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Parastrongylus (=*Angiostrongylus*) *cantonensis* Now Endemic in Louisiana Wildlife

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ABSTRACT: *Parastrongylus* (=*Angiostrongylus*) *cantonensis*, a lung worm of rats, was first reported in the United States in 1987, with a probable introduction by infected rats from ships docking in New Orleans, Louisiana, during the mid-1980s. Since then, it has been reported in nonhuman primates and a boy from New Orleans, and in a horse from Picayune, Mississippi, a distance of 87 km from New Orleans. *Parastrongylus cantonensis* infection is herein reported in a lemur (*Varencia variegata rubra*) from New Iberia, Louisiana, a distance of 222 km from New Orleans, and in a wood rat (*Neotoma floridanus*) and in 4 opossums (*Didelphis virginiana*) from Baton Rouge, Louisiana, a distance of 124 km from New Orleans. The potential of a great variety of gastropods serving as intermediate hosts in Louisiana may pose a threat to wildlife as well as to domesticated animals in the areas where infected Norway rats (*Rattus norvegicus*) are present.

Parastrongylus (=*Angiostrongylus*) *cantonensis* (Chen, 1935) Chabaud 1972 is a lung worm of rats, originally described from the Norway rat *Rattus norvegicus*, which can also use other rodents as definitive hosts. The change of name from *Angiostrongylus* to *Parastrongylus* follows the taxonomy of Andersen (1978) and Ubelaker (1986). Adult worms in the pulmonary arteries of the infected rats produce eggs that hatch into first-stage larvae in the bloodstream, penetrate into the airways in the lung, migrate up the respiratory tree, and are shed in host feces. The first-stage larvae then develop into third-stage infective larvae in many species of land and aquatic snails or slugs. The infective larvae are neurotropic and, in the natural host, migrate to the brain where they grow and molt to young adults over a period of 2 wk, producing an extensive inflammatory reaction; the young adults then migrate to the pulmonary arteries where they permanently reside. The prepatent period is approximately 6 wk. The sequelae in abnormal mammalian hosts are dependent on the location, number, and degree of development of the worms in the brain and spinal cord.

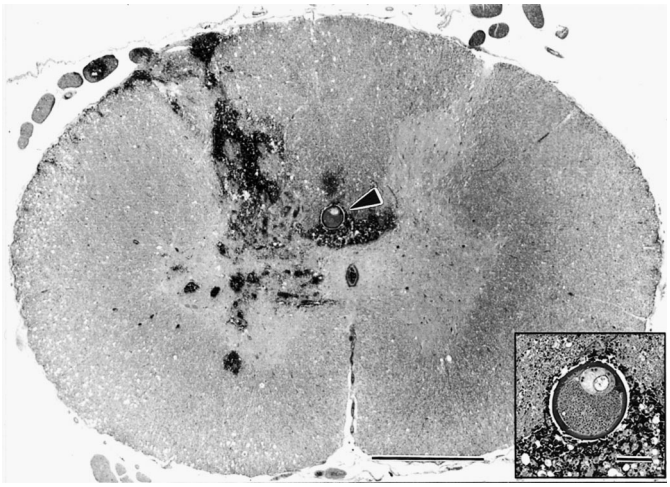

FIGURE 1. Cervical spinal cord of the lemur infected with *Parastrongylus cantonensis*. Note the aberrant migration of *P. cantonensis* (arrow head) into the deep spinal cord parenchyma, resulting in focally extensive area of malacia with hemorrhage. Bar = 1 cm. Insert: high magnification of cross section of the *P. cantonensis*. Bar = 100 μm.

