



"Protecting Rural Indian Communities from Brain-Eating Amoeba: The Efficacy of Ayurvedic Medicine and Early Treatment"

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Abstract

The occurrence of fatal infections caused by *Naegleria fowleri*, commonly known as the brain-eating amoeba, poses a significant threat to rural communities in India, particularly those relying on natural water sources for daily activities. This review explores the potential of Ayurvedic medicine in conjunction with early treatment strategies to prevent and manage such infections effectively. The amoeba typically enters the human body through the nasal passages during activities like bathing in contaminated ponds, leading to severe brain damage and often death due to delayed diagnosis and treatment.

Ayurveda, with its rich repository of medicinal plants and traditional practices, offers promising first aid and preventive measures against *N. fowleri* infections. Key Ayurvedic herbs such as Neem (*Azadirachta indica*), Turmeric (*Curcuma longa*), Tulsi (*Ocimum sanctum*), Ginger (*Zingiber officinale*) possess potent antimicrobial and anti-inflammatory properties that can help mitigate the infection's impact. This review discusses the application of these herbs in various forms such as decoctions, powders, and oils for nasal cleansing, immune support, and inflammation reduction. Additionally, practices like Jal Neti (nasal irrigation) and steam inhalation are highlighted as preventive strategies to clear nasal passages and eliminate pathogens before they can cause harm.

Integrating these Ayurvedic approaches with timely medical intervention could significantly reduce the morbidity and mortality associated with *N. fowleri*. By emphasizing early diagnosis, immediate application of Ayurvedic first aid, and ongoing preventive measures, this review underscores the potential for a holistic approach to safeguarding rural populations from this deadly pathogen. This synergistic model of healthcare could serve as a template for managing other infectious diseases in resource-limited settings.

Keywords: *N. fowleri*, brain-eating amoeba, Ayurvedic medicine, early treatment, rural communities, preventive healthcare, India.

1. Introduction

Occurrence of *N. fowleri* Infections

N. fowleri, commonly known as the brain-eating amoeba, is a free-living microorganism found in warm freshwater environments such as lakes, rivers, and hot springs. It causes a rare but fatal brain infection called primary amebic meningoencephalitis (PAM). PAM typically occurs when contaminated water enters the nasal passages, allowing the amoeba to travel up the olfactory nerve to the brain, where it causes severe inflammation and tissue destruction.

Risk Factors in Rural Communities

Rural communities in India are particularly vulnerable to *N. fowleri* infections due to several environmental, socio-economic, and infrastructural factors:

1. Dependence on Natural Water Sources:

Many rural areas lack access to treated and piped water supplies, relying instead on natural water bodies such as ponds, rivers, and wells for bathing, washing, and drinking. These water sources, especially in warmer climates, provide a suitable habitat for *N. fowleri* to thrive.

2. Lack of Awareness and Education: There is generally a low level of awareness about *N. fowleri* and the risks associated with using untreated water. Educational campaigns about the dangers of the amoeba and preventive measures are often limited, contributing to the persistence of risky behaviors such as swimming or bathing in contaminated water.

3. Inadequate Health Infrastructure: Rural areas frequently suffer from inadequate healthcare infrastructure, including limited access to medical facilities and trained healthcare professionals. This results in delays in diagnosis and treatment of infections. In the case of *N. fowleri*, early detection and treatment are crucial for survival, but the lack of rapid diagnostic tools and specialized knowledge can lead to fatal outcomes.

4. Environmental Conditions: The warm climate prevalent in many parts of rural India creates ideal conditions for the growth and proliferation of *N. fowleri*. Higher temperatures accelerate the life cycle of the amoeba, increasing the likelihood of human exposure during activities involving water contact.

5. Cultural Practices: Cultural practices such as ritual bathing in communal water bodies can also elevate the risk of infection. These practices are deeply ingrained and often performed without considering the potential health risks posed by waterborne pathogens.

