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Usefulness of imaging techniques in the diagnosis of zoonotic parasitic infections: A Review

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Abstract
Advancements in the diagnostic imaging techniques have facilitated the detection and management of parasitic zoonotic diseases more effectively. Increase in the global population and modern lifestyle has intensified the risk of exposure to contaminated food and water sources infecting millions of people across the globe. The parasitic infections may be of protozoal or helminthic origin. Non-invasive imaging techniques such as Computed Tomography, Radiography, Ultrasonography, Contrast-Enhanced Ultrasound, Magnetic Resonance Imaging along with Fundoscopy, Endoscopy, Endoscopic Retrograde Cholangiopancreatography, and Colonoscopy have revolutionized the diagnosis of parasitic diseases. These imaging techniques promotes visualization of the parasites with its location and extent of the damage across various organs. Imaging techniques along with clinical history, examination and laboratory findings helps in the early intervention, effective management, and appropriate treatment of the diseases especially in areas with denser population and poor sanitation. This review emphasizes the necessity for enhanced surveillance, community education, and collaboration across the medical and veterinary sectors in mitigation of the global burden of zoonotic parasitic infections.

Keywords: Parasitic infections, zoonosis, diagnosis, imaging techniques

Introduction
The rapid rise in the global population with improved living standards, increased international travel and climatic change has intensified concerns regarding the safety and quality of food and water resources. The health of humans, animals and environment is closely interconnected. Zoonotic diseases, which are naturally transmitted between animals and humans, not only pose significant public health risks but also result in greater economic losses in both healthcare and livestock sectors. Hence, efforts should be taken to mitigate risks and help in the timely diagnosis of these diseases among diseased population to promote sustainable health outcomes. It is reported by the World Health Organization (WHO) that 1.7 billion people across the globe use drinking water contaminated with faecal matter (WHO, 2023) [21]. An estimate of 21% of the Indian population is reported to be infested with helminthic parasites which cause 39 million disability-adjusted life years (DALYs) of illness worldwide (Praharaj *et al*., 2017) [17].

Parasitic infections continue to pose a significant health problem worldwide, impacting millions of individuals globally. It is reported that approximately 3.5 billion people are affected by intestinal parasites with more than 450 million related illness and 200000 deaths every year (Bhaumik *et al*., 2025) [2]. These infections are caused by various parasites including protozoa, helminths and arthropods which are transmitted through various routes such as direct contact or consumption of contaminated food and water. The impacts are malnutrition, anaemia, organ damage, impaired immunity and economic burden to humans. The parasitic infections may be of protozoal or helminthic origin (Jen Huang, 2023) [9]. It is observed that 24% of the global population is infected with Gastro intestinal parasites (GIPs) (Dabrowska *et al*., 2024) [6]. The increased prevalence has resulted in a rise in both morbidity and mortality. In India, these diseases often go under reported due to factors like improper surveillance and monitoring, unawareness among public, and presence of asymptomatic animal carriers. The emergence and re-emergence of parasitic zoonoses pose serious challenges, especially in highly dense areas with poor sanitation and close human-animal interactions.

To address these challenges, it requires an integrated approach combining enhanced surveillance, community education, improvement in sanitation, and collaboration between human and veterinary health sectors to effectively prevent the spread of the diseases. Accurate and rapid diagnosis represents the crucial weapon in combating parasitic infections.

The major parasitic zoonotic infections are toxoplasmosis, cryptosporidiosis, sarcocystosis, amoebiasis, giardiasis, balantidiasis, fascioliasis, fasciolopsiasis, dicrocoeliasis, paragonimiasis, opisthorchiasis, clonorchiasis, taeniasis (cysticercosis), echinococcosis, trichinellosis, and toxocariasis.

Diagnostic Imaging Techniques

Imaging techniques have become a tool in accurate diagnosis of parasitic infections by providing a non-invasive way of viewing the presence, location of the parasite and extent of parasitic lesions within the body making the diagnosis and treatment more effective. Although brain biopsy with laboratory testing is reported to be the gold standard in the diagnosis, neuroimaging plays a major role in both diagnosis and monitoring by revealing the severity and complications of the disease (Jayakumar *et al*., 2013) [10].

Computed Tomography (CT)

The Computed Tomography (CT) is a computerized imaging method that uses a thin X-ray beam, which rotates rapidly around the patient's body, capturing the data that the computer converts into cross-sectional images, or "slices," known as tomographic images. These series of images are digitally merged to develop a three-dimensional (3D) image of the visceral structures.