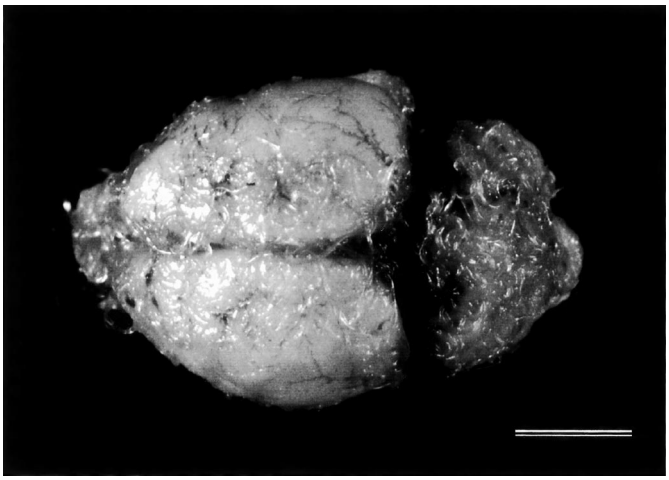

FIGURE 2. Brain of the wood rat almost completely covered with numerous *Parastrongylus cantonensis*. Bar = 3 cm.

The first human infection, according to Alicata (1991), was reported by Nomura and Lin (1944) in Taiwan. The fact that *P. cantonensis* had reached almost epidemic proportions in areas of the Pacific basin was not established until 1961 (Alicata, 1991). Dispersal of the giant African snail, *Achatina fulica*, is thought to have played an important role in endemic areas because a single snail can harbor more than 10,000 infective larvae (Alicata, 1991).

In the Western Hemisphere *P. cantonensis* was first reported in both rats and humans in Cuba in 1981 (Aguiar et al., 1981; Pascual et al., 1981) and then in Puerto Rico (Andersen et al., 1986). Since its problematic arrival into the United States in the early 1980s, and the first report from New Orleans, Louisiana in 1987 (Campbell and Little, 1988), 6 infections (including 3 deaths) of nonhuman primates (Gardiner et al., 1995; Aguilar et al., 1999), a human infection (New et al., 1995), and death of a miniature horse (Costa et al., 2000) from Picayune, Mississippi, a distance of 87 km from New Orleans have been attributed to *P. cantonensis*. *Parastrongylus cantonensis* infection of a lemur (*Varencia variegata rubra*) in New Iberia, Louisiana, a distance of 222 km from New Orleans, and a wood rat (*Neotoma floridanus*) and 4 opossums (*Didelphis virginiana*) from Baton Rouge, Louisiana, a distance of 124 km from New Orleans is reported here.

Since 1996, a series of animals with neurological abnormalities have been submitted for necropsy to the School of Veterinary Medicine, Louisiana State University. Normal procedures were followed for the gross examination of all organs, culturing of infectious agents, preserving

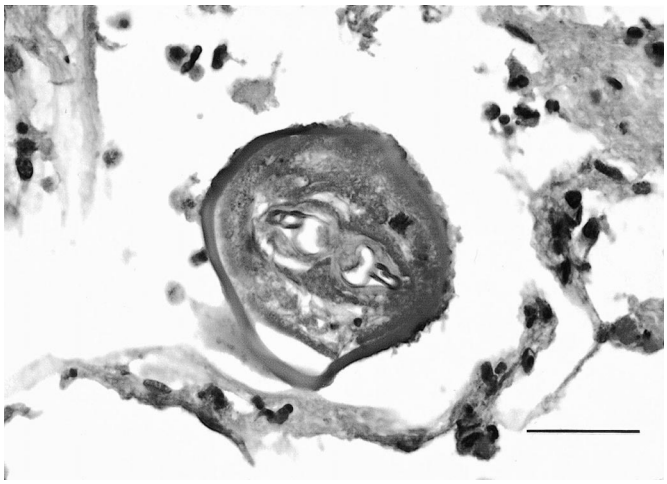

FIGURE 3. Cross section of a male *Parastrongylus cantonensis*, with thin spicules, in the meninges of an opossum. Bar = 35 μm.

tissues for microscopic examination, and specific tests appropriate for postmortem findings. Specimens from the major organs were collected, fixed in 10% neutral buffered formalin, processed by routine procedures, sectioned, and stained with hematoxylin and eosin.

The first case of *P. cantonensis* infection from Louisiana State University was of a 5-mo-old American miniature filly in 1996 (Costa et al., 2000). Histopathological examination revealed a cross section of a nematode in the spinal cord. Follow-up dissection of the preserved spinal cord yielded 22 whole sexually mature male and female *P. cantonensis*.