Reported Cases and Impact

Although *N. fowleri* infections are rare, they are almost always fatal. The rarity of the disease contributes to a general lack of clinical experience and preparedness among healthcare providers, exacerbating the challenges in managing such cases when they do occur. Reported cases in India, although sporadic, highlight the critical need for increased vigilance and improved public health measures in rural settings. The contextual background underscores the urgent need for enhanced awareness, better healthcare infrastructure, and effective preventive measures to protect rural communities in India from *N. fowleri* infections. Addressing these challenges through a combination of modern medical practices and traditional Ayurvedic medicine could significantly reduce the incidence and fatality rates associated with this deadly pathogen.

Importance of the Study: Exploring Alternative and Complementary Treatments for *N. fowleri* Infections

Significance of Alternative Treatments

1. Delays in Diagnosis and Treatment: *N. fowleri* infections are challenging to diagnose and treat promptly due to their rarity and the rapid progression of the disease. Primary amebic meningoencephalitis (PAM), caused by *N. fowleri*, often leads to death within a week of

symptom onset. Early symptoms resemble bacterial meningitis, leading to potential misdiagnosis and treatment delays (Marciano-Cabral & Cabral, 2007). Rapid and accurate diagnosis is critical for patient survival but is often hampered by the limited availability of diagnostic tools and expertise, especially in rural areas (Cope *et al.*, 2015).

2. Limited Effectiveness of Conventional Treatments: The current treatment regimen for *N. fowleri* infections includes a combination of drugs such as amphotericin B, miltefosine, fluconazole, rifampin, and azithromycin. However, these treatments have had limited success, with only a few documented survivors. The high mortality rate, despite aggressive treatment, underscores the need for alternative and adjunctive therapies (Schuster & Visvesvara, 2004).

3. Potential of Ayurvedic Medicine: Ayurvedic medicine, with its holistic approach and use of natural remedies, offers a promising complementary strategy. Ayurveda has a rich history of treating various infectious diseases using medicinal plants and traditional formulations that have anti-inflammatory, antimicrobial, and immune-boosting properties (Gogtay *et al.*, 2002). Exploring Ayurvedic treatments can provide additional therapeutic options that may help mitigate the infection's impact and enhance the effectiveness of conventional therapies (Patwardhan & Mashelkar, 2009).

4. Accessibility and Cultural Acceptance: In rural Indian communities, Ayurvedic medicine is widely accepted and practiced due to its deep cultural roots and accessibility. Integrating Ayurvedic treatments into the existing healthcare framework can facilitate quicker adoption and adherence to treatment protocols, especially where modern medical facilities are lacking (Singh, 2010). This integration can enhance the overall healthcare response, providing a more robust defense against *N. fowleri* infections.

5. Preventive Measures: Ayurvedic medicine also emphasizes preventive care through lifestyle modifications and herbal prophylactics. Educating communities about these practices can help reduce the incidence of *N. fowleri* infections. For example, using nasal oils or herbal decoctions may offer protective barriers against pathogens entering through the nasal passages, a common route for *N. fowleri* infection (Sharma, 1996). The significance of this study lies in its potential to bridge the gap between traditional and modern medicine, offering a comprehensive approach to managing *N. fowleri* infections. By exploring the efficacy of Ayurvedic medicine, we can provide alternative and complementary treatments that are accessible, culturally accepted, and potentially lifesaving. This holistic approach could lead to improved outcomes and reduced mortality in affected rural communities.

Objectives:

Evaluate Ayurvedic medicine's efficacy in managing *N. fowleri* infections. Investigate early treatment strategies, focusing on timely diagnosis and effective clinical management. Assess the potential synergistic effects of combining Ayurvedic medicine with conventional treatments. Identify preventive measures and lifestyle modifications advocated in Ayurveda to reduce infection risks. Provide evidence-based recommendations for integrating Ayurvedic principles into public health initiatives.

2. Overview of *N. fowleri*

Description of the Pathogen

N. fowleri is a thermophilic, free-living amoeba found in warm freshwater environments, such as lakes, rivers, and hot springs, and poorly maintained or improperly chlorinated swimming pools. It belongs to the phylum Percolozoa, class Heterolobosea. Commonly referred to as the "brain-eating amoeba," it is known for causing a rare but often fatal infection of the brain called primary amoebic meningoencephalitis (PAM).

