SECTION 17 Protozoal and Helminthic Infections: General Considerations

CHAPTER e25 Laboratory Diagnosis of Parasitic Infections

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The cornerstone for the diagnosis of parasitic infections is a thorough history of the patient's illness. Epidemiologic aspects of the illness are especially important because the risks of acquiring many parasites are closely related to occupation, recreation, or travel to areas of high endemicity. Without a basic knowledge of the epidemiology and life cycles of the major parasites, it is difficult to approach the diagnosis of parasitic infections systematically. Accordingly, the medical classification of important human parasites in this chapter emphasizes their geographic distribution, their transmission, and the anatomic location and stages of their life cycle in humans. The text and tables are intended to serve as a guide to the correct diagnostic procedures for the major parasitic infections; in addition, the reader is referred to other chapters that contain more comprehensive information about each infection (Chaps. 209–220). Tables e25-1, e25-2, and e25-3 summarize the geographic distributions, the anatomic locations, and the methods employed for the diagnosis of flatworm, roundworm, and protozoal infections, respectively.

In addition to selecting the correct diagnostic procedures, physicians must counsel their patients to ensure that specimens are collected properly and arrive at the laboratory promptly. For example, the diagnosis of bancroftian filariasis is unlikely to be confirmed by the laboratory unless blood is drawn near midnight, when the nocturnal microfilariae are active. Laboratory personnel and surgical pathologists should be notified in advance when a parasitic infection is suspected. Continuing interaction with the laboratory staff and the surgical pathologists increases the likelihood that parasites in body fluids or biopsy specimens will be examined carefully by the most capable individuals.

INTESTINAL PARASITES

Most helminths and protozoa exit the body in the fecal stream. The patient should be instructed to collect feces in a clean waxed or cardboard container and to record the time of collection on the container. Contamination with water (which could contain free-living protozoa) or with urine (which can damage trophozoites) should be avoided. Fecal samples should be collected before ingestion of barium or other contrast agents for radiologic procedures and before treatment with antidiarrheal agents and antacids, because these substances change the consistency of the feces and interfere with microscopic detection of parasites. Because of the cyclic shedding of most parasites in the feces, a minimum of three samples collected on alternate days should be examined. Examination of a single sample can be up to 50% less sensitive. When delays in transport to the laboratory are unavoidable, fecal samples should be kept in polyvinyl alcohol or another fixative to preserve protozoal trophozoites. New collection kits with instructions for the patient to transfer portions of the sample directly into fixative and bacterial carrier medium may enhance the recovery of trophozoites. Refrigeration will also preserve trophozoites for a few hours and protozoal cysts and helminthic ova for several days.

Analysis of fecal samples entails both macroscopic and microscopic examination. Watery or loose stools are more likely to contain protozoal trophozoites, but protozoal cysts and all stages of helminths may be found in formed feces. If adult worms or tapeworm segments are observed, they should be transported promptly to the laboratory or washed and preserved in fixative for later examination. The only tapeworm with motile segments is *Taenia saginata*, the beef tapeworm, which patients sometimes bring to the physician. Because the ova of *T. saginata* are morphologically indistinguishable from those of *Taenia solium* (the cause of cysticercosis), motility is an important distinguishing characteristic.

Microscopic examination of feces is not complete until direct wet mounts have been evaluated and concentration techniques as well as permanent stains have been applied. Before accepting a report of negativity for ova and parasites as final, the physician should insist that the laboratory undertake each of these procedures. Some intestinal parasites are more readily detected in material other than feces. For example, examination of duodenal contents is sometimes necessary to detect *Giardia lamblia*, *Cryptosporidium*, and *Strongyloides* larvae. Use of the "cellophane tape" technique to detect pinworm ova on the perianal skin sometimes also reveals ova of *T. saginata* deposited perianally when the motile segments disintegrate (Table e25-4).

Two routine solutions are used to make wet mounts for identification of the various life stages of helminths and protozoa: physiologic saline for trophozoites, cysts, ova, and larvae and dilute iodine solution for protozoal cysts and ova. Iodine solution must never be used to examine specimens for trophozoites because it kills the parasites and thus eliminates their characteristic motility.

The two most common concentration procedures for detecting small numbers of cysts and ova are formalin-ether sedimentation and zinc sulfate flotation. The formalin-ether technique is preferable because all parasites sediment but not all float. Slides permanently stained for trophozoites should be prepared before concentration. Additional slides stained for cysts and ova may be made from the concentrate.

