OPOSSUM NEMATODIASIS: DIAGNOSIS AND TREATMENT OF STOMACH, INTESTINE, AND LUNG NEMATODES IN THE VIRGINIA OPOSSUM (*DIDELPHIS VIRGINIANA*)

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Abstract

Internal parasitic infections are common in the Virginia opossum (*Didelphis virginiana*). More than 50 different species of nematodes have been identified from the genus *Didelphis*. Of them, 3 can cause significant illness to native opossums in Southern California, 2 gastrointestinal nematodes and 1 pulmonary nematode. This article provides an overview of the life cycles, methods for identification, pathologic findings, diagnostic tests, clinical signs, and options for treating these common nematode species. Copyright 2013 Elsevier Inc. All rights reserved.

Key words: *Cruzia americana*; *Didelphostrongylus hayesi*; *Didelphis virginiana*; nematodes; opossum; *Turgida turgida*

Virginia opossums (*Didelphis virginiana*) acquire endoparasites because of their foraging and scavenging behavior. The type of parasite and source of exposure depend on the maturity of the opossum and various environmental factors, including weather, seasonal temperature, habitat, and food availability. In Southern California, opossums are often infected with 3 clinically important nematodes: a stomach roundworm (*Turgida turgida*) from the family Physalopteroidea, an intestinal roundworm (*Cruzia americana*) from the family Cruzidae, and a lung nematode (*Didelphostrongylus hayesi*) from the family Metastrongyloidea.[1]

In the author's experience, every opossum captured from the wild has endoparasites. Nematodes cause pathology to their host by direct physical damage to tissues, leading to easier access for opportunistic bacterial organisms to invade and disseminate. The cumulative effect of endoparasitism contributes to chronic debilitation of the host.[2] Nematode infections can lead to sepsis, blood loss, anemia, stomach ulceration, respiratory problems, peritonitis, and organ damage. Chronic, prolonged infection combined with trauma, stress, and malnutrition results in systemic compromise, delayed disease recovery, and often death. Levamisole was previously used for the treatment of internal parasites in Virginia opossums. According to the World Health Organization, levamisole has been restricted in its use and availability since 2001. Veterinarians should be aware of available alternative drug choices to treat endoparasites in parasitized animals, including the Virginia opossum.

STOMACH NEMATODES

Opossums become infected with *T. turgida* by ingesting coprophagic insects such as beetles, crickets, cockroaches, and earwigs. Adult *T. turgida* consume ingesta within the stomach of the

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opossum and attach to the mucosal lining of this organ when not feeding. The worm burden found in the stomach can be overwhelming (Fig. 1A). *Turgida turgida* attaches to the mucosal lining of the greater curvature of the stomach wall (Fig. 1B), with larvae scattered throughout the remainder of the stomach. Adult *T. turgida* can live for 360 days in the opossum host.[3]

Ulceration occurs at the site of attachment and can vary in diameter from 1 to >24 mm (Fig. 1C and D). Gastric ulcers associated with the attachment sites of *T. turgida* can result in chronic blood loss and anemia. The ulcer size and bleeding that occurs with the nematode infection is directly correlated with the number of parasites present.[2] The parasites compromise the mucosal and submucosal stomach wall layers, leaving only a thin layer of granulation tissue separating the parasites from the peritoneal cavity. In severe cases, perforation of the stomach wall occurs. Ulceration allows opportunistic enteric bacteria to enter the host's circulatory system.

Fibrinous exudate may be present on the serosal surface as the muscularis externa is replaced with granulation tissue. The tissue becomes infiltrated with eosinophils, neutrophils, fibroblasts, collagen fiber and nerotic debris.

Microscopic examination of affected tissue would often reveal eosinophils on the surface of the ulcer (Fig. 1E and F).[3]

Clinical signs associated with *T. turgida* infection include weight loss, anorexia, profuse black diarrhea (melena), anemia, poor hair coat, and death.[4] A definitive diagnosis is achieved with fecal centrifugation floatation analysis. The eggs of this parasite are 40 to 45 μm in length and are ovoid shaped with a thick clear colorless shell that contains a fully formed larval worm.[5] Parasitized animals can shed a large number of eggs in their feces.