- **Pulmonary paragonimiasis -** Better visualization of multiple nodules in the thorax is achieved better by CT than radiographic imaging.
- **Cerebral paragonimiasis -** The CT of brain shows distinctive ring-shaped shadows described as ‘grape cluster’ or ‘soap bubble appearance’ in one hemisphere of the cerebral cortex (Singh *et al*., 2012) [19].
- **Fascioliasis** - Contrast-enhanced abdominal CT scan helps in viewing Fasciola hepatica in humans, revealing hypodense, track like hepatic lesions (Caravedo and Cabada, 2020) [4].
- **Cerebral Schistosomiasis -** The CT scan shows a space occupying lesion that is non-calcified, non-haemorrhagic and nodular with prominent perilesional edema called Buddha’s hand (Jayakumar *et al*., 2013) [10].
- **Echinococcosis -** An intra-orbital hydatid cyst was observed by CT inside the left eye, near the medial rectus muscle which led to displacement of the optic nerve from its normal position without any infiltration (Alabed *et al*., 2025) [1]. CT imaging aids in detection of characteristic calcification of the lesions.
- **Neurocysticercosis -** The CT images provide a higher sensitivity to detect brain calcifications and clearly show the intracranial cystic lesions with scolex (Guzman *et al*., 2021) [8].
- **Trichinellosis** - Muscles are visualized for inflammatory lesions.
- **Toxocariasis** - The CT reveals multiple hypoattenuating well defined lesions in both cortical and subcortical areas of brain, and granulomas in liver (Jayakumar *et al*., 2013) [10].
- **Amoebiasis -** The CT identifies amoebic colitis, including deep ulceration, patchy distribution of colitis and omental wrapping. However, CT alone should not be used solely for diagnosing amoebic colitis as its imaging features may be closely resembling Inflammatory Bowel Disease (IBD) making the differentiation difficult (Cooney *et al*., 2025) [5].
- **Cerebral toxoplasmosis -** Patients with Acquired immunodeficiency syndrome (AIDS) show contrast enhanced multiple and bilateral intraparenchymal brain lesions (Parasitic infections, 2004) [16].
- **Fascioliasis -** Detection by CT is difficult.

Radiography

The waves of electromagnetic energy produced by high-velocity electrons colliding with the metal plates are called X-Rays. The X-Ray beams form an image on the metal film upon passing through the body tissues. These high energy rays are not absorbed by soft tissue organs and skin making the beam pass through them while denser areas (bones) absorb the rays. The image on the film depends on the type of area exposed. White areas show denser bones that absorbs the X-Rays whereas black areas represent soft tissues which allows the rays to pass through.

- **Paragonimiasis -** Radiography shows patchy airspace consolidation and opacity with associated pleural thickening, bilateral pleural effusion and nodular opacities. In brain, the distinctive feature is the presence of multiple conglomerate ring enhancing granulomatous lesions surrounded by edema, typically resembling “cluster of grapes” or “soap bubbles” commonly affecting one hemisphere (Jayakumar *et al*., 2013) [10].
- **Fascioliasis -** Cholangiography shows several round filling defects representing the adult worms in bile duct.
- **Neurocysticercosis** - The X-ray imaging shows numerous “cigar-shaped” calcified spots within the muscles of thigh and calf.
- **Strongyloidiasis -** Nematode Strongyloides stercoralis causing patchy or disseminated pulmonary infiltrates are seen by thoracic radiography. Barium swallow indicates dilated duodenum and jejunum with intestinal edema and narrowing of lumen due to fibrosis (Parasitic infections, 2004) [16].
- **Ascariasis -** Abdominal X-rays detects infection in liver and bile duct.
- **Amoebiasis -** The X-ray of the thorax reveals amoebic abscesses and elevation of the right hemidiaphragm, atelectasis, or pleural effusion while plain abdominal radiography indicates non-specific colitis characterised by colonic wall thickening, gaseous distension and loss of haustral folds (Moran *et al*., 2023) [15].
- **Toxoplasmosis -** Diagnosis of pneumonia caused by Toxoplasma gondii may be challenging. Thoracic radiography might reveal bilateral pulmonary infiltration with interstitial infiltrates (Parasitic infections, 2004) [16].
- **Cryptosporidiosis -** Radiographic imaging may reveal thickening of the mucosal lining and dilation of the small intestine (Parasitic infections, 2004) [16].