Morphology

N. fowleri exists in three distinct forms:

1. Cyst: The cyst form is spherical, with a smooth, single-layered wall. It is the most resilient form, enabling the amoeba to withstand harsh environmental conditions. In this dormant stage, the amoeba can survive in unfavorable conditions such as cold temperatures and dryness.

2. Trophozoite: The trophozoite is the active, feeding, and reproductive stage. It is amoeboid in shape and measures about 10-35 micrometers in diameter. The trophozoite has pseudopodia (temporary arm-like projections) that it uses for movement and to engulf food, such as bacteria and yeast. This stage is responsible for causing infection in humans.

3. Flagellate: The flagellate form is a temporary, motile stage that occurs when trophozoites are exposed to a change in ionic concentration, such as being placed in distilled water. This stage is pear-shaped and has two flagella that enable it to move rapidly. The flagellate stage does not divide and can revert to the trophozoite stage.

Life Cycle

The life cycle of *N. fowleri* involves the transition between its three forms—cyst, trophozoite, and flagellate depending on environmental conditions.

Acanthamoeba spp. are ubiquitous in the environment and have been found in a variety of sites, including soil; fresh, brackish, and seawater; field-grown vegetables; sewage; swimming pools; contact lens supplies; medicinal pools; dental treatment units; dialysis machines; heating, ventilating, and air conditioning systems; and tap water; mammalian cell cultures; and vegetables. *Acanthamoeba* has two stages; (1) cysts and (2) trophozoites in its life cycle and lacks a flagellate stage. The trophozoites replicate by mitosis (3) (nuclear membrane does not remain intact). The trophozoites are the infective forms,

although both cysts and trophozoites can enter the (4) body through various means. Entry can occur through the (5) eye, the nasal passages to the lower respiratory tract (6), or ulcerated or broken skin (7). When *Acanthamoeba* spp. enters the eye, it can cause severe keratitis in otherwise healthy individuals, particularly contact lens users (8). When it enters the respiratory system or through the skin, it can invade the central nervous system by hematogenous dissemination causing granulomatous amoebic encephalitis (GAE) (9) or disseminated disease (10), or skin lesions (11) in individuals with compromised immune systems. Both *Acanthamoeba* spp. cysts and trophozoites are found in tissue.

Infection in Humans

N. fowleri can infect humans when contaminated water enters the body through the nose. This usually occurs during activities such as swimming or diving in warm freshwater bodies. The infection process involves several steps:

1. Entry: The trophozoite form of the amoeba enters the nasal passages when a person comes into contact with contaminated water.

2. Migration: The amoeba adheres to the olfactory epithelium, penetrates the nasal mucosa, and migrates along the olfactory nerves through the cribriform plate into the brain.

3. Brain Infection: Once in the brain, *N. fowleri* trophozoites consume brain tissue by releasing cytolytic substances and proteases. This leads to the destruction of brain cells and the subsequent inflammation and necrosis characteristic of primary amoebic meningoencephalitis (PAM).

4. Symptoms and Progression: The symptoms of PAM typically appear 1-9 days after exposure and include severe headache, fever, nausea, vomiting, stiff neck, confusion, loss of balance, seizures, and hallucinations. The disease progresses rapidly, often leading to death within about 5 days of symptom onset if not treated promptly and effectively.