INTESTINAL NEMATODES

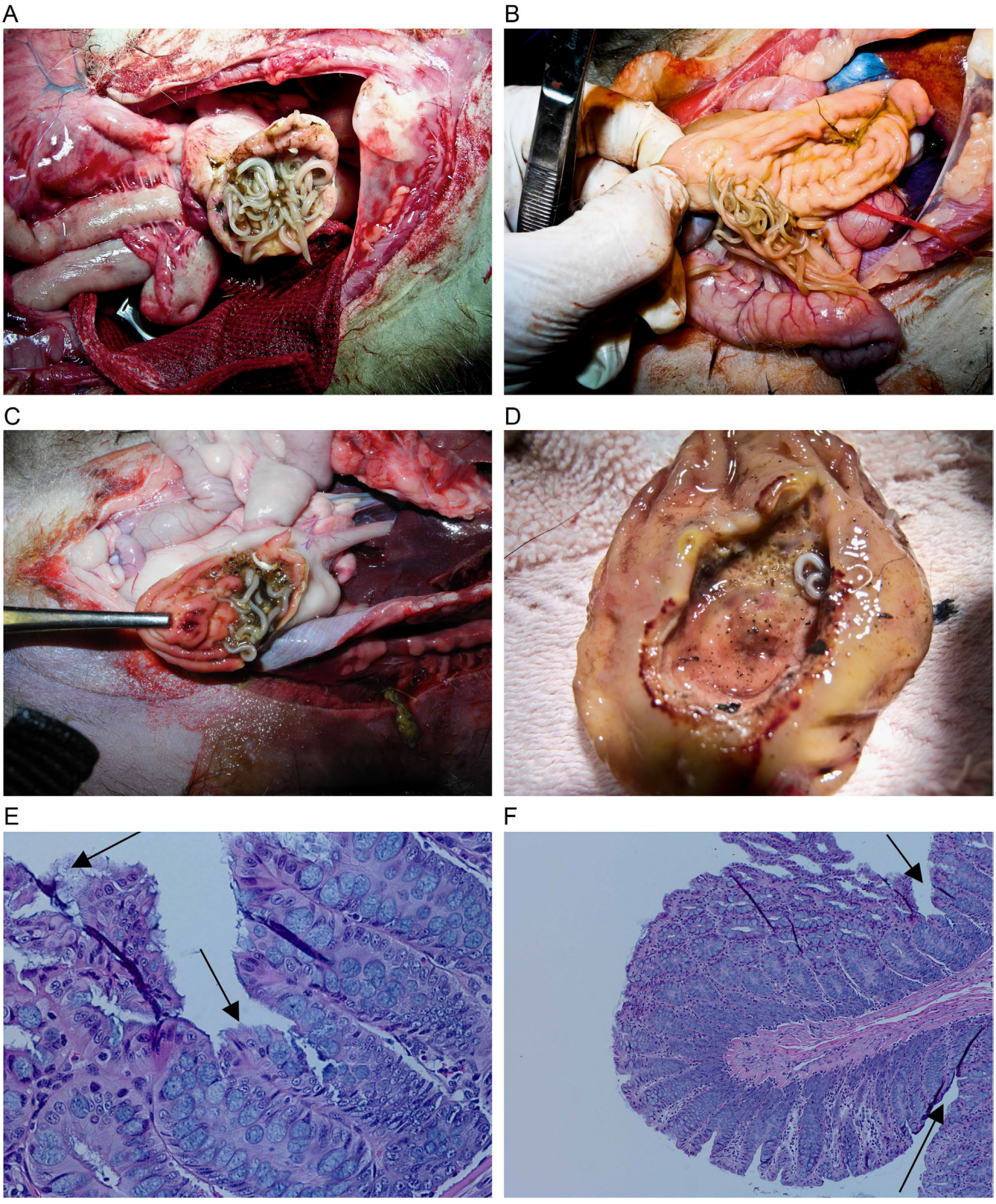
Cruzia americana parasitizes the cecum and large intestine of the opossum. These intestinal parasites have also been identified in armadillos, raccoons, and pigs. It is believed that reptiles may be the natural host of *C. americana*.[6] The exact mode of transmission for *C. americana* is unknown; however, it is believed to be direct. First-stage larvae are formed in 7 to 9 days, and the first molt takes place within 10 days of the eggs being shed in the feces. In the opossum, ingested eggs with second-stage larvae are hatched in the duodenum or upper ileum. After hatching, the larvae are transported through the intestines via peristalsis to the cecum. In the cecum, the larvae undergo 3 molts to reach the adult stage (Fig. 2A and B); the adults go on to infect the colon (Fig. 2C). *Cruzia americana* eggs are typically shed 46 to 48 days after worm maturation within the intestinal tract.[7]

