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Trichinellosis: The Silent Parasite in Meat and Its Public Health Significance

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Abstract

The parasitic roundworms of the genus Trichinella are the source of the food-borne zoonotic disease trichinellosis. Eating raw or undercooked pork or meat from wild animals with infectious larvae can infect humans. Despite being relatively rare in many nations, the disease's extensive distribution, effects on food safety, and financial losses related to livestock production, meat inspection, and trade restrictions make it a significant veterinary and public health concern. When the larvae go into skeletal muscles, the disease first manifests as gastrointestinal symptoms like diarrhoea and stomach discomfort, which are followed by fever, facial oedema, muscle pain, weakness, and noticeable eosinophilia. Clinical history, blood results, serological testing, molecular methods, and, in certain situations, muscle biopsies are used to make the diagnosis. Treatment is done with albendazole or mebendazole, which is frequently coupled with corticosteroids in severe cases. Since there is presently no approved vaccine, prevention relies on appropriate meat preparation, regular meat inspections, enhanced farm biosecurity, increased public knowledge, and integrated One Health surveillance to lower transmission in both humans and animals.

Introduction

Trichinellosis, often known as trichinosis, is a serious food-borne zoonotic illness that affects people, domestic animals, and wildlife. It is caused by parasitic worms called *Trichinella spp*. The disease is contracted by eating raw or undercooked meat that contains infective larvae especially pork and meat of wild carnivores (Gottstein *et al.*, 2009). The parasite still poses a serious threat to public health and the economy in many parts of Asia, Eastern Europe, South America, and Africa, despite the fact that improved meat inspection and food safety procedures have decreased the frequency of trichinellosis in many affluent nations (Pozio and Murrell. 2009). Although trichinellosis has long been regarded as a

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neglected zoonosis in India, new molecular research suggests that the variety and distribution of Trichinella species may be higher than previously thought (Kalambhe *et al.*, 2024).

Etiology

Trichinella is a member of the Trichinellidae family within the phylum Nematoda. Based on molecular and biological traits, 12 species and many genotypes have been identified so far. Although *T. britovi, T. nativa, T. pseudospiralis, T. nelsoni, T. murrelli, T. papuae, and T. zimbabwensis* have all been linked to human illnesses, *Trichinella spiralis* is the most significant species that infects humans (Gajadhar and Gamble. 2000). Each infected animal serves as both the definitive and intermediate host because, in contrast to other nematodes, Trichinella completes its life cycle in a single host. The parasite's extraordinary capacity to survive in the natural world is partly due to its special biological characteristic (Pozio and Murrell. 2009).

Life Cycle of the parasite

When a susceptible host eats meat that contains live encysted first-stage larvae (L1), the life cycle starts. The larvae are released during gastric digestion and reach into the small intestine's epithelial cells (Pozio and Murrell. 2009). The larvae develop into adult worms and mate in around 30 to 48 hours. While female worms produce thousands of newborn larvae over several weeks, male worms die soon after fertilisation. These young larvae move throughout the body after entering the blood and lymphatic systems. The only larvae that survive are those that infiltrate striated skeletal muscles. They change the infected muscle cell inside muscle fibres into a specialised "nurse cell," where the larvae become encapsulated (apart from non-encapsulated species) and stay contagious for months or years. When another carnivore or omnivore eats contaminated meat, the life cycle is finished (Mitreva and Jasmer. 2006).

Host Specificity

Among parasitic nematodes, Trichinella has one of the widest host ranges. There have been reports of over 150 species of birds, reptiles, and mammals serving as natural hosts. Globally, domestic pigs are the main source of human infection. Wild boars, bears, foxes, wolves, horses, walruses, crocodiles, and a variety of carnivorous animal species are additional significant reservoirs (Gajadhar and Gamble. 2000). Two interrelated epidemiological cycles are used by the parasite to spread:

---**Domestic cycle**: pigs, rats, and sometimes canines are involved.

---**Sylvatic cycle**: omnivores and wild carnivores.

Transmission between these cycles occurs through scavenging, predation, improper disposal of carcasses, and feeding pigs with infected meat waste.

Economic Impact: Global and Indian Scenario

Global Perspective: Public health institutions, the livestock industry, and the global meat trade all suffer significant financial losses as a result of trichinellosis (Roberts *et al.*, 1994). Trichinellosis is recognised by the World Health Organization and the World Organization for Animal Health as a significant food-borne zoonosis that necessitates ongoing surveillance due to the ongoing chances for transmission created by the globalisation of the meat trade and the rising consumption of wild carnivore’s meat. Hospitalisation expenses, loss of productivity and outbreak investigations are other consequences of human outbreaks (Murrell and Pozio. 2000).

Indian Scenario: In the past, India has recorded very few confirmed human cases, mostly due to poor surveillance and underdiagnosis rather than the lack of infection. Trichinella was first reported in 1942, and it was isolated from animals in West Bengal in the 1960s (Schad and Chowdhury. 1967; Maplestone and Bhaduri. 1942). The epidemiology may be more complicated than previously thought, as recent molecular studies have revealed genetically unique Trichinella genotypes circulating across Indian fauna (Kalambhe *et al.*, 2024). As a result, trichinellosis is no longer just considered a neglected illness but rather an emergent food safety concern in India (Ram *et al.*, 2018).

Pathogenesis Inside the Host: The disease develops in three overlapping phases.

Intestinal Phase: Adult worms harm epithelial cells and trigger inflammatory reactions; larvae breach the intestinal mucosa after ingestion, resulting in enteritis, which is characterised by stomach pain, nausea, vomiting, diarrhoea, and mild fever.