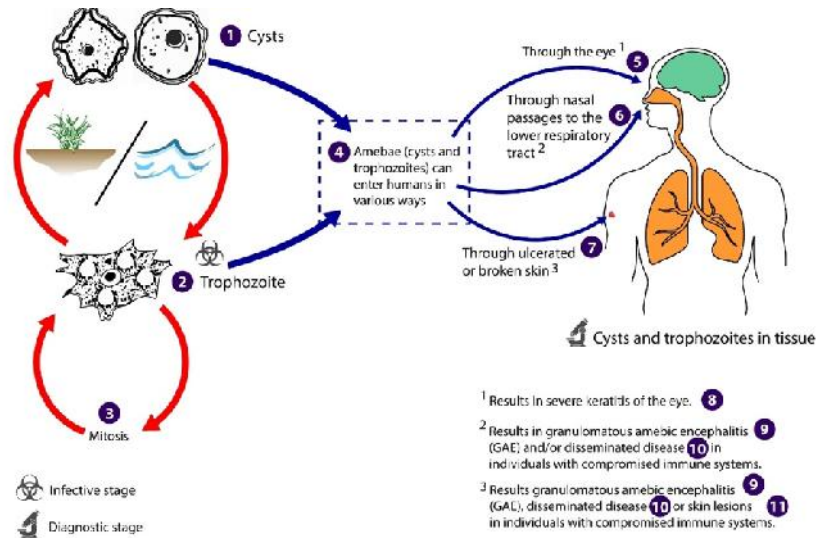


Fig-1 Life Cycle of *Acanthamoeba* spp

Epidemiology: *N. fowleri* infections are rare but almost always fatal. Most cases occur in the summer months when water temperatures are higher, and in geographical locations with warm climates. The amoeba is found worldwide, but infections are most reported in the United States, particularly in southern states.

Prevention

Preventing *N. fowleri* infections involves minimizing exposure to potentially contaminated water. Recommendations include:

-)] Avoiding activities in warm freshwater during high-temperature months.
-)] Using nose clips or keeping the head above water when swimming in warm freshwater.
-)] Ensuring proper maintenance and chlorination of swimming pools and other recreational water facilities.
-)] Avoiding the use of untreated tap water for nasal irrigation or sinus rinsing.

Understanding the biology, life cycle, and infection mechanisms of *N. fowleri* is crucial for developing effective prevention and treatment strategies against this deadly pathogen.

Transmission and Symptoms: The amoeba typically enters the human body through the nasal passages during activities such as swimming,

diving, or bathing in contaminated water. Once inside, it can travel to the brain, causing infection.

Symptoms of infection include Severe headache, Fever, Nausea, Vomiting, Stiff neck, Confusion, Loss of balance, Seizures, and Hallucinations

These symptoms usually appear within 1-9 days after exposure and can rapidly progress, requiring prompt medical attention.

Challenges in Diagnosis and Treatment:

Early Diagnosis:

)] **Non-specific Symptoms:** Initial symptoms of the infection, such as headache, fever, and nausea, are like those of common viral or bacterial infections, making early diagnosis difficult.

)] **Rapid Progression:** The infection progresses quickly, often within days, leaving a narrow window for accurate diagnosis and effective treatment.

)] **Limited Awareness:** Many healthcare providers may not immediately consider amoebic infections, particularly *N. fowleri*, due to their rarity.

Treatment:

) **Lack of Effective Drugs:** There are few effective treatments available, and the standard treatments may not always be successful.

) **Late Detection:** By the time the infection is accurately diagnosed, it is often in an advanced stage, reducing the likelihood of successful treatment.

) **Severe Outcomes:** Due to the rapid progression and difficulty in early diagnosis, the infection often leads to severe outcomes, including high mortality rates. Prompt recognition and aggressive treatment are crucial for improving survival chances.

1. Aayurvedic Medicine: An Overview

Principles of Ayurveda: Ayurveda, an ancient system of medicine from India, is based on a holistic approach to health and disease prevention. It emphasizes balance in the body, mind, and spirit and focuses on maintaining health through a balanced lifestyle. Key principles include:

) **Doshas:** Ayurveda identifies three fundamental energies or doshas—Vata, Pitta, and Kapha—that govern bodily functions. Everyone has a unique combination of these doshas, which influences their health and personality.

) **Prakriti:** An individual's constitution or Prakriti, determined by the balance of doshas, dictates their susceptibility to various diseases and their response to treatments.

) **Agni:** Digestive fire or Agni is crucial for health. Proper digestion, absorption, and assimilation of food are essential for maintaining health and preventing disease.