Cruzia americana attaches to the wall of the cecum and lower intestine. This parasite feeds on the intestinal mucosa, ingesting blood and absorbing nutrients. Adult *C. americana* reside in the ileum and colon. The pathology associated with this parasite can be correlated with the parasite burden. Gross pathologic findings in an infected animal reveal evidence of localized hemorrhage and tissue damage (Fig. 2D). Histopathologic examination of affected tissues often reveals localized inflammation and hyperplastic crypts (Fig. 2E and F).

Diarrhea is the only overt clinical sign reported in animals infected with *C. americana*.[1] The clinical disease associated with this parasite is routinely overshadowed by the pathology caused by *T. turgida*. *Cruzia americana* appears to interfere with host nutrition and causes blood loss and anemia.[2]

Clear 48- to 52-μm × 84- to 100-μm eggs with fine irregular transverse striations in a morula or

FIGURE 1. The nematode *Turgida turgida* in the stomach of an opossum. (A) Large numbers of nematodes in the stomach of an 8-month-old opossum. Larvae and adults feed on stomach contents and attach to the mucosal lining of the organ when not feeding. Larvae scatter throughout the stomach, but adults often congregate in 1 to 3 groups in the cranial areas. (B) Adult *T. turgida* attach to the greater curvature of the stomach. Most worms are found in this location immediately caudal to the fundus. (C) Ulceration caused by *T. turgida*. Ulcers always occur at the site of the attachment. The size of the ulcer is related to the number of adult worms present and the length of time the animals have been infected. Small ulcers, 2 to 3 mm in diameter, are associated with the attachment of only a few adults. Small ulcers extend superficially into the submucosa. (D) Severe ulceration with mucosal compromise and perforation. Note large ulcers 6 to 15 mm in diameter. The mucosa and submucosa are destroyed, but some of the muscularis externa remains intact in the region of the ulcer. Large ulcers extend deep into the submucosa. A thin layer of granulation tissue separates nematodes from the peritoneal cavity. Most of the muscularis externa is replaced by granulation tissue. (E) Eosinophils, neutrophils, fibroblasts, and collagen fiber material are present at the surface of the ulcer and are associated with attachment areas (arrows). (F) Multifocal to coalescing, mild to marked, nodular to polypoid gastric mucosal hyperplasia with nodular to confluent mural lymphocytic, plasmacytic, pyogranulomatous, and eosinophilic and ulcerative gastritis (arrows).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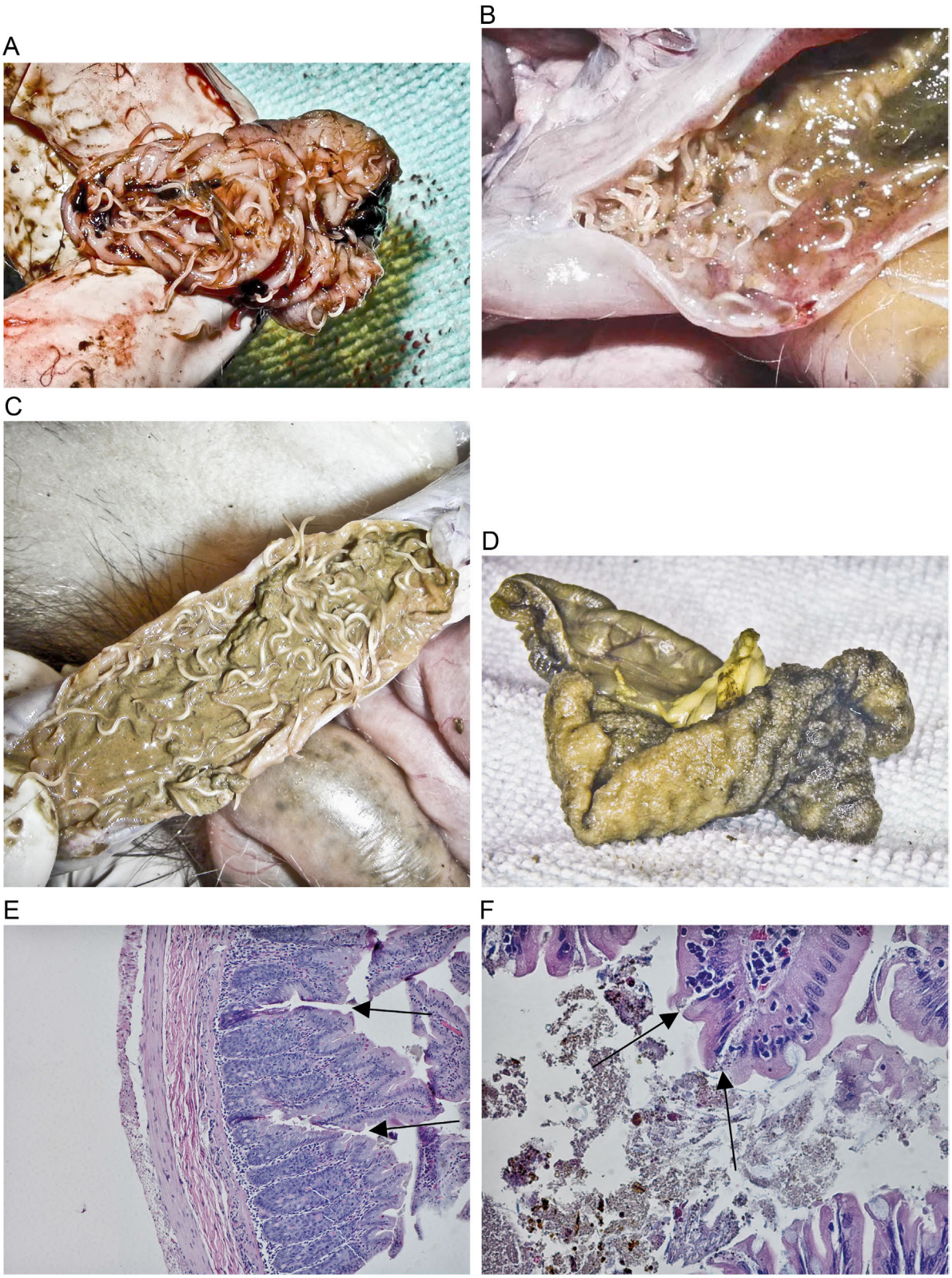