Ultrasonography

Ultrasonography (USG) is a non-invasive diagnostic tool to image inside the body. The transducer emits ultrasound

waves, and thereby detect the echoes reflected back. The sound waves bounce back to the transducer by the boundaries between tissues along the path of the beam. When these echoes reach the transducer, they produce electrical signals that are transmitted to the ultrasound scanner. This distance from the transducer to the tissue boundary is used to create two-dimensional images of visceral tissues and organs.

- **Fasciolopsiasis -** Adults of the trematode Fasciolopsis buski produce an inflammatory reaction in the gall bladder, showing dilatation of the bile ducts and hypertrophy of the gall bladder wall (Luo *et al*., 2025) [14].
- **Fascioliasis -** Detection of flukes in the bile duct during milder cases is challenging. But, during heavy infection the worms that parasitize the gall bladder appear as floating echogenic foci within the lumen. In addition, increased periductal echogenicity, diffuse dilatation of the intrahepatic bile ducts, and gall bladder distention are observed.
- **Hepatic alveolar echinococcosis (HAE) -** The USG is the first preferred choice of diagnostic method in the diagnosis of HAE.
- **Amoebic liver abscesses -** Diagnosis by USG is referred as the gold standard technique (Cooney *et al*., 2025) [5].

Contrast-Enhanced Ultrasound (CEUS)

- Contrast-Enhanced Ultrasound (CEUS) provides better visualization of blood vessel in liver lesions, providing more accuracy in qualitative assessment.
- The CEUS is more reliable than USG for differentiation of Alveolar echinococcosis (AE) and Cystic echinococcosis (CE) (Liu *et al*., 2025) [13].

Magnetic Resonance Imaging (MRI)

It is a non-invasive imaging technique that produces three dimensional anatomical images. Powerful and strong magnets are employed to create a strong magnetic field that makes the protons in the body to align with the field and spin against the pull of the field. After the radio frequency field is turned off, the protons realign with the magnetic field which is detected by the MRI sensors.

- **Fascioliasis -** Even though the periductal fibrosis is a characteristic sign, it is crucial to view the dilatation of the small intrahepatic bile ducts and the large bile ducts for diagnosis by MRI.
- **Paragonimiasis -** Presence of flukes in brain parenchyma shows marked "tunnel sign" indicating the migratory tracts through brain tissue (Robertson *et al*., 2025) [18].
- **Neurocysticercosis -** Intracranial lesions are visualized by the MRI.
- **Echinococcosis -** Cystic lesions with scolex can be identified.

***Cystic echinococcosis* -** The MRI imaging classifies hydatid cysts into 4 types based on the internal structure.

Type I - A simple unilocular cyst with thin wall appears as distinctive "rim sign" indicative of fibrous and inflammatory reaction around the cyst.

Type II - A complex cyst containing daughter cysts with a detached endocyst membrane can be noticed. Type II A - A cyst with several circular daughter cysts in periphery can be demonstrated like a "spoke wheel". Type II B - A mother cyst containing irregular daughter cysts can be identified with a "rosette-like" appearance. Type II C - The degenerated and collapsed daughter cysts resemble like "serpent or snake".

Type III - The dead cysts are inactive and appear densely calcified.

Type IV - Complicated cysts resemble like "water lily" and "meniscus". The cyst with rupture or superinfection, causing mass effect and spreading into adjacent brain areas can be identified by MRI (Robertson *et al*., 2025; Kraft *et al*., 2023) [18, 12].

- **Toxocariasis -** The lesions appear hypointense on T1-weighted images, and hyperintense on T2-weighted images in brain cortical and subcortical areas (Jayakumar *et al*., 2013) [10]. Imaging of orbit identifies uveal and scleral thickening along with retinal detachment and intraocular masses (Robertson *et al*., 2025) [18].
- **Neurotoxoplasmosis -** The MRI reveals lesions of isointense to hypointense on T1-weighted images and hyperintense to isointense T2-weighted images arranged in alternate concentric zones typically producing "target sign" feature (Robertson *et al*., 2025) [18].

Thus, the MRI can provide a better diagnosis than CT in uncertain cases when the lesions are non-calcified or partially calcified.