) **Ojas:** Vital essence or Ojas represents the body's immunity and overall vitality. Strong Ojas is associated with good health and resilience to disease.

Relevant Ayurvedic Practices:

1. Medicinal Herbs & Ayurvedic Herbs and Their Efficacy:

Neem (*Azadirachta indica*): Known for its antibacterial, antiviral, and antifungal properties, neem is used to prevent and treat various infections. Neem has strong antibacterial, antiviral, and antifungal properties, making it effective against a wide range of pathogens. (Biswas et.al., 2002).

Methods of Use:

Decoctions: Boil neem leaves in water and use the liquid for washing wounds or as a gargle for throat infections.

Oils: Neem oil can be applied to the skin to treat infections, wounds, and other skin conditions. (Tiwari et.al., 2012).

Tulsi (*Ocimum sanctum*): Also known as holy basil, tulsi has antimicrobial and anti-inflammatory properties that help boost immunity and fight infections.

Immune-boosting and Antimicrobial Properties: Tulsi, or holy basil, enhances immune function and has antibacterial, antiviral, and antifungal properties. (Cohen 2014).

Usage Methods:

Fresh Leaves: Chewing fresh tulsi leaves or adding them to food can boost immunity. (Mondal, et.al., 2009)

Decoctions: Boiling tulsi leaves in water to make tea can help relieve respiratory infections and improve overall health.

Turmeric (*Curcuma longa*): Contains curcumin, which has powerful anti-inflammatory and antimicrobial effects, making it useful in treating infections.

Anti-inflammatory and Antiseptic Properties:

Turmeric contains curcumin, which has powerful anti-inflammatory and antiseptic effects. It helps reduce inflammation and fight infections. (Aggarwal et.al., 2009)

Forms of Consumption:

In Warm Water: Mixing turmeric powder in warm water can help with digestion and boost immunity.

In Milk: Known as "golden milk," mixing turmeric with warm milk is a popular method for reducing inflammation and promoting overall health. (Hewlings et.al., 2017)

Ashwagandha (*Withania somnifera*): An adaptogenic herb that enhances immune function and helps the body resist infections. An adaptogen that helps reduce stress, enhance immune function, and increase energy levels. It can be consumed as a powder, capsule, or in herbal teas.

Ginger (*Zingiber officinale*):

Antioxidant and Anti-inflammatory Effects:

Ginger contains bioactive compounds like gingerol and shogaol, which possess antioxidant and anti-inflammatory properties. (Mashhadi, et.al., 2013).

Ways to Use:

Ginger Tea: Boiling fresh ginger slices in water to make tea is a popular method to alleviate inflammation and promote digestive health.

Mixed with Honey: Combining ginger juice with honey creates a soothing remedy for coughs and sore throats. (Shukla and Singh, (2007).

Additional Herbs:

Amla (*Indian Gooseberry*): Rich in vitamin C, amla boosts immunity, has antioxidant properties, and is used to improve skin and hair health. It can

be consumed as fresh fruit, juice, or in powder form.

Garlic (*Allium sativum*): Known for its antimicrobial and immune-boosting properties, garlic can be eaten raw, added to food, or taken as supplements to combat infections and improve cardiovascular health.

Brahmi (*Bacopa monnieri*): Known for its cognitive-enhancing properties, Brahmi improves memory, reduces anxiety, and acts as an antioxidant. It can be used as a powder, capsule, or in herbal teas.

Nasal Cleansing Techniques (Neti):

Jala Neti: This practice involves flushing the nasal passages with saline water to clear out mucus, allergens, and pathogens. It helps maintain nasal hygiene and prevent respiratory infections.

Nasya: This involves administering herbal oils or powders into the nostrils to lubricate the nasal passages, enhance respiratory function, and prevent infections. It is particularly beneficial in balancing the Kapha dosha and promoting respiratory health. Ayurvedic practices, by emphasizing balance and natural remedies, offer complementary approaches to modern medicine in the prevention and treatment of infections.

2. Preventive Measures and First Aid

Nasal Cleansing (Jal Neti): Detail the procedure and its benefits in preventing *N. fowleri* from entering the brain.