In many instances, especially in the differentiation of *Entamoeba histolytica* from other amebas, identification of parasites from wet mounts or concentrates must be considered tentative. Permanently stained smears allow study of the cellular detail necessary for definitive identification. The iron-hematoxylin stain is excellent for critical work, but trichrome staining, which can be completed in 1 h, is a satisfactory alternative that also reveals parasites in specimens preserved in polyvinyl alcohol fixative. Modified acid-fast staining and fluorescent auramine microscopy are useful adjuncts for detection and identification of several intestinal protozoa, including *Cryptosporidium* and *Cyclospora*. Microsporidia, which cause chronic diarrhea in HIV-infected patients, may be missed unless a special modified trichrome stain is requested (Table e25-3).

TABLE e25-1 Flatworm Infections

Parasite	Geographic Distribution	Life-Cycle Hosts: Intermediate (Transmission)	Life-Cycle Hosts: Definitive	Diagnosis: Parasite Stage	Diagnosis: Body Fluid or Tissue	Diagnosis: Serologic Tests	Diagnosis: Other
Tapeworms (Cestodes)							
Intestinal tapeworms							
Taenia saginata (beef tapeworm)	Worldwide	Beef	Humans	Ova, segments	Feces	—	Motile segments
Hymenolepis nana (dwarf tapeworm)	Worldwide	Grain beetles	Humans, mice[a]	Ova	Feces	—	—
Diphyllobothrium latum (fish tapeworm)	Worldwide	Copepods–fish[b]	Humans, other mammals	Ova, segments	Feces	—	Megaloblastic anemia in 1%
T. solium[c] (pork tapeworm)	Worldwide	Swine	Humans	Ova, segments	Feces	WB	Especially Mexico, Central and South America, Africa
Somatic tapeworms							
Echinococcus granulosus (hydatid disease)	Sheep-raising and hunting areas	Sheep, camels, humans, others	Dogs	Hydatid	Lung, liver	WB, EIA	Chest radiography, CT, MRI
E. multilocularis (hydatid disease)	Subarctic areas	Rodents, humans	Foxes, dogs, cats	Hydatid	Liver	—	May resemble cholangiocellular carcinoma
T. solium[c] (pork tapeworm)	Worldwide	Swine, humans	Humans	Cysticercus	Muscles, CNS	WB	CT, MRI, radiography
Flukes (Trematodes)							
Intestinal flukes							
Fasciolopsis buski	China, India	Snails–water chestnuts	Humans	Ova	Feces	—	—
Heterophyes heterophyes	Far East, India	Snails–fish	Humans	Ova	Feces	—	—
Metagonimus yokogawai	Far East, Balkans, North Africa	Snails–fish	Humans	Ova	Feces	—	—
Liver flukes							
Clonorchis sinensis	China, Southeast Asia	Snails–fish	Humans	Ova	Feces, bile	—	Recurrent bacterial cholangitis
Fasciola hepatica	Sheep-raising areas	Snails–watercress	Humans, sheep	Ova	Feces,[d] bile	EIA	Cirrhosis, portal hypertension
Lung flukes							
Paragonimus spp.	Orient, Africa, the Americas	Snails–crabs/crayfish	Humans, other mammals	Adults, ova	Lung, sputum, feces	WB, EIA	Chest radiography, CT, MRI
Blood flukes							
Schistosoma mansoni	Africa, Central and South America, West Indies	Snails	Humans	Ova, adults	Feces	EIA, WB	Rectal snips, liver biopsy
S. haematobium	Africa	Snails	Humans	Ova, adults	Urine	WB	Liver, urine, or bladder biopsy
S. japonicum	Far East	Snails	Humans	Ova, adults	Feces	WB	Liver biopsy

[a] Larvae also can mature in intestinal villi of humans and mice.

[b] When there are two intermediate hosts, the first is separated from the second by a dash. Definitive hosts are infected by the second intermediate host.

[c] *T. solium* can cause either intestinal infections or cysticercosis. Its ova are identical to those of *T. saginata*; scolices and segments of the two species differ.

[d] Ova seldom reach the fecal stream during acute disease.

Note: CNS, central nervous system; EIA, enzyme immunoassay; WB, western blot. Serologic tests listed in Tables e25-1, e25-2, and e25-3 are available commercially or from the Centers for Disease Control and Prevention, Atlanta, GA.

