**Introductory statement**

Angiostrongylus cantonensis occurs naturally in introduced black and Norway rats but causes neuroangiostrongyliasis in eutherian and marsupial mammals and birds. It is the primary cause of eosinophilic meningitis in humans in Australia and an expanding area of the world, including within south eastern Australia (see Prociv et al 2000 for comprehensive review).

**Aetiology**

A. cantonensis is a parasitic lungworm belonging to the nematode superfamily Metastrongyloidea. It is believed to have arrived in Australia with introduced rat species.

**Natural hosts**

The rat lungworm occurs naturally in the pulmonary arteries, rarely the right ventricle of the Norway rat, Rattus norvegicus, and the black rat, R. rattus. It occurs accidentally in a wide range of native and non-native eutherian and marsupial mammals and some native birds. It causes zoonotic infection in humans, especially young children prone to ingesting the intermediate or paratenic hosts of the parasite: snails, slugs, planarians and crabs (Ash 1976).

**World distribution**

The parasite has a wide geographical distribution encompassing much of south-east Asia, Melanesia, Polynesia and eastern Australia. It has established a foothold in Africa, India, the Caribbean and, more recently, in south-eastern USA (Kliks et al 1992; Prociv et al 2000).
**Occurrences in Australia**

The parasite occurs in eastern coastal Queensland and New South Wales as far south as Jervis Bay (Stokes et al 2007). Naturally occurring, non-human infections were first recognised in dogs in Brisbane in 1972 (Mason et al 1976) and in Sydney in 1989 and 1991 (Collins et al 1992).

The first natural infection in a marsupial was reported in 1978, from a captive Bennett’s wallaby in Brisbane, with morphological confirmation of *A. cantonensis* worms recovered from the central nervous system (CNS) (McKenzie et al 1978).

Subsequently, natural infections have been confirmed by autopsy in horses (Wright et al 1991), a range of potoroid and macropodid marsupials (Higgins et al 1997; Rose and Spratt pers. comm.), ringtail and brushtail possums (Prociv pers. comm., Rose and Spratt pers. comm.), captive tamarins (Carlisle et al 1998; Clark et al 1999) and squirrel monkeys (Rose and Spratt pers. comm.), free-living flying foxes (Reddacliff et al 1999), tawny frogmouths and a yellow-tailed black cockatoo (Monks et al 2005).

**Epidemiology**

When the life cycle of the rat lungworm was investigated in Brisbane more than 50 years ago (Mackerras and Sandars 1955), it was not then generally known to be a human pathogen. Nor was it realised at the time that the parasite under investigation was actually *A. mackerrasae*, almost identical to *A. cantonensis*; *A. mackerrasae* was not recognised as a distinct and indigenous species found in native rats until 14 years later (Bhaibulaya 1968).

Eggs released by female worms in the pulmonary arteries are carried in the circulation to the lungs where they embryonate. Hatched, first-stage larvae penetrate alveoli and are then carried up the respiratory escalator, swallowed and subsequently passed in the faeces. They are ingested by intermediate hosts, which include a wide range of native and introduced slugs and snails. They develop to the third larval stage in molluscan tissues and are directly infective to rats, although a variety of paratenic or transport hosts (which eat molluscs) may be interspersed in transmission, including terrestrial planarians and crabs, fresh-water shrimp and fish, frogs and toads. Third-stage larvae ingested by rats penetrate the stomach, enter the hepatic portal and the mesenteric lymphatic systems, are subsequently carried around the body by the arterial circulation and enter the CNS 2–3 days postinfection. They undergo an obligatory migration to the brain, moulting twice en route to the subarachnoid space 12–14 days postinfection. At 28–33 days, worms enter the cerebral vein and travel to the heart and pulmonary arteries, where they mature (Mackerras and Sandars 1955; Bhaibulaya 1975). This parasite is not highly specific for its definitive or intermediate hosts.

There is reasonable knowledge of some of the infection pathways from snails and slugs (indigenous and introduced) ingested by Australian hosts, including humans (Mackerras and Sandars 1955; Bhaibulaya 1975; Yong et al 1981; Collins et al 1992; Higgins et al 1997; Carlisle et al 1998). However, the infection pathway responsible for the high prevalence of infection in tawny frogmouths, *Podargus strigoides*, in the northern suburbs of Sydney has not been clearly elucidated (Spratt 2005). The relevance of snails and slugs in the diet of these birds has not been clarified.