In June 1998 a red-ruffed lemur (*V. v. rubra*) was found with hyperspastic limbs in an exhibit enclosure at the Zoo of Acadiana, New Iberia, Louisiana. Radiographs showed C5–C6 fractures and possible C1–C2 luxation. The lemur was killed humanely. Gross findings were limited to the central nervous system. The spinal cord had a lengthy reddened area in the gray matter from C1 to C6. The cerebral meninges were multifocally hemorrhagic. Histological examination showed coalescing areas of malacia characterized by infiltrates of numerous lipid-laden macrophages (gitter cells) in the cervical spinal cord and multiple cross sections of nematodes with multifocal areas of meningeal hemorrhage and mild eosinophilic and histiocytic infiltration (Fig. 1). Whole adult male and female nematodes recovered from the surface of the brain were identified as *P. cantonensis*.

A wood rat (*N. floridanus*) was submitted to the Wildlife Hospital of Louisiana after being caught in Baton Rouge, Louisiana, in August 1998. The rat had been behaving erratically and within 2 days of hospitalization became stuporous. At necropsy the meninges of the cerebrum, cerebellum, and cervical spinal cord were almost completely covered with nematodes, 0.5–1.00 cm in length (Fig. 2). Histologically, the cerebral and cerebellar meninges and lateral ventricles had numerous cross sections of nematodes. In the cerebellum some sulci were deeply invaginated into the parenchyma and markedly dilated, with cross sections of nematodes. The surrounding cerebellar parenchyma was severely atrophied. No inflammatory response to the parasites was noted. Dissection of half the brain yielded 120 whole female worms and 82 whole male worms identified as *P. cantonensis*. Additional broken pieces from the half-brain included 16 female and 13 male tails for a total of 231 nematodes.

During the years 1998 and 1999, 3 opossums (*D. virginiana*) were presented to the Wildlife Hospital of Louisiana with common clinical histories of weakness, ataxia, and neurological signs such as circling. All the opossums were captured wild in the vicinity of Baton Rouge. Because of the grave prognoses and the public concerns regarding rabies, necropsies were performed. Virological tests for rabies virus were negative. The animals were not examined for parasites. In general, the microscopic lesions in the brains were similar in character in all the animals but slightly different in severity. Multifocal areas of cerebral and cerebellar leptomeninges were thickened with infiltrates of a few to moderate numbers of eosinophils, macrophages, lymphocytes, a few multinucleated giant cells, and occasional cross sections of nematodes that were morphologically consistent with those of *P. cantonensis* (Chitwood and Lichtenfels, 1972).

In September 2000 a juvenile opossum was presented to the Wildlife Hospital of Louisiana with a history of circling and lateral recumbency for 2 wk after being captured in the vicinity of Baton Rouge, 3 wk previously. Half of the fresh brain presented for gross examination for parasites contained a male *P. cantonensis* on the surface. Cross section of the spicules of a male nematode from the brain tissue conformed to the morphology of those of *P. cantonensis*, which are long and thin (Fig. 3).

Adult *P. cantonensis* reside in the pulmonary arteries of several genera of rodents. Most importantly in the United States, Norway rat (*R. norvegicus*) and the roof rat (*R. rattus*) are known to serve as definitive hosts. In a survey of rats from the harbor area of New Orleans, however, of the 94 *R. norvegicus* examined, 21.3% were infected with *P. cantonensis*, whereas none of the 19 *R. rattus* was infected (Campbell and Little, 1988). In experimental exposures of freshwater mollusks to first-stage larvae of *P. cantonensis*, third-stage infective larvae developed in 20 of 26 species (Richards and Merritt, 1967). All 11 species of terrestrial gastropods collected from New Orleans and exposed to first-stage larvae developed third-stage larvae by 21 days (Campbell and Little, 1988).

The wood rat has not been previously reported as harboring *P. cantonensis*. The severe infection with overwhelming numbers of adult male and female nematodes in the cerebral, cerebellar, and cervical spinal meninges, surprisingly, was not associated with an inflammatory response. The physically atrophied cerebral and cerebellar parenchyma likely caused the neurological problems reported. According to an experimental study many Wistar rats died after receiving more than 50 infective larvae at 1 time (Kwong and Dobson, 1982).