TABLE e25-2 Roundworm Infections

Parasite	Geographic Distribution	Life-Cycle Hosts		Diagnosis			
		Intermediate (Transmission)	Definitive	Parasite Stage	Body Fluid or Tissue	Serologic Tests	Other
Intestinal Roundworms							
Enterobius vermicularis (pinworm)	Temperate and tropical zones	Fecal-oral	Humans	Ova	Perianal skin	—	"Cellophane tape" test
Trichuris trichiura (whipworm)	Temperate and tropical zones	Soil, fecal-oral	Humans	Ova	Feces	—	Rectal prolapse
Ascaris lumbricoides (roundworm of humans)	Temperate and tropical zones	Soil, fecal-oral	Humans	Ova	Feces	—	Sx of pulmonary migration
Ancylostoma duodenale (Old World hookworm)	Eurasia, Africa, Pacific	Soil to skin	Humans	Ova/larvae	Feces	—	Sx of pulmonary migration, anemia
Necator americanus (New World hookworm)	U.S., Africa, worldwide	Soil to skin	Humans	Ova/larvae	Feces	—	Sx of pulmonary migration, anemia
Strongyloides stercoralis (strongyloidiasis)	Moist tropics and subtropics	Soil to skin	Humans	Larvae	Feces, sputum, duodenal fluid	EIA	Dissemination in immunodeficiency
Capillaria philippinensis	Southeast Asia, Taiwan, Egypt	Raw fish	Birds	Ova, larvae, adults	Feces	—	Malabsorption/ autoinfection, biopsy
Tissue Roundworms							
Trichinella spiralis (trichinellosis)	Worldwide	Swine/humans	Swine/ humans	Larvae	Muscle	EIA	Muscle biopsy
Wuchereria bancrofti (filariasis)	Coastal areas in tropics and subtropics	Mosquitoes	Humans	Microfilariae	Blood, lymph nodes	EIA, RAPID	Nocturnal periodicity[a]
Brugia malayi (filariasis)	Asia, Indian subcontinent	Mosquitoes	Humans	Microfilariae	Blood	EIA, RAPID	Nocturnal
Loa loa (African eye worm)	West and Central Africa	Mango flies (*Chrysops*)	Humans	Microfilariae	Blood	RAPID	May be visible in eye, diurnal
Onchocerca volvulus (river blindness)	Africa, Mexico, Central and South America	Blackflies	Humans	Adults/larvae	Skin/eye	—	Examine nodules or skin snips
Dracunculus medinensis (guinea worm)	Africa	*Cyclops*	Humans	Adults/larvae	Skin	—	May be visible in lesion
Angiostrongylus cantonensis	Southeast Asia, Pacific, Caribbean	Snails/slugs, shrimp/fish	Rats	Larvae	CSF (rarely found)	—	Eosinophilic meningitis
Larva Migrans Syndromes							
Ancylostoma braziliense (creeping eruption)	Tropical and temperate zones	Soil to skin	Dogs/cats, humans	Larvae	Skin	—	Dog and cat hookworm
Toxocara canis and *cati* (visceral larva migrans)	Tropical and temperate zones	Soil, fecal-oral	Dogs/cats, humans	Larvae	Viscera, CNS, eye	EIA	Also caused by roundworms of other species

[a]Except for infection acquired in the South Pacific, blood should be drawn at midnight.

Note: CNS, central nervous system; CSF, cerebrospinal fluid; EIA, enzyme immunoassay; RAPID, rapid immunographic assay (available at the National Institutes of Health: 301-496-5398); Sx, signs/symptoms.

BLOOD AND TISSUE PARASITES

Invasion of tissue by protozoa and helminths renders the choice of diagnostic techniques more difficult. For example, physicians must understand that aspiration of an amebic liver abscess rarely reveals *E. histolytica* because the trophozoites are located primarily in the abscess wall. They must remember that the urine sediment offers the best opportunity to detect *Schistosoma haematobium* in the young Ethiopian immigrant or the American traveler who returns from Africa with hematuria. Tables e25-1, e25-2, and e25-3, which offer a quick guide to the geographic distribution and anatomic locations of the major tissue parasites, should help the physician to select the appropriate body fluid or biopsy site for microscopic examination. Tables e25-5 and e25-6 provide additional information about the identification of parasites in samples from specific anatomic locations. The laboratory procedures for detection of parasites in other body fluids are similar to those used in the examination of feces. The physician should insist on wet mounts, concentration techniques, and permanent stains for all body fluids.

