics other host and the pathogen. As a result of about 25% of the transplant patients are with renal dysfunction in the diagnosis of cryptococcal meningitis,<sup>[11]</sup> liposome amphotericin B

**Table 1: Antifungal therapeutic schedule for non-HIV associated CM patients**

Schedule	Course	
Induction period	AmB 0.5-1 mg/kg per day + 5-FC 100 mg/kg per day	≥ 8 weeks
Consolidation period	FCZ/Itraconazole 200-400 mg/day	≥ 12 weeks
Maintenance period	Not mentioned	

HIV: human immunodeficiency virus; CM: cryptococcal meningitis; AmB: amphotericin B; 5-FC: 5-Flurocytosine; FCZ: fluconazole

(LAmB)/amphotericin B lipid complexes (ABLC) with small renal toxicity are recommended in the induction period.<sup>[11,24]</sup> In 2010, IDSA<sup>[24]</sup> suggests induction therapy with LAmB (3-4 mg/kg per day i.v.) or ABLC (5 mg/kg per day i.v.) plus 5-FC (100 mg/kg per day i.v.) for at least 2 weeks, consolidation therapy with FCZ 400-800 mg (6-12 mg/kg) per day for 8 weeks. And maintenance therapy with FCZ 200-400 mg (3-6 mg/kg) per day lasts for 6-12 months [Table 2]. LAmB should be used at least 4-6 weeks without the use of 5-FC in induction therapy. Increasing dosage (6 mg/kg per day) should be conducted when the fungal load is higher or palindromia.

Treatment for non-HIV associated or non-transplant patients includes induction therapy with AmB 0.7-1.0 mg/kg per day or LAmB 3-4 mg/kg per day or ABLC 5 mg/kg per day plus 5-FC 100 mg/kg per day for 4-6 weeks. IDSA also recommends that it is essential to extend induction period if treated with AmB/LAmB monotherapy or treatment interrupted. In addition, consolidation therapy with FCZ 400-800 mg (6-12 mg/kg) per day lasts for 8 weeks, and maintenance therapy with FCZ 200 mg (3 mg/kg) per day lasts for 6-12 months [Table 3].

It is difficult to achieve effective concentration in the CSF for AmB or LAmB because of their poor ability to traverse BBB. Intravenous combined intrathecal administration of AmB can improve the drug concentration in CSF to inhibit the *C. neoformans* effectively, and observational studies suggest that it could be associated with improved survival.<sup>[45]</sup> However, it is necessary to prevent the occurrence of complications caused by intrathecal administration, such as paresthesias, radiculitis, or myelopathy.<sup>[46]</sup>

Previous studies in humans and animals indicate that intrathecal administration of lipid formulations of AmB is better tolerated than AmB.<sup>[47-49]</sup> Furthermore, there is an animal experiment suggesting that the combination of intravenous antifungal drugs with intrathecal administration of LAmB could be beneficial in terms of

survival and reduction of fungal load in CSF.<sup>[47,50]</sup>

AmB is easy to combine with human cholesterol cell membrane,<sup>[48,49]</sup> so the adverse reactions are more and serious. AmB has high toxicity, especially liver and kidney toxicity. Renal toxicity which could lead to lowering glomerular filtration rate and electrolyte disturbances is the most common. Renal function can be restored by early termination of the use of AmB<sup>[51]</sup> or replacement of LamB.<sup>[11]</sup> In addition, some studies<sup>[11,52,53]</sup> support that preemptive hydration and electrolyte supplementation are the effective methods to minimize the toxicity in middle- and low-income countries (MLICs).<sup>[4]</sup> Anemia is another common side effect of AmB,<sup>[54]</sup> the reason is that the effect of the bone marrow on the synthesis of the erythropoietin.<sup>[55]</sup> 5-FC could get through the BBB easily and has slight adverse reactions, such as gastrointestinal reaction, rash, erythropenia, light degree damage of liver and kidney function, etc. Symptoms can be relieved after stopping taking the drug. The incidence rate of adverse reactions of FCZ is low, the symptoms mainly include gastrointestinal reaction, rash, and so on. Liver and kidney impairment are transient and would returned to normal after drug withdrawal generally.<sup>[56]</sup>

### Treatment of high intracranial pressure

The incidence of HICP in patients with cryptococcal meningitis is more than 50%.<sup>[50]</sup> HICP is the leading cause of death and complications.<sup>[44]</sup> Therefore, effective control of intracranial pressure for improving clinical symptoms to gain enough time for the success of anti-fungal therapy is of crucial importance. Active treatment of HICP is crucial whether it is HIV-associated patients or not.<sup>[57]</sup> Methods used to reduce intracranial pressure commonly as follows:<sup>[58]</sup> (1) Drugs such as mannitol, glycerin fructose, corticosteroids, acetazolamide and so on. While the long-term effect of medical management is not clear that is not used routinely;<sup>[57,59]</sup> (2) Lumbar puncture. Patients whose intracranial pressure > 2.4 kPa are performed with regular lumbar paracentesis to maintain normal

**Table 2: Antifungal therapeutic schedule for CM patients with renal dysfunction**

Schedule	Course	
Induction period	LAmB 3-4 mg/kg per day/ABLC 5 mg/kg per day + 5-FC 100 mg/kg per day	≥ 2 weeks
Consolidation period	FCZ 400-800 mg/day or 6-12 mg/kg per day	≥ 8 weeks
Maintenance period	FCZ 200-400 mg/day or 3-6 mg/kg per day	6-12 months