FIGURE 2. Appearance of *Cruzia americana* in the intestines: (A) both male and female immature nematodes are found in the distal ileum and cecum, attached to the mucosa wall; (B) detached *C. americana* enter the proximal colon, maturing in the colon; (C) large numbers of free-living *C. americana* are found in the colon and produce eggs; (D) attachment lesions in the preserved ileum with evidence of superficial hemorrhage; and (E and F) histopathology sections of the ileum contain prominent hyperplasia of crypt epithelial cells with adjoined mild eosinophilic inflammation from areas of attachment (arrows).

subvermiform stage are shed in the feces, and *C. americana* eggs are typically found in a 4- to 6-celled stage.[8]

LUNG NEMATODES

Didelphostrongylus hayesi infection occurs via ingestion of infected gastropods (e.g., snails, slugs, and earthworms). The L3 stage of *D. hayesi* is found in gastropods, and once consumed by the opossum, it enters the lymphatic system, blood vessels, hepatic portal system, and heart before finally invading the lung parenchyma. Larvae can also pass through the intestine, travel through the peritoneum, cross the diaphragm, and enter directly into the lungs (Fig. 3A). Once in the lungs, the fully developed parasite deposits its eggs. Unlike other lungworms, *D. hayesi* are distinguished by ovoviviparity, or the production of eggs that hatch within the body of the parent (parasite). In experimentally infected opossums, the prepatent period was determined to be 22 days.[9] The newly hatched larvae (L1) migrate up the trachea, are swallowed by the host animal, and are then shed in the feces (Fig. 3B). The L1 stage larvae are ingested by gastropods and the life cycle starts anew.[10]

Opossums develop granulomatous bronchopneumonia with local inflammation associated with migrating or degenerating *D. hayesi* L3 larva in the lung parenchyma and airways (verminous pneumonia). Radiographic images of infected animals often reveal severe lung lesions (Fig. 3C). Lungworms cause secondary bacterial bronchopneumonia, resulting in further tissue deterioration, and in severe cases, respiratory distress. (Fig. 3D and E).[2,11] Bacterial pneumonia is characterized by moderate to severe smooth muscle airway hyperplasia, including terminal respiratory bronchioles and alveolar ducts. Migrating larvae may cause lesions in the liver, heart, dermis, and central nervous system.

