Neosporosis and hammondiosis in dogs

The dog is a definitive host of the protozoan parasite *Neospora caninum*, and in many parts of the world, infection is relatively common as determined by serology. Reported seroprevalences usually range from 0 to 20 per cent, however, reports of clinically affected dogs are infrequent. Affected dogs are generally less than six months old and predominantly have signs of an ascending hindleg paralysis, with the associated lesions of polyradiculoneuritis and granulomatous polymyositis. Although any organ may be affected, infections are more common in the central nervous system, muscles, lungs and skin. Ante-mortem diagnosis is difficult but serology and cytology can aid diagnosis. The diagnosis can be confirmed by histology, immunohistochemistry, the use of molecular techniques on biopsy material, or on post-mortem examination. *Neospora caninum* oocysts are rarely found in faeces and must be differentiated from oocysts of related coccidians such as *Hammondia heydorni* and *Toxoplasma gondii*. *Hammondia heydorni* can cause diarrhoea in immunosuppressed dogs. Neosporosis should be suspected in young pups with an ascending paralysis of the hindlegs. Treatment with clindamycin and potentiated sulphonamides may be useful in cases where muscular atrophy and fibrosis are absent. Feeding of raw meat is a potential risk factor for infection of dogs and should be discouraged.

**INTRODUCTION**

A neosporosis-like illness was first recognised in Norway in boxer dogs which developed neurological disorders soon after birth (Bjerkaås and others 1984), but the organism, *Neospora caninum*, causing the disease was not identified until it was named a few years later (Dubey and others 1988). Since then, infections due to *N caninum* have been described in many countries worldwide (Dubey and Lindsay 1996, Lindsay and Dubey 2000, Dubey and others 2002). Before the identification of *N caninum* as a new species, and the realisation that neosporosis was a separate disease, dogs were often diagnosed as suffering from *Toxoplasma gondii* infection (Dubey and others 1988). Subsequent retrospective analyses have now re-classified a number of cases as due to *N caninum* infections (Dubey and others 1988, Munday and others 1990, Patitucci and others 1997, Ellis 1998). Nevertheless, *T gondii* infection may still cause a very similar clinical picture in dogs and must be included in the differential diagnosis. In addition, until recently, another coccidian species, *Hammondia heydorni*, was not known to be of clinical significance in dogs but is now emerging as a cause of diarrhoea.

This review attempts to present the current state of knowledge on neosporosis and hammondiosis in dogs in a concise form focusing on clinical signs. It discusses treatment and preventive measures available to dog owners and veterinarians.

**LIFE CYCLE**

Dogs (*Canis familiaris*) and coyotes (*Canis latrans*) are a definitive host of *N caninum* (McAllister and others 1998, Gondim and others 2004). Experimentally and naturally infected dogs shed low numbers of oocysts, with oocyst excretion commencing between five and 13 days postinfection and shedding lasting for up to 27 days. Oocysts sporulate 24 to 72 hours after being passed in the faeces and then become infective. Recent reports suggest that young puppies are more likely to shed more oocysts than older dogs (Gondim and others 2005). In addition, the source of infective material is important, as oocyst production is far greater in dogs fed *N caninum*-infected beef than in those fed infected-murine tissues (Gondim and others 2002). There is epidemiological evidence that the life cycle can be maintained between dogs and cattle. Dogs have been infected by feeding infected bovine foetal membranes (Dijkstra and others 2001), and it is believed that infection may occur from ingested raw meat such as beef that contain the encysted stage of the parasite (Peters and others 2001). Infection of dogs as a primary host produces infective...
Neospora caninum oocysts, which have the potential to infect cattle (Fig 1). N caninum oocysts have, in turn, been shown to be infective to cattle experimentally (De Marez and others 1999). Adult cattle generally show no signs of clinical disease but may abort sometimes in epidemic proportions. Transplacental infection in cattle, however, is very efficient and up to 80 to 90 per cent of calves might be born infected, yet clinically normal if the dam is infected with N caninum in the later stages (last trimester) of gestation (Paré and others 1996, Williams and others 2000).