TABLE e25-3 Protozoal Infections

Parasite	Geographic Distribution	Life-Cycle Hosts: Intermediate (Transmission)	Life-Cycle Hosts: Definitive	Diagnosis: Parasite Stage	Diagnosis: Body Fluid or Tissue	Diagnosis: Serologic Tests	Diagnosis: Other
Intestinal Protozoans							
Entamoeba histolytica (amebiasis)	Worldwide, especially tropics	Fecal-oral	Humans	Troph, cyst	Feces, liver	EIA, antigen detection	Ultrasound, liver CT, PCR
Giardia lamblia (giardiasis)	Worldwide	Fecal-oral	Humans	Troph, cyst	Feces	Antigen detection	String test, DFA, PCR
Isospora belli	Worldwide	Fecal-oral	Humans	Oocyst	Feces	—	Acid-fast[a]
Cryptosporidium	Worldwide	Fecal-oral	Humans, other animals	Oocyst	Feces	Antigen detection	Acid-fast,[a] DFA, biopsy, PCR
Cyclospora cayetanensis	Worldwide?	Fecal-oral	Humans, other animals?	Oocyst	Feces	—	Acid-fast,[a] modified safranin, autofluorescence, biopsy, PCR
Microsporidia (*Enterocytozoon bieneusi, Encephalitozoon* spp.) (microsporidiosis)	Worldwide?	?	Animals, humans	Spore	Feces	—	Modified trichrome, biopsy, PCR
Free-Living Amebas							
Naegleria	Worldwide	Warm water	Humans	Troph, cyst	CNS, nares	DFA	Biopsy, nasal swab, culture
Acanthamoeba	Worldwide	Soil, water	Humans	Troph, cyst	CNS, skin, cornea	DFA	Biopsy, scrapings, culture
Balamuthia	The Americas	Soil?	Humans, other animals	Troph, cyst	Brain	DFA	Biopsy
Blood and Tissue Protozoans							
Plasmodium spp. (malaria)	Subtropics and tropics	Mosquitoes	Humans	Asexual	Blood	Limited use	PCR
Babesia microti (babesiosis)	U.S., especially New England	Ticks	Rodents, humans	Asexual	Blood	IIF	Animal spp. in asplenia, PCR
Trypanosoma rhodesiense (African sleeping sickness)	Sub-Saharan East Africa	Tsetse flies	Humans, herbivores	Tryp	Blood, CSF	IIF[b]	Also chancre, lymph nodes
T. gambiense (African sleeping sickness)	Sub-Saharan West Africa	Tsetse flies	Humans, swine	Tryp	Blood, CSF	Card agglutination,[c] IIF[b]	Also chancre, lymph nodes
T. cruzi (Chagas' disease)	Mexico to South America	Reduviid bugs (triatomes)	Humans, dogs, wild animals	Amastigote, tryp	Multiple organs/blood	IIF, EIA	Reactivation in immunosuppression
Leishmania tropica, etc.	Widespread in tropics and subtropics	Sandflies (*Phlebotomus*)	Humans, dogs, rodents	Amastigote	Skin	IFA, EIA[d]	Biopsy, scrapings, culture
L. braziliensis (mucocutaneous)	Mexico to South America	Sandflies (*Lutzomyia*)	Humans, dogs, rodents	Amastigote	Skin, mucous membranes	IFA[b], EIA	Biopsy, scrapings, culture
L. donovani (kala-azar)	Widespread in tropics and subtropics	Sandflies (*Phlebotomus*)	Humans, dogs, wild animals	Amastigote	RE system	IFA[b], EIA	Biopsy, culture, PCR
Toxoplasma gondii (toxoplasmosis)	Worldwide	Humans, other mammals	Cats	Cyst, troph	CNS, eye, muscles, other	EIA, IIF	PCR

[a] Acid-fastness is best demonstrated by auramine fluorescence or modified acid-fast stain.

[b] Contact the CDC at 770-488-7760.

[c] Card agglutination is provided to endemic countries by the World Health Organization.

[d] Limited specificity; most sensitive for *L. donovani.*

Abbreviations: CNS, central nervous system; CSF, cerebrospinal fluid; DFA, direct fluorescent antibody; EIA, enzyme immunoassay; IFA, indirect fluorescent antibody; IIF, indirect immunofluorescence; PCR, polymerase chain reaction; RE, reticuloendothelial; troph, trophozoite; tryp, trypomastigote form.