Both *D. hayesi* ova and larvae can be detected in the feces of the affected opossum.

ROUTINE FECAL SCREENING

Every opossum presenting for veterinary care should be screened for nematodes. In the author's experience, opossums harbor tremendous parasite burdens. Adult *T. turgida* and *C. americana* were found in 84.4% and 62.5% of sampled opossums, respectively, whereas ova were present in opossum feces less frequently at 40% and 35%, respectively. *Didelphostrongylus* were found in 79% of opossum feces (Fig. 4A-C).[12] Fecal centrifugation and Baermann analysis techniques are recommended for endoparasite diagnosis and to monitor a patient's response to treatment.

TREATMENT

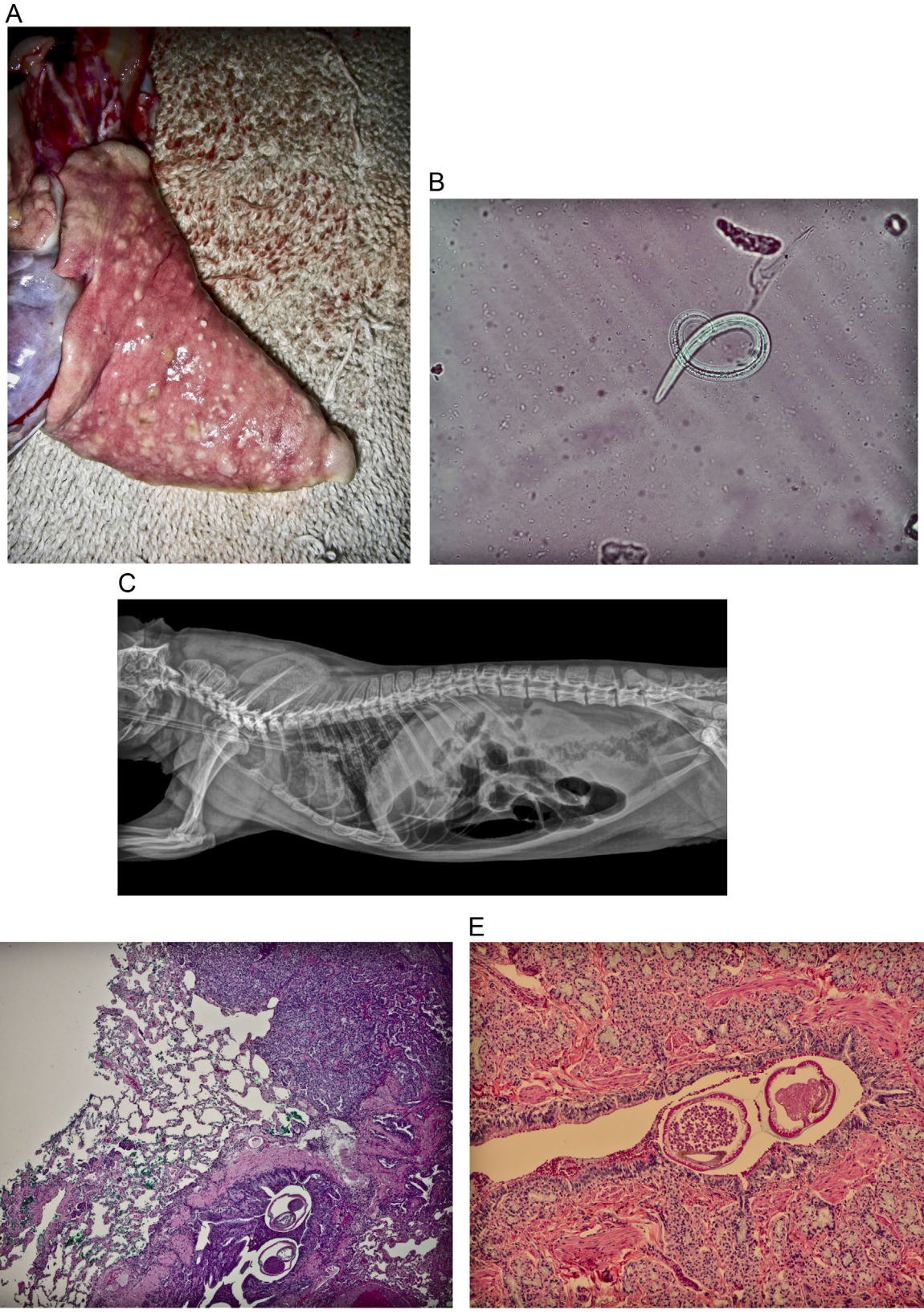
Levamisole was a widely recommended and an effective therapeutic agent to treat gastrointestinal nematodes in opossums. Levamisole currently is difficult to locate and, if available, is often sold by unreliable foreign sources. A combination of ivermectin and fenbendazole is an effective alternative treatment option, as these drugs appear to have a synergistic action.[13-16] Fenbendazole disrupts the metabolic pathways of nematodes, the therapeutic effects are local, it is minimally absorbed, and appears extremely safe to use. The suggested dosage of fenbendazole for the Virginia opossum is 25 to 50 mg/kg, and its bioavailability is increased when administered with food.[13] Ivermectin is effective against lung nematodes and migrating larva.[14] The injectable preparation of ivermectin can be given orally at a dose of 0.1 to 0.2 mg/kg (100 to 200 mcg/kg). Of orally administered ivermectin, 95% is absorbed in the intestinal tract. Ivermectin reaches migrating larva in the lung tissue and circulatory system and acts as an inhibitory neurotransmitter causing paralysis and death in the nematode.[13]