Transplacental transmission from dam to pup appears to be efficient but is unlikely to sustain infection in the dog population (Barber and Trees 1998, Dubey and others 2005). Up to 50 per cent of pups of N caninum-positive dams might become infected transplacentally, with 25 per cent developing clinical signs. In contrast, little is known about H heydorni, which has frequently been confused in the past with N caninum, although both are now recognised as independent species (Dubey and others 2002) and can be distinguished by the application of molecular techniques (Slápetta and others 2002a). Similar to N caninum, H heydorni has a dog-cattle life cycle (Dubey and others 2002), although other animals (such as deer) can act as intermediate hosts (Dubey and others 2004b).

SEROPREVALENCE

The prevalence of infection with N caninum in clinically normal dog populations ranges from apparently nil in the Falkland Islands and Kenya to around 20 per cent of a population being infected in Tanzania and Uruguay (Barber and others 1997a) and up to 54-2 per cent in dogs from beef farms in Argentina (Basso and others 2001). Similar levels of seroprevalence are reported from other parts of South America (de Souza and others 2002, Gennari and others 2002, Fernandes and others 2004, Azevedo and others 2005). Worldwide prevalences have been summarised (Lindsay and Dubey 2000, Dubey 2003).

In Europe, two to 13 per cent of randomly studied dogs were seropositive to N caninum in Austria (Wanha and others 2005), Belgium (Barber and others 1997b), England (Trees and others 1993), Hungary (Hornok and others 2006), Italy (Capelli and others 2004), the Netherlands (Wouda and others 1999), Spain (Ortuño and others 2005), Sweden (Björkman and others 1994) and Turkey (Coskun and others 2000). In selected subpopulations, the seroprevalence may be considerably higher or lower (Basso and others 2001, Antony and Williamson 2003, Wanha and others 2005). For example, higher seroprevalences have been reported for farm dogs than for urban dogs (Sawada and others 1998, Basso and others 2001, Sager and others 2006).

COPROSCOPIC STUDIES OF INFECTION

Oocysts of N caninum, which are found infrequently in the faeces of dogs, are also indistinguishable from those of some other apicomplexan parasites that cycle through dogs, in particular H heydorni (Lindsay and others 1999b, Slápetta and
Oocysts of the feline coccidians, *T. gondii* and *Hammondia hammondi*, can also be mechanically transmitted by dogs and hence either may be present in the faeces of dogs (Lindsay and others 1997, Schares and others 2005); apparently some of these oocysts pass through the canine gut unexcysted after dogs ingest cat faeces. Hence, oocyst morphology is not helpful in species identification of these cyst-forming coccidian found in faeces. Molecular techniques, based on polymerase chain reaction (PCR) and sequencing, can help identify the species present; however, these approaches are constrained by the number of oocysts present. Infection of gerbils with oocysts can result in seroconversion if *N. caninum* is present (Schares and others 2005); however, it is difficult to determine the presence of *H. heydorni* because of the absence of appropriate serological tests.

Studies have reported diarrhoea in normal and an immunosuppressed dog associated with *H. heydorni* infection (Blagburn and others 1988, Schares and others 2005, Abel and others 2006). Dogs can repeatedly shed oocysts of *N. caninum* (McGarry and others 2003, Gondim and others 2005, Sager and others 2006). There are a number of possible explanations for these observed phenomena, such as failure to induce host immunity; however, the results of research on this topic have yet to be reported.

**SOURCES OF INFECTION**

Dogs consuming raw meat are at risk of becoming infected with both *N. caninum* (McAllister and others 1998, Lindsay and others 1999a) and *H. heydorni* (Dubey and others 2003, Schares and others 2005). A wide range of animals, known to act as intermediate hosts for these parasites, may be infected and these include cattle, sheep, and deer, among others (Dubey 2003, Rosypal and Lindsay 2005). Evidence for the importance of raw meat in the transmission of *N. caninum* to dogs is provided by the higher seroprevalence among hunting hounds (51 per cent) compared with pet dogs (7.5 per cent) living in the UK (Trees and Williams in [Hemphill and Gottstein 2000]).

**CLINICAL SIGNS**

Two main neurological forms are observed: encephalomyelitis and myositis-polyradiculoneuritis. Protozoal myositis-polyradiculoneuritis is probably the most commonly reported infectious myositis in dogs. It is generally observed in dogs under six months of age, which were infected transplacentally, and over half of these dogs may go on to have signs of a progressive, ascending paralysis of the hindlegs (Fig 2). Muscle atrophy and a rigid hyperextension of the limb often develops (Barber and Trees 1996). Serum creatine kinase levels may be increased. Muscle biopsy is indicated and may reveal non-suppurative inflammation and tachyzoites within myocytes (Knowler and Wheeler 1995, Ruehlmann and others 1995).