TABLE e25-4 Alternative Procedures for Laboratory Diagnosis of Parasites Found in Feces[a]

Parasites and Fecal Stages	Alternative Diagnostic Procedures
Tapeworms (Cestodes)	
Taenia saginata ova and segments	Perianal "cellophane tape" test for ova
T. solium ova and segments	Serology; brain biopsy for neurocysticercosis
Flukes (Trematodes)	
Clonorchis (Opisthorchis) sinensis ova	Examination of bile for ova and adults in cholangitis
Fasciola hepatica ova	Examination of bile for ova and adults in cholangitis
Paragonimus ova	Serology; sputum; biopsy of lung or brain for larvae
Schistosoma ova	Serology for all; rectal snips (especially for *S. mansoni*), urine (*S. haematobium*), liver biopsy and liver ultrasound
Roundworms	
Enterobius vermicularis ova and adults	Perianal "cellophane tape" test for ova and adults
Trichuris trichiura ova	None
Ascaris lumbricoides ova and adults	Examination of sputum for larvae in lung disease
Hookworm ova and occasional larvae	Examination of sputum for larvae in lung disease
Strongyloides larvae	Duodenal aspirate or jejunal biopsy; serology; sputum or lung biopsy for filariform larvae in disseminated disease
Protozoans	
Entamoeba histolytica trophozoites and cysts	Serology; liver biopsy for trophozoites
Giardia lamblia trophozoites and cysts	Duodenal aspirate or jejunal biopsy[b]
Isospora belli oocysts	Duodenal aspirate or jejunal biopsy[b]
Cryptosporidium oocysts	Duodenal aspirate or jejunal biopsy[b]
Microsporidial spores	Duodenal aspirate or jejunal biopsy[b]

[a] Stains and concentration techniques are discussed in the text.

[b] Commercial string test is satisfactory; *Isospora* and *Cryptosporidium* are acid-fast.

The trichrome or iron-hematoxylin stain is satisfactory for all tissue helminths in body fluids other than blood, but microfilarial worms and blood protozoa are more easily visualized with Giemsa or Wright's staining.

The most common parasites detected in Giemsa-stained blood smears are the plasmodia, microfilariae, and African trypanosomes (Table e25-5). Most patients with Chagas' disease present in the chronic phase, when *Trypanosoma cruzi* is no longer microscopically detectable in blood smears. Wet mounts are sometimes more sensitive than stained smears for the detection of microfilariae and African trypanosomes because these active parasites cause noticeable movement of the erythrocytes in the microscopic field. Filtration of blood through a polycarbonate filter (pore size, 3–5 μm) facilitates the detection of microfilariae. The intracellular amastigote forms of *Leishmania* spp. and *T. cruzi* can sometimes be visualized in stained smears of peripheral blood, but aspirates of the bone marrow, liver, and spleen are the best sources for microscopic detection and culture of *Leishmania* in kala-azar and of *T. cruzi* in chronic Chagas' disease. The diagnosis of malaria and the critical distinction among the various *Plasmodium* species are made by microscopic examination of stained thick and thin blood films (Chap. 210). Detection of subpatent infection and identification of *Plasmodium* species can be confirmed by PCR. Recently, *P. knowlesi,* a simian parasite, has been identified as the cause of an increasing number of infections in Malaysian Borneo and other areas of Southeast Asia. PCR or another molecular method is required to differentiate *P. knowlesi* from *P. malariae.*

Although most tissue parasites stain with the traditional hematoxylin and eosin, surgical biopsy specimens should also be stained with appropriate special stains. The surgical pathologist who is accustomed to applying silver stains for *Pneumocystis* to induced sputum and transbronchial biopsies may need to be reminded to examine wet mounts and iron-hematoxylin–stained preparations of pulmonary specimens for helminthic ova and *E. histolytica*. The clinician should also be able to advise the surgeon and pathologist about optimal techniques for the identification of parasites in specimens obtained by certain specialized minor procedures (Table e25-6). For example, the excision of skin snips for the diagnosis of onchocerciasis, the collection of rectal snips for the diagnosis of schistosomiasis, and punch biopsy of skin lesions for the identification and culture of cutaneous and mucocutaneous species of *Leishmania* are simple procedures, but the diagnosis can be missed if the specimens are improperly obtained or processed.