CM: cryptococcal meningitis; LAmB: liposome amphotericin B; ABLC: amphotericin B lipid complexes; 5-FC: 5-Fluorocytosine; FCZ: fluconazole

**Table 3: Antifungal therapeutic schedule for non-HIV associated or non-transplant patients**

Schedule	Course	
Induction period	AmB 0.7-1.0 mg/kg per day or LAmB 3-4 mg/kg per day or ABLC 5 mg/kg per day + 5-FC 100 mg/kg per day	
Consolidation period	FCZ 400-800 mg/day or 6-12 mg/kg per day	8 weeks
Maintenance period	FCZ 200 mg or 6 mg/kg per day	6-12 months

HIV: human immunodeficiency virus; AmB: amphotericin B; LAmB: liposome amphotericin B; ABLC: amphotericin B lipid complexes; 5-FC: 5-Fluorocytosine; FCZ: fluconazole

intracranial pressure. Release CSF 10-30 mL per day until the intracranial pressure has been normalized may be required for a few days. The treatment guideline of IDSA in 2010 points out that this method is the most effective and rapid way to reduce the pressure currently;<sup>[24]</sup> (3) Lumbar cistern drainage. This method could reduce the number of lumbar puncture and avoid patients' pain. In addition, it is a better method for patients whose intracranial pressure > 3.9 kPa and cannot be controlled effectively by frequent lumbar puncture. Make the open brain pressure fall to 50% by enough drainage of the cerebrospinal fluid. Regulate the drainage 300-400 mL per 24 h. It is best no more than 15 days for drainage each time in principle in case of CSF leakage or secondary infection; (4) Ommaya reservoir. This involves a device that allows for ventricle drainage invented by Sheldon and Ommaya<sup>[60]</sup> in 1963 and applied as common treatment in adults with cryptococcal meningitis for relief of the symptoms of HICP. The anti-fungal drugs could be injected into ventricles using this device directly and reach effective concentration without influence of BBB. In addition, we could obtain CSF from the ommaya reservoir expediently and securely that it is useful in the evaluation of the state of illness changes and therapeutic effect advantageously. This method reduces the risk of exogenous infection due to the hermetic type structure. However, percutaneous puncture repeatedly may lead to the damage of reservoir or secondary infection; (5) Ventriculoperitoneal shunt. We should consider the ventriculoperitoneal shunt under following circumstances: the control of intracranial pressure is not ideal, recurrent cerebral hernia, occurrence of persistent or progressive cranial nerve defects. Anti-fungal therapy should be used at the same time to avoid peritoneal cavity infection; (6) Lateral ventricle drainage. If measures above mentioned cannot reduce the intracranial pressure effectively, or there is an expansion of the ventricles, lateral ventricle drainage should be performed in time. But the drainage time should not be too long (2-3 weeks), otherwise it is easy to cause infection. These surgical techniques above could not only reduce intracranial pressure but also be used to intrathecal or ventricular injection to improve the therapeutic effect.

### Immune therapy

The main infection routes of *Cryptococcus* is through the respiratory tract, asymptomatic latent state is the most common infection state.<sup>[44]</sup> When there is immune function defect in people that could not resist the growth and reproduction of the fungi, *Cryptococcus* will proliferate and migrate through the blood to other organs in the body, leading to the CM eventually. Therefore, anti-*Cryptococcus* infection by immune

regulation opens up a new way. Anti-fungal drugs combined immunotherapy has been put forward in recent years.

In a phase I clinical study overseas, twenty cases of cryptococcosis are treated with monoclonal antibody from mice aimed at capsule antigen, the result shows that high doses of monoclonal antibodies can reduce the level of polysaccharide antigen in serum temporarily, but there may appear allergic reactions and other side effects.<sup>[61]</sup>

It has been reported that clinical application of interferon in the treatment of fungal resistance in 2004.<sup>[62]</sup> Jarvis *et al.*<sup>[63]</sup> conduct a randomized controlled experiment and show that the rate of fungal clearance is accelerated by adding interferon on the basis of AmB combined with 5-FC, and there is no other side effects. But there is no statistical significance in mortality of patients between group with interferon 100 µg (Day 1, Day 3) and group with 100 µg (Day 1, Day 3, Day 5, Day 8, Day 10, Day 12).

The treatment guidelines set out by Infectious disease society of American in 2010 recommended to give formal antifungal agents combined with IFN-γ to patients with persistent infection (whose culture result of CSF is positive after 4 weeks of antifungal therapy with 100 µg/m<sup>2</sup> for more than 50 kg, 50 µg/m<sup>2</sup> for less than 50 kg 3 times a week for 10 weeks. Small-scale phase 2 clinical trials have shown the good curative effect. However, larger clinical trials are needed to verify.

In recent years, radioimmunotherapy has become an adjuvant immunotherapy for the treatment of *Cryptococcus* infection. The principle is to use the radioactive substances to label monoclonal antibodies, thus killing the fungi with cytotoxic radiation substance. Bryan *et al.*<sup>[64]</sup> have performed animal experiment, demonstrated that RIT is more effective to mice infected with *C. neoformans* than AmB. Besides, RIT could prevent the development of fungal resistance.<sup>[42]</sup>

### CONCLUSION

Higher morbidity and mortality has caused great concern from scholars all over the world. How to make early diagnosis and effective treatment is the key point of the current study. Immunotherapy opens up a new way of treatment for CM. But it is in the bud. Therefore, the development of new drugs with effective antifungal activity and low toxicity as well as effective treatment is still a problem we need to solve.

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## Conflicts of interest

There are no conflicts of interest.

## Patient consent

No patient involved.

## Ethics approval

This article does not contain any studies with human participants or animals.

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