Steam Inhalation: Explain how to perform steam inhalation and its role in killing pathogens in the nasal passages.

Hydration and Nutrition: Emphasize the importance of maintaining proper hydration and nutrition to support the immune system.

Herbal Teas and Decoctions: Provide recipes and preparation methods for herbal teas that boost immunity and prevent infections.

3. Discussion

Effectiveness of Ayurvedic Treatments:

The efficacy of Ayurvedic treatments varies based on available evidence. While some studies suggest promising results for certain Ayurvedic interventions, such as the use of herbs like turmeric and tulsi for their anti-inflammatory and antimicrobial properties, the overall evidence base is limited and often inconclusive. More rigorous research, including randomized controlled trials, is needed to determine the true effectiveness of Ayurvedic treatments (Rathaur *et al.*, 2008; Cohen, 2014).

4. Challenges and Limitations:

Several challenges and limitations exist in the application of Ayurvedic medicine. These include a lack of standardized protocols and quality control measures, variability in the composition and potency of herbal formulations, and a paucity of high-quality clinical trials (Saper *et al.*, 2008). Additionally, cultural and language barriers may hinder the dissemination of Ayurvedic knowledge and practices to wider populations. Moreover, there is a need for better integration of Ayurvedic medicine with modern healthcare systems to ensure safe and effective treatment outcomes (Patwardhan & Mashelkar, 2009).

5. Future Research Directions:

Future research in Ayurveda should focus on conducting well-designed clinical trials to evaluate the efficacy and safety of Ayurvedic treatments for various health conditions. There is a need for the development of standardized protocols and quality assurance measures to ensure consistency and reproducibility of Ayurvedic formulations. Furthermore, research should explore the potential synergistic effects of integrating Ayurvedic medicine with modern treatments, particularly in chronic and complex diseases. Collaborative efforts between Ayurvedic practitioners, researchers, and healthcare professionals can help advance the evidence base

and promote the integration of Ayurveda into mainstream healthcare practices (Rao & Rao, 2017).

6. Conclusion

In conclusion, the review highlights the potential benefits of using Ayurvedic medicine in conjunction with early treatment for *N. fowleri* infections. While the evidence supporting the efficacy of Ayurvedic treatments for specific infections is still evolving, several herbs such as neem, turmeric, tulsi, and ginger possess antimicrobial, anti-inflammatory, and immune-boosting properties that could aid in the prevention and management of infections caused by *N. fowleri*. Integrating Ayurvedic medicine with modern treatment approaches may offer a holistic and complementary approach to combating these infections, especially in rural communities where access to healthcare services may be limited.

7. Recommendations:

To effectively implement these strategies in rural communities, the following recommendations are proposed:

- 1. Education and Awareness Campaigns:** Conduct educational programs to raise awareness about the potential benefits of Ayurvedic medicine in preventing and managing infections. This could involve training healthcare providers and community members on the use of Ayurvedic herbs and practices.
- 2. Community-based Healthcare Initiatives:** Establish community health centers or mobile clinics that offer integrated healthcare services, including Ayurvedic treatments, alongside modern medical care.
- 3. Promotion of Herbal Gardens:** Encourage the cultivation of medicinal herbs in community gardens or individual households to increase access to fresh and locally sourced Ayurvedic remedies.

4. **Research and Monitoring:** Support research initiatives to evaluate the efficacy and safety of Ayurvedic treatments for various infections, including *N. fowleri*, through rigorous clinical trials and monitoring of outcomes.
5. **Policy Support:** Advocate for policies that recognize and regulate Ayurvedic medicine within the broader healthcare system, ensuring quality control and adherence to safety standards.

By implementing these recommendations, rural communities can harness the potential of Ayurvedic medicine to complement existing healthcare practices and effectively prevent and manage infections caused by *N. fowleri* and other pathogens. Collaboration between government agencies, healthcare providers, researchers, and community leaders is essential to facilitate the integration of Ayurveda into rural healthcare systems and improve health outcomes for all.

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