Carefully dosed drugs are added to palatable foods such as applesauce or yogurt or administered via a feeding tube. In severely affected animals, it may be beneficial to administer the low end of the dose range to prevent a massive nematode die-off, which could lead to intestinal obstruction, esophageal blockage, and/or suffocation (Fig. 5).

The ivermectin/fenbendazole combination treatment should be administered once daily for at least 2 weeks or until fecal sample results are parasite negative. Efficacy can also be demonstrated by improved clinical condition (i.e., resolution of diarrhea and black tarry stool or improvement of radiographically demonstrated lung lesions) and further confirmed with repeated fecal analysis.

CONCLUSIONS

There is a high probability that every rescued opossum has internal parasites. The amount and type of nematodes found in the Virginia opossum depend on the age of the animal and on environmental factors. Three types of nematodes are found in opossums in Southern California: the stomach nematode *T. turgida*, intestinal nematode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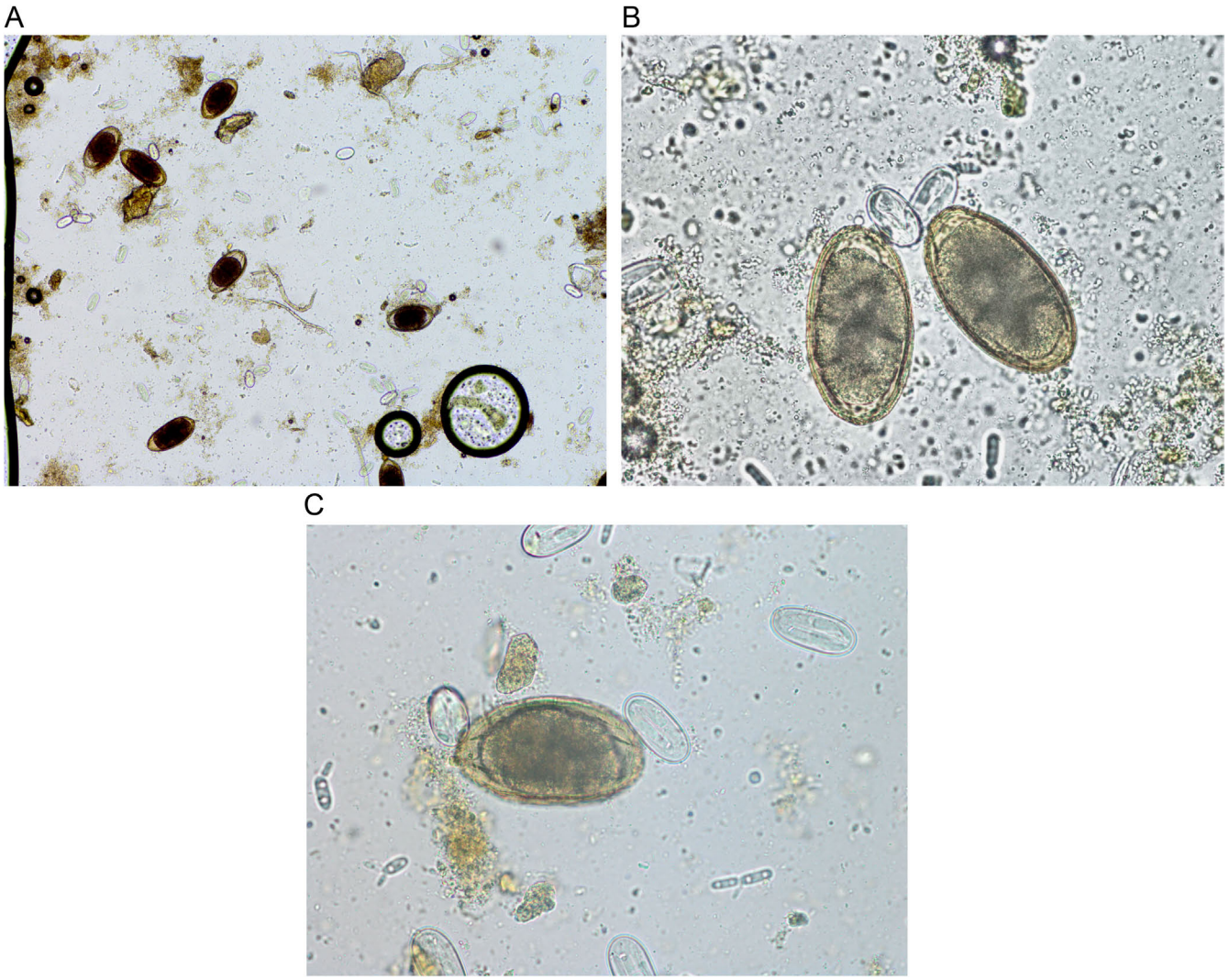

FIGURE 4. Appearance of nematode ova on fecal floatation: (A) The larger ova are *Cruzia americana* and the smaller ova are *Turgida turgida*; (B and C) *C. americana* ova, higher magnification.