NONSPECIFIC TESTS

Eosinophilia (>500/μL) commonly accompanies infections with most of the tissue helminths; absolute numbers of eosinophils may be high in trichinellosis and the migratory phases of filariasis (Table e25-7). Intestinal helminths provoke eosinophilia only during pulmonary migration of the larval stages. Eosinophilia is not a manifestation of protozoal infections. Parasitic causes of eosinophilia in cerebrospinal fluid include nematodes (e.g., *Angiostrongylus*, *Gnathostoma*, *Toxocara*, and *Baylisascaris* species) as well as flatworms (e.g., *Taenia solium* and *Schistosoma* species).

Like the hypochromic microcytic anemia of heavy hookworm infections, other nonspecific laboratory abnormalities may suggest parasitic infection in patients with appropriate geographic and/or environmental exposures. Biochemical evidence of cirrhosis or an abnormal urine sediment in an African immigrant certainly raises the possibility of schistosomiasis, and anemia and thrombocytopenia in a febrile traveler or immigrant are among the hallmarks of malaria. CT and MRI also contribute to the diagnosis of infections with many tissue parasites and have become invaluable adjuncts in the diagnosis of neurocysticercosis and cerebral toxoplasmosis.

ANTIBODY AND ANTIGEN DETECTION

Useful antibody assays for many of the important tissue parasites are available; most of those listed in Table e25-8 can be obtained from the Centers for Disease Control and Prevention (CDC) in Atlanta. The results of serologic tests not listed in the tables should be interpreted with caution.

TABLE e25-5 Identification of Parasites in Blood and Other Body Fluids

Body Fluid, Parasite	Enrichment/Stain	Culture Technique
Blood		
Plasmodium spp.	Thick and thin smears/Giemsa or Wright's	Not useful for diagnosis
Leishmania spp.	Buffy coat/Giemsa	Media available from CDC
African trypanosomes[a]	Buffy coat, anion column/wet mount and Giemsa	Mouse or rat inoculation[b]
Trypanosoma cruzi[c]	As for African species	As above and xenodiagnosis
Toxoplasma gondii	Buffy coat/Giemsa	Fibroblast cell lines
Microfilariae[d]	Filtration/wet mount and Giemsa	None
Urine		
Schistosoma haematobium	Centrifugation/wet mount	None
Microfilariae (in chyluria)	As for blood	None
Spinal fluid		
African trypanosomes	Centrifugation, anion column/wet mount and Giemsa	As for blood
Naegleria fowleri	Centrifugation/wet mount and Giemsa or trichrome	Nonnutrient agar overlaid with *Escherichia coli*

[a] *Trypanosoma rhodesiense* and *T. gambiense.*

[b] Inject mice intraperitoneally with 0.2 mL of whole heparinized blood (0.5 mL for rats). After 5 days, check tail blood daily for trypanosomes as described above. Call the CDC (770-488-7775) for information on diagnosis and treatment.

[c] Detectable in blood by conventional techniques only during acute disease. Xenodiagnosis is successful in ~50% of patients with chronic Chagas' disease.

[d] Daytime (1000–1400 h) and nighttime (2200–0200 h) blood samples should be drawn to maximize the chance of detecting *Wuchereria* (nocturnal except for Pacific strains), *Brugia* (nocturnal), and *Loa loa* (diurnal).

The value of antibody assays is limited by several factors. For example, the preparation of thick and thin blood smears remains the procedure of choice for the diagnosis of malaria in individual patients because diagnostic titers to plasmodia develop slowly and do not differentiate species—a critical step in patient management. Filarial antigens cross-react with those from other nematodes; as in assays for antibody to most parasites, the presence of antibody in the filarial assay fails to distinguish between past and current infection. Despite these specific limitations, the restricted geographic distribution of many tropical parasites increases the diagnostic usefulness of both the presence and the absence of antibody in travelers from industrialized countries. In contrast, a large proportion of the