Human angiostrongyliasis was first reported in Australia by Gutteridge from Brisbane, in 1971, although case records indicated infections might have occurred as early as 1959 (Heaton and Gutteridge 1980). Human infection has resulted from ingestion of small intermediate or paratenic hosts, either deliberately or
accidentally (for example on poorly or unwashed salad greens) (Gutteridge 1971; Gutteridge et al 1972; Saltos 1975; Prociv and Tiernan 1987). There have been three reported Australian fatalities in infants, probably through direct ingestion of snails or a planarian (Prociv and Tiernan 1987, Prociv 1999; Cooke-Yarborough et al. 1999). A human case in Sydney resulted from deliberate ingestion of a large slug on a bet (Senanayake et al 2003). Infective lungworm larvae escaping from molluscan tissues in the mucous deposited on salad vegetables may be another source of infection (Heyneman and Lim 1967).

Evidence of a long association of *A. cantonensis* with its “domiciliated” rat hosts, *R. norvegicus* and *R. rattus*, stems from the fact that they can survive relatively large infective doses (150 parasites developing in the brain at 28 days), often without significant disturbances to the CNS (Prociv et al 2000). Surveys of rats in the environs of Brisbane confirmed that *A. cantonensis* occurred only in these two exotic rat species, that its distribution was focal and concentrated near the river, and that virtually all slugs and snails tested experimentally were suitable intermediate hosts, including *Helix aspersa*, the exotic European garden snail (Yong et al. 1981). The presence of the indigenous species of *Angiostrongylus, A. mackerrasae*, only in indigenous rats *R. fuscipes* and *R. lutreolus* in Australia, including Tasmania, indicates a long co-evolution of this association (Prociv et al 2000). Like *A. malaysiensis* in Malaysia, *A. mackerrasae* has not been associated with infections of humans or other accidental hosts.

**Clinical signs**

In animals, the predominant clinical features of angiostrongyliasis are neurological and include depression, ataxia, muscle wasting, ascending paresis, lumbar hyperalgesia and paralysis of the limbs, which in severe forms may involve the muscles of the head and neck (Mason et al 1976; Mason 1987; Wright et al 1991; Monks et al 2005). The most common, and often only, symptom of neuroangiostrongyliasis in adult humans is severe, prolonged headache (Punyagupta et al 1970).

**Diagnosis**

Histological examination of the brain and spinal cord and dissection and recovery of worms is essential for definitive diagnosis. Because cerebrospinal fluid (CSF) collection is rarely performed in birds, antemortem diagnosis in birds can only be presumptive, relying on history and clinical signs in endemic areas (Monks et al 2005). It is noteworthy that several flying foxes in Brisbane with neurological disease tentatively attributed to lyssavirus infection, were, on retrospective examination of preserved brain tissue, shown to have variable numbers of *A. cantonensis* (Redd acliff et al 1999).

**Clinical pathology**

In animals, the classic presentation is eosinophilic meningoencephalitis, presumptive diagnosis being strongly supported by the finding of marked eosinophilic pleocytosis and sometimes even larval *A. cantonensis* in the CSF (Mason et al 1976; Wright et al 1991; Collins et al 1992). Along with the clinical signs of ascending paresis and lumbar hyperalgesia, CSF analysis is a valuable aid in the diagnosis of neuroangiostrongyliasis (Mason 1989). Peripheral eosinophilia is commonly present.
**Pathology**

There is often severe eosinophilic granulomatous meningoencephalomyelitis throughout the brain and spinal cord (Mason et al 1976; Wright et al 1991; Collins et al 1992). Inflammatory foci may contain dying or degenerating nematodes. Monks et al (2005) reported Wallerian degeneration of white matter and variable chronic inflammation in infected birds.

**Differential diagnosis**

The morphology of lungworms, in general, does not allow for confidence in specific determination from histological sections. However, identification can be achieved by morphological examination of whole worms. The size of the spicules of males in particular is highly diagnostic, with spicule length in *A. cantonensis* being approximately 1.0 mm and about twice the length of that in *A. mackerrasae* (Bhaibulaya 1968).

First-stage larvae passed in the faeces of infected rat hosts cannot be satisfactorily differentiated from other lungworm species. Infection in accidental vertebrate hosts generally does not develop to the stage of production of first-stage larvae or their subsequent occurrence in faeces.

**Laboratory diagnostic specimens**

Fresh brain and CNS in saline - frozen or fixed - are useful for dissection and recovery of larval and adult worms, subsequent to microscopic identification to species level.

**Laboratory diagnostic procedures**

Assessment of human patient sera, in an enzyme-linked immunosorbent assay (ELISA) based upon purified extracts from adult female worms, and using a wide range of controls, showed a sensitivity of 100% in clinically affected patients, but a very low specificity and positive predictive value of the test (Nuomtanong 1996). A major drawback in diagnosing subclinical infection is that small numbers of worms might not elicit detectable serological responses. This could also apply to monoclonal antibody (mAb)-based tests, aimed at detecting *Angiostrongylus* antigens in sera and CSF, which have shown promise in patients with clinical eosinophilic meningoencephalitis (Chye et al 1997). PCR-based assays for parasite DNA may prove more useful, but these have not yet been investigated in angiostrongyliasis.