Neurological signs associated with protozoal encephalomyelitis are variable and may reflect a focal or multi-focal disease process. Cerebrospinal fluid exhibits mild mixed pleocytosis and protein increase. Eosinophils are found in only a few cases. Adults are more commonly affected than the young. *N. caninum* has a predilection for lumbosacral roots in puppies, resulting in pelvic limb atrophy and immobile joints (contractures) (Ruehlmann and others 1995).

There are also reports of dermatitis, myocarditis and pneumonia (Ruehlmann and others 1995, McInnes and others 2006). No reports of sex predilection exist but the boxer breed is frequently mentioned (Trees and others 1993, Barber and others 1997b, Cringoli and others 2002). Most affected dogs come from litters where other littermates are infected, but which show no signs of clinical infection (Dubey and others 1988, 2004a Dubey and Lindsay 1996, Reichel and others 1998).

A parasitic dermatitis containing *N. caninum*-like tachyzoites is increasingly being recognised (McInnes and others 2006). Other organs infected might include heart, lung and, less frequently, liver, rarely the adrenal gland, thyroid gland and uterus, although clinical signs resulting from damage to these organs are rarely reported. *Hammondia heydorni* is not normally associated with disease in dogs, although it is increasingly becoming associated with diarrhoea (Schares and others 2005, Abel and others 2006).

**DIAGNOSIS**

Dogs typically seroconvert two to three weeks after infection with *N. caninum* (McAllister and others 1998), and so diagnosis of neosporosis in the live animal can be based on clinical signs with serology. Antibody titres in the indirect fluorescent antibody test rarely exceed 1:800 in clinically unaffected dogs (Barber and Trees 1996). However, dogs with proven neosporosis may have only low antibody titres (Dubey and others 1998, 2005). Immunoglobulin M detection may not be rewarding, especially in congenitally infected dogs (Dubey and others 1998).

A commercially available competitive ELISA test is also available (and validated) for testing dog sera (Capelli and others 2006).

Histological examinations (from biopsy material or post-mortem samples) yield typical lesions of meningoencephalomyelitis and myositis in various muscles throughout the body (Barber and others...
Molecular tools like PCR can also help in providing a diagnosis (Ellis 1998). Identification of the disease-causing organism can be made by its isolation into cell cultures or immunosuppressed mice, immunohistochemistry or molecular techniques (Dubey and others 1998, 2004a). Numerous *N caninum* tachyzoites may be found in fluid squeezed from dermal lesions (Dubey and others 1988). For unknown reasons, there is immunohistochemical cross-reactivity between *N caninum* and *T gondii* in dermal neosporosis.

**TREATMENT**

Early treatment with potentiated sulphonamides and clindamycin may resolve clinical disease, as described in 10 of 16 cases in one report from the UK (Barber and others 1996). Clindamycin was used at dose rates of up to 22 mg/kg twice a day for up to 60 days, 15 to 30 mg/kg potentiated sulphonamides twice a day for up to 28 days, alone or in combination with 1 mg/kg pyrimethamine daily for up to 35 days. Treatment with clindamycin is very effective in treating cutaneous neosporosis (Dubey and others 1995). Frequently, however, the limb lesions progress to muscle atrophy, and in about 50 per cent of cases rigid hyperextension develops that does not respond to treatment (Fig 2). Ponazuril, at 20 mg/kg, daily for up to 35 days. Treatment with potentiated sulphonamides and clindamycin promises success if begun before atrophy and fibrotic lesions have occurred.

**Acknowledgements**

Our thanks to Cindy Burton, whose story prompted us to complete this article (http://www.angelfire.com/stars3/starridge/Gatsby_Mtarni.htm). Thanks are also due to Dr Laurent Garosi for valuable comments on the manuscript.

**References**


Genetics of Neospora caninum in dogs


Lindsay, D. S., Dury, J. P. & Duncan, R. B. (1999a) Confirmation that the dog is a definitive host for Neospora caninum. Veterinary Parasitology 82, 327-333