TABLE e25-6 Minor Procedures for Diagnosis of Parasitic Infections

Parasite(s) and Stage	Procedure
Onchocerca volvulus and *Mansonella streptocerca* microfilariae	*Skin snips:* Lift skin with a needle and excise ~1 mg to a depth of 0.5 mm from several sites. Weigh each sample, place it in 0.5 mL of saline for 4 h, and examine wet mounts and Giemsa stains of the saline either directly or after filtration. Count microfilariae.[a]
Loa loa adults and *O. volvulus* adults and microfilariae	*Biopsies of subcutaneous nodules:* Stain routine histopathologic sections and impression smears with Giemsa.
Trichinella spiralis larvae (and perhaps *Taenia solium* cysticerci)	*Muscle biopsies:* Excise ~1.0 g of deltoid or gastrocnemius muscle and squash between two glass slides for direct microscopic examination.
Schistosoma ova of all species, but especially *S. mansoni*	*Rectal snips:* From four areas of mucosa, take 2-mg snips, tease onto a glass slide, and flatten with a second slide before examining directly at 10×. Preparations may be fixed in alcohol or stained.
Trypanosoma gambiense and *T. rhodesiense* trypomastigotes	*Aspirate of chancre or lymph node:*[b] Aspirate center with an 18-gauge needle, place a drop on a slide, and examine for motile forms. An otherwise insufficient volume of material may be stained with Giemsa.
Acanthamoeba spp. trophozoites or cysts	*Corneal scrapings:* Have an ophthalmologist obtain a sample for immediate Giemsa staining and culture on nutrient agar overlaid with *Escherichia coli.*
Cutaneous and mucocutaneous *Leishmania* spp.	*Swabs, aspirates, or punch biopsies of skin lesions:* Obtain a specimen from the margin of a lesion for Giemsa staining of impression smears; section and culture on special media from the CDC.

[a] Counts of >100/mg are associated with a significant risk of complications.

[b] Lymph node aspiration is contraindicated in some infections and should be used judiciously.

TABLE e25-7 Parasites Frequently Associated With Eosinophilia[a]

Parasite	Comment
Tapeworms (Cestodes)	
Echinococcus granulosus	When hydatid cyst leaks
Taenia solium	During muscle encystation and in cerebrospinal fluid with neurocysticercosis
Flukes (Trematodes)	
Paragonimus spp.	Uniformly high in acute stage
Fasciola hepatica	May be high in acute stage
Clonorchis (Opisthorchis) sinensis	Variable
Schistosoma mansoni	50% of infected travelers
S. haematobium	25% of infected travelers
S. japonicum	Up to 6000/μL in acute infection
Roundworms	
Ascaris lumbricoides	During larval migration
Hookworm species	During larval migration
Strongyloides stercoralis	Profound during migration and early years of infection
Trichinella spiralis	Up to 7000/μL
Filarial species[b]	Varies but can reach 5000–8000/μL
Toxocara spp.	>3000/μL
Ancylostoma braziliense	With extensive cutaneous eruption
Gnathostoma spinigerum	In visceral larva migrans and eosinophilic meningitis
Angiostrongylus cantonensis	In eosinophilic meningitis
A. costaricensis	During larval migration in mesenteric vessels

[a] Virtually every helminth has been associated with eosinophilia. This table includes both common and uncommon parasites that frequently elicit eosinophilia during infection.

[b] *Wuchereria bancrofti, Brugia* spp., *Loa loa,* and *Onchocerca volvulus.*

TABLE e25-8 Serologic and Molecular Tests for Parasitic Infections[a]

Parasite, Infection	Antibody	Antigen or DNA/RNA
Tapeworms		
Echinococcosis	WB, EIA	
Cysticercosis	WB	
Flukes		
Paragonimiasis	WB, EIA[b]	
Schistosomiasis	EIA, WB	
Fascioliasis	EIA[b]	
Roundworms		
Strongyloidiasis	EIA	
Trichinellosis	EIA	
Toxocariasis	EIA	
Filariasis	EIA[c]	RAPID[c]
Protozoans		
Amebiasis	EIA	EIA,[b] RAPID,[b] PCR
Giardiasis		EIA,[b] RAPID,[b] DFA, PCR
Cryptosporidiosis		EIA,[b] DFA, RAPID,[b] PCR
Malaria (all species)	IIF[d]	RAPID, PCR
Babesiosis	IIF	PCR
Chagas' disease	IIF, EIA	PCR
Leishmaniasis	IIF, EIA	PCR[b]
Toxoplasmosis	IIF, EIA (IgM)[e]	PCR[b]
Microsporidiosis		PCR
Cyclosporiasis		PCR
Acanthamebiasis		DFA, PCR
Naegleriasis		DFA, PCR
Balmuthiasis		DFA

[a] Unless otherwise noted, all tests are available at the CDC.