C. americana, and the lung nematode *D. hayesi*. Nematode infection of the host animal contributes to sepsis, compromises overall health, delays recovery, and often leads to death. Diagnosis and treatment response is monitored through fecal diagnostic testing. A therapeutic combination of ivermectin and fenbendazole is recommended to treat gastrointestinal and lung nematodes in Virginia opossums.

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FIGURE 3. *Didelphostrongylus hayesi*. (A) Gross pathologic lesions in the lungs. Lungs at necropsy were moderately firm and failed to collapse when the thorax was opened. The lung lobes were consolidated and homogeneously gray to red in color. Small white foci approximately 1 mm in diameter can be seen on the surface. Lungworms produce multifocal, indurated lesions that result in generalized consolidation. (B) Example of *D. hayesi* larvae seen at fecal examination using the Baermann detection method. (C) Radiographic image of an opossum with severe dyspnea muffled heart sounds, and aerophagia associated with *D. hayesi* infestation. (D) Histopathologic examination of the lungs reveals several cross sections of nematodes with lesions featuring hypertrophy of smooth muscle, extensive peribronchiolar adenomatoid hyperplasia of alveolar epithelium, and diffuse areas of granulomatous interstitial pneumonia (H and E stain). (E) Histopathologic lung lesions in an affected opossum. Cross section of nematodes in an expanded bronchiole. Intrabronchial and intrabronchiolar location of *D. hayesi* is associated with severe clinical signs and fatal outcome (H and E stain).