Migratory Phase: Newborn larvae spread through lymphatic and blood arteries. The host suffer from severe eosinophilia and systemic inflammatory responses during migration. Common symptoms include fever, headache, conjunctivitis, facial oedema, and allergic reactions.

Muscle Phase: Highly active skeletal muscles, including the diaphragm, tongue, extraocular muscles, masseter, and intercostal muscles, are invaded by larvae. They use substantial molecular remodelling to turn infected muscle fibres into nurse cells. In addition to protecting the parasite, this special nurse-cell complex modifies host cell metabolism, angiogenesis, immunological responses, and gene expression. Severe myalgia, dysphagia, muscle weakness, and persistent exhaustion are the observed clinical symptoms. Myocarditis, encephalitis, and pneumonia can occur and be lethal in cases of severe infections (Pozio and Murrell. 2009; Mitreva and Jasmer. 2006).

Diagnosis

Due to the fact that many febrile disorders share similar clinical indications, early identification is still difficult. As a result, the diagnosis is based on a number of factors, including the patient's history of eating raw or undercooked pork or wild carnivore's meat, clinical signs such as fever with facial oedema, severe myalgia, and peripheral eosinophilia, laboratory tests, molecular assays, and parasitological confirmation (Gottstein *et al.*, 2009). Various serological tests are the most popular diagnostic techniques. Because of its high sensitivity and specificity after two to three weeks of infection, the **Enzyme-linked immunosorbent assay** (ELISA) is regarded as the major screening test. Western blot is frequently used to validate positive ELISA results, increasing diagnostic precision and reducing false-positive reactions (Mapplestone and Bhaduri. 1942). Trichinella species and genotypes from infected muscle tissues are increasingly being identified using molecular methods such as DNA sequencing, multiplex PCR, real-time PCR, and polymerase chain reaction (Pozio and Murrell. 2009). In certain situations, **Muscle Biopsy** is still the most reliable diagnostic technique. Under a microscope, samples taken from the quadriceps, gastrocnemius, or deltoid muscles may show distinctive encysted larvae and nurse-cell complexes (Gajadhar and Gamble. 2000). The World Organization for Animal Health (WOAH) and the International Commission on Trichinellosis suggest the artificial digestion approach for routine surveillance in food animals. When it comes to identifying larvae in pig and horse meat intended for human consumption, this technique is more sensitive than traditional trichinoscopy (Mitreva and Jasmer. 2006).

Treatment

Prompt treatment during the intestinal phase significantly reduces disease severity by eliminating adult worms before extensive larval migration occur. The principal anthelmintic drugs used are:

- **Albendazole** (400 mg twice daily for 8–14 days)
- **Mebendazole** (200–400 mg three times daily for 3 days, followed by 400–500 mg three times daily for 10 days)

In patients with severe disease or complications like myocarditis, encephalitis, or severe allergic manifestations, corticosteroids, especially prednisone, are used in conjunction with antiparasitic therapy. Supportive treatment consists of analgesics for muscle pain, antipyretics for fever, adequate hydration, nutritional support, and, in severe cases, cardiac and neurological monitoring. These benzimidazole compounds are highly effective against adult worms and migrating larvae (Gottstein *et al.*, 2009).

Control Strategies

Effective control requires a One Health approach integrating veterinary, medical, and environmental interventions.

On farms: Preventing pigs from consuming raw meat waste, maintaining strict rodent control, improvinng biosecurity and hygiene and proper disposal of animal carcasses.

At slaughterhouses: Routine inspection using artificial digestion methods, surveillance of pigs and wildlife reservoirs and enforcement of food safety standards.

Consumer education: Thorough cooking of pork and wild carnivore's meat to safe internal temperatures, avoiding consumption of raw or undercooked meat products and public awareness regarding food-borne zoonoses.

Wildlife management: Monitoring infection in wild boars and carnivores, safe disposal of hunted carcasses and surveillance of sylvatic transmission cycles.

Research Priorities: Molecular surveillance of circulating species, especially in nations like India where epidemiological data is still scarce, through enhanced diagnostic methods, vaccine development, and empowering national surveillance systems (Gajadhar and Gamble. 2000; Pozio and Murrell. 2009; Ram *et al.*, 2018).

Vaccination Strategy

Despite decades of research, **no commercially available vaccine exists for trichinellosis in humans or food-producing animals** (Wang and Cui. 2024).

Experimental Vaccine Development

- Numerous vaccine candidates, such as excretory-secretory (ES) antigens, cathepsins, serine proteases, surface proteins, peptide vaccines, and recombinant protein vaccines, have been studied by researchers to target various stages of parasite development.
- Partial protection has been shown by experimental immunisation in mice, as evidenced by lower muscle larval counts and intestinal worm burdens. Sterile immunity has not yet been attained (Wang and Cui. 2024). The intricate parasite life cycle, genetic variety among *Trichinella* spp., immune evasion mechanisms, stage-specific antigen expression and practical difficulties in vaccinating cattle and wildlife reservoirs are some of the main barriers to vaccine development.

Conclusion

One of the most significant food-borne parasite zoonoses in the world is still *Trichinella* spp. Eradication is challenging due to their distinct biology, wide host range, and capacity to move between domestic animals and wildlife. Trichinellosis still poses a hazard to food safety in a number of developing nations, despite the fact that many affluent countries have successfully decreased disease incidence through better husbandry and meat inspection. India has a higher diversity of Trichinella than previously thought, according to recent molecular studies. Thus, there is a need of more thorough surveillance, enhanced diagnostic capabilities, and robust food safety regulations. To reduce the public health and financial impact of this neglected zoonosis, integrated One Health approach involving veterinarians, doctors, wildlife biologists, food safety authorities, and policymakers will be crucial.

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