[b] Research or commercial laboratories only.

[c] Available at the NIH (301-496-5398) and commercially.

[d] Of limited use for management of acute disease.

[e] Determination of infection within the last 3 months may require additional tests by a research laboratory.

Note: DFA, direct fluorescent antibody; EIA, enzyme immunoassay; IIF, indirect immunofluorescence; PCR, polymerase chain reaction; RAPID, rapid immunographic assay; WB, western blot. Most antigen and antibody parasite detection kits are available commercially. Most PCRs listed are now available at the CDC and in commercial or research laboratories. Contact Dr. Alexandre da Silva at the CDC (770-488-4072).

world's population has been exposed to *Toxoplasma gondii*, and the presence of IgG antibody to *T. gondii* does not constitute proof of active disease.

Fewer antibody assays are available for the diagnosis of infection with intestinal parasites. *E. histolytica* is the major exception. Sensitive, specific serologic tests are invaluable in the diagnosis of amebiasis. Commercial kits for the detection of antigen by enzyme-linked immunosorbent assay or of whole organisms by fluorescent antibody assay are now available for several protozoan parasites. A rapid test (approved by the U.S. Food and Drug Administration) for the detection of *P. falciparum* in blood is less sensitive than thick smears read by an experienced microscopist, but its use is increasing in developing countries because of its simplicity (Table e25-8).

MOLECULAR TECHNIQUES

DNA hybridization with probes that are repeated many times in the genome of a specific parasite and amplification of a specific DNA fragment by the polymerase chain reaction (PCR) have now been established as useful techniques for the diagnosis of several protozoan infections (Table e25-8). Although PCR is very sensitive, it is an adjunct to conventional techniques for parasite detection and should be requested only when microscopic and immunodiagnostic procedures fail to establish the probable diagnosis. For example, only multiple negative blood smears or the failure to identify the infecting species justifies PCR for the diagnosis or proper management of malaria. In addition to PCR of anticoagulated blood, the CDC (contact Dr. Alexandre da Silva, 770-488-4072, for details)

and several commercial laboratories now perform PCRs for detection of certain specific parasites in stool samples, biopsy specimens, and bronchoalveolar lavage fluid (Table e25-8). Although PCRs are now used primarily for the detection of protozoans, active research efforts are likely to establish their feasibility for the detection of several helminths.

FURTHER READINGS

Cox-Singh J et al: *Plasmodium knowlesi* malaria in humans is widely distributed and potentially life threatening. Clin Infect Dis 46:165, 2008

Freedman DO et al: Spectrum of disease and relation to place of exposure among ill returned travelers. N Engl J Med 354:119, 2006

Garcia LS et al: Algorithms for detection and identification of parasites, in *Manual of Clinical Microbiology*, 9th ed, vol 2, PR Murray et al (eds). Washington, DC, ASM Press, 2007, pp 2020–2039

Graff-Teixeira C et al: Update on eosinophilic meningoencephalitis and its clinical relevance. Clin Microbiol Rev 22:322, 2009

Murray CK et al: Update on rapid diagnostic testing for malaria. Clin Microbiol Rev 21:97, 2008

Rosenblatt JE: Laboratory diagnosis of infections due to blood and tissue parasites. Clin Infect Dis 49:1103, 2009

Schuster FL et al: Under the radar. *Balamuthia* amebic encephalitis. Clin Infect Dis 48:879, 2009

Seybolt LM et al: Diagnostic evaluation of newly arrived asymptomatic refugees with eosinophilia. Clin Infect Dis 42:363, 2006

Stark D et al: Clinical significance of enteric protozoa in the immunosuppressed human population. Clin Microbiol Rev 22:634, 2009

Thellier M, Breton J: *Enterocytozoon bieneusi* in humans and animals, focus on laboratory identification and molecular epidemiology. Parasite 15:349, 2008

Walker M et al: Parasitic central nervous system infections in immunocompromised hosts: Malaria, microsporidiosis, leishmaniasis, and African trypanosomiasis. Clin Infect Dis 42:115, 2006

Wilson M et al: Molecular immunological approaches to the diagnosis of parasitic infection, in *Manual of Molecular and Clinical Laboratory Immunology,* 7th ed, B Detrick et al (eds). Washington, DC, ASM Press, 2006, pp 557–568