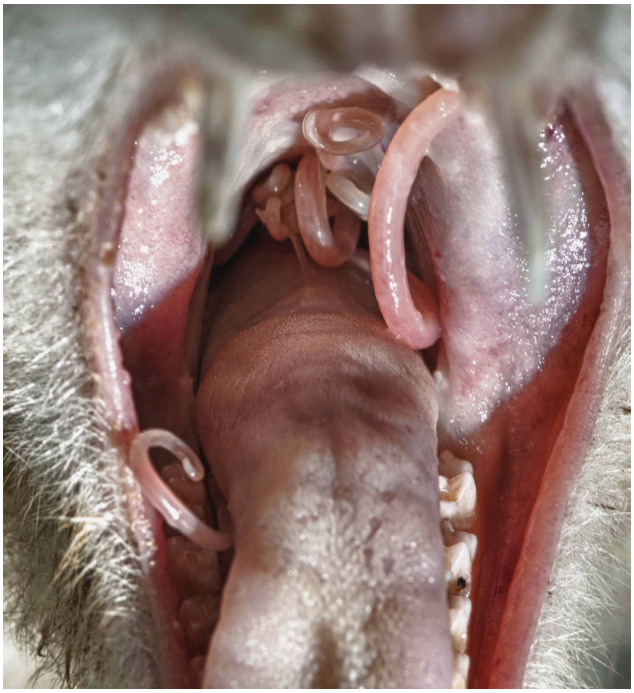

Figure 5. Adult *T. turgida* in the host animal's oral cavity obstructing the airway.

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REFERENCES

1. Nichelason AE, Rejmanek D, Dabritz HA, et al: Evaluation of *Cruzia americana*, *Turgida turgida*, and *Didelphostrongylus hayesi* infection in the, Virginia opossum (*Didelphis virginiana*) and risk factors along the, California coast. J Parasitol 94(5):1166-1168, 2008
2. Comer JA, Davidson WR, Prestwood AK, et al: An update on the, distribution of *Parelaphostrongylus tenuis* in the southeastern United States. J Wildl Dis 27(2): 348-354, 1991
3. Gray JB, Anderson RC: Observations on *Turgida turgida*. J Wildl Dis 18(3):279-285, 1982
4. Potkay S: Diseases of marsupials, in Hunsaker D (ed): The Biology of Marsupials. San Francisco, CA, Academic Press, pp 446-450, 1977
5. Martin DS: National Chief of Parasitology: IDEXX Reference Laboratories Ltd. ON, Canada, Markham. Personal communication. Accessed Jan 2012
6. Bartholomew AR, Crites JL: On the occurrence of the nematode *Cruzia americana* in a raccoon. Ohio J Sci 65(4): 219, 1965
7. Crites JL: The chemistry of the membranes of the egg envelope of *Cruzia americana*. Ohio J Sci 58(6):343, 1958
8. Bowman DD: Companion Animal and Exotic Animal Parasitology. Ithaca, New York, IVIS, 2007
9. Prestwood AK: *Didelphostrongylus hayesi* gen. et sp. n. (*Metastrogyloidea*: *Filaroididae*) from the opossum, *Didelphis marsupialis*. J Parasitol 62(2):272-275, 1976
10. Kahn CM: Respiratory system, in Kahn CM (ed): The Merck Veterinary Manual (ed 9). Whitehouse Station, NJ, Merck and Aventis Company, pp 1181-1186, 2005
11. Baker DG, Cook LF, Johnson DM, et al: Prevalence, acquisition, and treatment of *Didelphostrongylus hayesi* infection in opossums. J Zoo Wildl Med 26(3):403-408, 1995
12. Lamberski N, Reader JR, Cook LF, et al: A retrospective study of 11 cases of lungworm (*Didelphostrongylus hayesi*) infection in opossums (*Didelphis virginiana*). J Zoo Wildl Med 33(2):151-156, 2002
13. Plumb DC: Plumb's Veterinary Drug Handbook (ed5). Ames, IA, Blackwell, Publishing, 2005
14. Evinger JV, Kazacos KR, Cantwell HD: Ivermectin for treatment of nasal capillariasis in a dog. J Am Vet Med Assoc 186(2):174-175, 1985
15. Beach MJ, Arana BM: Effectiveness of combined albendazole and ivermectin, treatment for intestinal worm infections. Centers for Disease Control and Prevention (CDC). http://CinicalTrials.gov/ct/show/ NCT00207753, accessed September 13, 2005
16. Cernea LC, Cernea M, Ognean L, et al: The efficacy of macrocyclic lactone and benzimidazoles combination in equine strongylidosis. http://www.usamvcluj.ro/cercetare/rezistenta_helmintoze, accessed October 2012