Susceptibility-weighted imaging (SWI) and Magnetic Resonance Cholangiopancreatography (MRCP)

In neurotoxoplasmosis, the SWI can reveal presence of heamorrhagic lesions in brain (Robertson *et al*., 2025) [18]. The MRCP uses MRI to visualize the common bile duct in fasciolopsiasis to identify the streak pattern caused by *Fasciolopsis buski* (Luo *et al*., 2025) [14].

Fundoscopic Examination

- **Hydatidosis -** Fundoscopy or ophthalmoscopy is useful in the diagnosis of ocular hydatid cysts caused by *Echinococcus granulosus* and ocular toxocariasis (Dietrich *et al*., 2020) [7].
- **Ocular toxoplasmosis -** Chorioretinitis caused by *Toxoplasma gondii* can be diagnosed using ophthalmoscopy characterized by clusters of necrotizing retinitis that appear as elevated, whitish-yellow cottony patches with indistinct, blurred margins (Parasitic infections, 2004) [16]. The presence of "headlights in the fog" lesion indicates retinal destruction and vitreous inflammation leaving a permanent scar (Umbu Lapu *et al*., 2025) [20].

Endoscopy

Endoscopy being a powerful diagnostic tool is the only modern day imaging technique that helps us visualize directly inside an organ. The medical endoscope operates using a cold light source to illuminate the visceral organs. The objective lens forms image of the object onto the photosensitive surface of Charge-Coupled Device (CCD) followed by the CCD converting the light signal into an electrical signal and gets transmitted through the cable to the video processor. The processed image is seen on a display.

The CCD photosensitive surface has orderly arranged diodes which are called as pixels. The total number of pixels directly influence the imaging quality.

- **Amoebiasis -** Endoscopy serves as a valuable tool for the microscopic examination of biopsy materials taken directly from the pathognomonic flask-shaped ulcer caused by *Entamoeba histolytica* and from other areas with mucosal lesions (Moran *et al*., 2023) [15].

Esophagogastroduodenoscopy

Aids in visualization of live flatworms adhering to the pyloric and duodenal mucosa. Endoscopic extractions of worms using biopsy forceps can be performed for confirmation of the parasite (Jha and Jha, 2019) [11].

Endoscopic Retrograde Cholangiopancreatography (ERCP)

- **Fasciolopsiasis -** The ERCP procedure involves guiding an electronic duodenoscope into the distal duodenum for observation of duodenal diverticulum.
- **Balantidiasis -** Motile trophozoites either in fresh stool samples or from the ulcer scrapings can be visualized during endoscopic examination.

Colonoscopy

An endoscopic technique which involves insertion of a flexible, lighted camera equipped tube into the body via the anus for the examination of large intestine including rectum and anus.

- **Fasciolopsiasis -** The live worms of *F. buski* can be diagnosed within the intestinal lumen. The gold standard test for confirming fasciolopsiasis involves the identification of *F. buski* eggs or adult worms in the intestinal lumen (Luo *et al*., 2025) [14].
- **Amoebiasis -** Amoebic colitis is characterized by patchy mucosal inflammation, pale exudate and ulcerative lesions, predominantly localized in the caecum and ascending colon. Ulcerations usually ranging from tiny erosions to large discrete ulcers (exceeding 2 cm) and are often numerous and discrete. A mucosal 'bump' sign denotes a pathognomonic endoscopic feature, with an inflammatory nodule greater than 1 cm infiltrated by trophozoites (Cooney *et al*., 2025) [5].
- **Balantidiasis -** Colonoscopy is useful in the diagnosis.

Conclusion

The application of modern diagnostic imaging techniques has led to tremendous impact in the diagnosis and management of parasitic zoonosis**.** Their ability to precisely locate and view the location and extent of lesions greatly help the clinicians to make appropriate decisions. This facilitates earlier intervention, proper monitoring and effective treatment for the diseases. These methods non-invasively locate the characteristic lesions of parasitic diseases while the laboratory microscopic examination may be inconclusive. CT and MRI imaging provides high resolution images of organs with cysts, calcifications or inflammatory nodules in case of neurocysticercosis, hydatid disease. Ultrasonography aids to detect lesions of hepatic fascioliasis and amoebic liver abscess. Endoscopic methods help in visualization and collection of biopsy materials for further microscopic examination while radiography provides better view of calcifications, pleural effusion, gaseous distention and mucosal wall thickening in various conditions. Ultimately, these imaging techniques in integration with history, clinical symptoms and laboratory examination provides better diagnostic accuracy and improves overall care and management of the patients.

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