**Treatment**

Fenbendazole has been used to successfully treat *A. cantonensis* infection in grey-headed flying-foxes (*Pteropus poliocephalus*) and its use could be considered in macropods (Reddacliff et al 1999). Transient but short-lived improvement was reported in a yellow-tailed black cockatoo following treatment with dexamethasone (0.7 mg/kg IM), but no improvement was evident in two tawny frogmouths 24 hours after treatment with dexamethasone (4 mg/kg IM) (Monks et al 2005).

Treatment of an infected foal with dexamethasone (0.5 mg/kg IV), procaine penicillin (20 mg/kg IM) once daily and ivermectin (0.2 mg/kg) administered by nasal gastric tube resulted in little improvement, and the animal was subsequently euthanased (Wright et al 1991). In puppies, betamethasone (1-2 mg/kg orally or by injection) was effective in reducing the severity of clinical signs in the initial 2-16 days after developing paresis and was also very effective in lessening the residual damage left at 32 days (Mason 1987). Treatment of eight...
puppies with anthelmintics (mebendazole at 30 mg/kg twice daily for 5 days or levamisole at 5 mg/kg once per day for 3 days) alone or together with corticosteroids resulted in only two survivors, and both of these suffered relapses (Mason 1987). Death could be attributed to neuroangiostrongyliasis in only four of the six puppies that died.

**Prevention and control**

The only effective strategy for prevention and control is to reduce or eliminate contact between potential vertebrate hosts and the intermediate or paratenic hosts of the parasite. This is obviously an impractical approach with free-living wildlife. However, the incidence of infection in zoos and fauna parks can be reduced with a broad-based rodent, snail and slug control program.

**Surveillance and management**

There is currently no formal surveillance or management of *A. cantonensis* in Australia, aside from control of rats and rat habitat in and around some zoos and faunal parks.

**Statistics**

Wildlife disease surveillance in Australia is coordinated by Wildlife Health Australia. The National Wildlife Health Information System (eWHIS) captures information from a variety of sources including Australian government agencies, zoo and wildlife parks, wildlife carers, universities and members of the public. Coordinators in each of Australia's States and Territories report monthly on significant wildlife cases identified in their jurisdictions. NOTE: access to information contained within the National Wildlife Health Information System dataset is by application. Please contact admin@wildlifehealthaustralia.com.au.

There are a large number of reports of neuroangiostrongyliasis in the national wildlife health information system eWHIS. Reports are primarily from flying-foxes (*Pteropus* sp.) and tawny frogmouths (*Podargus strigoides*) in north eastern New South Wales and coastal Queensland.

**Research**

The precise geographical distribution of *A. cantonensis* in Australia remains unknown, even between southern Queensland and Sydney. If *A. cantonensis* entered the continent through northern ports, one would expect it to be established throughout the wet tropical regions. A systematic survey of rats on the mainland of the Northern Territory and northern Western Australia could be very informative.

The geographical distribution of *A. cantonensis* has recently been found to extend as far south as the coastal forests of Jervis Bay (Stokes et al 2007). The occurrence of the parasite in black rats in bushland close to campgrounds and rural homes has possible human and wildlife health implications.

It is likely that most of the autochthonous human infections in Australia, at least in adult patients, were not acquired through the ingestion of molluscs, but through salad vegetables, especially lettuce. This raises the possibility of infective larvae being released in snail mucous, although current evidence for this probably derives from *A. malaysiensis* rather than *A. cantonensis* (Heyneman & Lim 1967).
Further studies should be directed towards establishing the modes of dispersal of *A. cantonensis*, the potential role of humans in its spread, its geographical distribution and its impact on native fauna. Finally, a test for accurate diagnosis of *A. cantonensis* infection in vertebrates would be highly beneficial.

**Conclusions**

Neuroangiostrongyliasis is a life-threatening disease of wildlife, pets and children and can occur wherever introduced black and Norway rats proliferate and where a spectrum of intermediate and paratenic hosts exist. These conditions are particularly found in cities, around fauna parks and zoos and, increasingly for the black rat, in temperate coastal forest areas and campgrounds.

**References and other information**


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To provide feedback on this fact sheet

We are interested in hearing from anyone with information on this condition in Australia, including laboratory reports, historical datasets or survey results that could be added to the National Wildlife Health Information System. If you can help, please contact us at admin@wildlifehealthaustralia.com.au.

Wildlife Health Australia would be very grateful for any feedback on this fact sheet. Please provide detailed comments or suggestions to admin@wildlifehealthaustralia.com.au. We would also like to hear from you if you have a particular area of expertise and would like to produce a fact sheet (or sheets) for the network (or update current sheets). A small amount of funding is available to facilitate this.

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