Parastrongylosis has been reported in marsupials from Australia (McKenzie et al., 1978; Higgins et al., 1997); hence, it is not surprising to find that the only native North American marsupial, the Virginia opossum (*D. virginiana*), is subject to infection. The opossum is omnivorous, feeding on fruits, insects, gastropods, and even rodents and is frequently found in the same habitat as Norway rats near populated areas. Positive identification of *P. cantonensis* as the nematode present in the brain was made in only 1 of the 4 opossums necropsied because fresh or preserved gross brain or spinal tissue was not available for recovery of whole nematodes from the first 3 opossums necropsied; however, the morphology of the nematode cross sections in brain tissue examined from the 4 opossums was similar.

All the cases of *P. cantonensis* infection reported from Louisiana State University (horse, lemur, wood rat, and opossums) involved sexually mature male and ovigerous female nematodes. The propensity to develop into adults in a variety of abnormal hosts increases the life-threatening potential of the parasite to domestic animals and wildlife. In 2 equine cases in Australia (Wright et al., 1991) only larval stages of both sexes were reported. Because several normal nematode parasites of horses may migrate to the central nervous system, differentiation between the larval stages is important, especially where both *Strongylus vulgaris* and *P. cantonensis* occur (Little, 1972).

In experimental infections of 5 pigs with 20,000 infective larvae of *P. cantonensis*, no symptom suggestive of the involvement of the nervous system was observed, whereas uncertain gait was noted in 3 of the 5 calves infected with 70,000 infective larvae (Jindrak and Alicata, 1968). All the calves had pathological changes in the brain at necropsy 3, 7, 14, 28, and 56 days after infection, whereas lesions were observed only in the pig necropsied on day 3 after infection. Larvae recovered from a pig and calf 3 days after infection produced cerebral infection when fed to rats. Larvae recovered from pigs or calves 7 or more days after infection failed to produce infection when fed to rats, indicating that pigs and cattle may not be successful paratenic hosts.

Mason (1987) has reported 55 canine cases of naturally occurring *P. cantonensis* infection selected from the veterinary clinics in the Brisbane metropolitan area of Australia. The disease is described by an ascending paresis in pups and the severe form causes paralysis of the limbs and involves head and neck muscles. Although the majority of the pups recovered with supportive care after 7–14 days, 7 pups (12.7%) died after 2 wk of progressive deterioration.

Wallace and Rosen (1965) reported that, according to L. R. Ash (pers. comm.), the previous examinations of rats from New Orleans for *P.*

cantonensis had been negative. Small numbers of rats trapped in the wharf area of New Orleans and necropsied each year from 1962 to 1976 in the Department of Tropical Medicine of Tulane University were negative for *P. cantonensis*. However, a rat survey conducted from 1986 to 1987 revealed that 21.4% of *R. norvegicus* trapped were infected with *P. cantonensis* (Campbell and Little, 1988).

Other than infected rats, infected intermediate hosts, such as snails and slugs, can also serve as vehicles for colonization and subsequent dissemination. In the Pacific basin it has been shown that aberrant infection in humans can be acquired by consuming raw or partly cooked freshwater prawns, land crabs, and frogs that harbor the larvae as paratenic hosts and by consuming inadequately washed fresh fruits and vegetables that are contaminated with mucous of infected snails or slugs or carnivorous planarians (Alicata, 1962; Ash, 1976). Recently, Slom et al. (2002) have reported that 12 persons of a group of 23 U.S. travelers developed eosinophilic meningitis within 6–31 days (median 11) of their return home from a visit to Jamaica. Among the patients there was a serological evidence of *P. cantonensis* infection in 11 persons who had eaten salad in the same restaurant. Although in most human cases only partial development of *P. cantonensis* occurs, and migration is restricted to brain and spinal cord, the presence of adults has been reported (Alicata, 1969).

The increase in the number of cases of parastrongylosis reported in Louisiana, radiating away from New Orleans, indicates that *P. cantonensis* is endemic in the Gulf Coast of North America. There is a strong possibility that *P. cantonensis* has moved north up the Mississippi River, and it may have also entered through other ports and moved up their respective rivers as well.

Specimens have been deposited in the U.S. National Parasite Collection. The accession numbers include USNPC 92099 through 92106 and 92142 through 92146.

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