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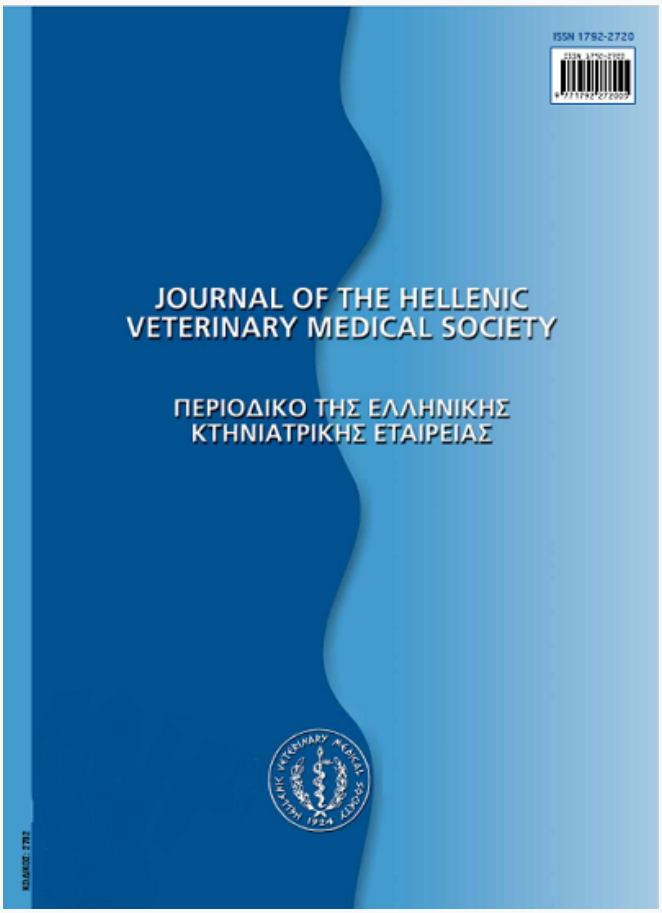

The influence of rodenticides in dissemination of endoparasites of dogs and cats

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Review article
Ανασκόπηση

The influence of rodenticides in dissemination of endoparasites of dogs and cats

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Η επίδραση των μυοκτόνων ουσιών στη διασπορά των ενδοπαρασίτων του σκύλου και της γάτας

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ABSTRACT. Mice and other rodents are well known to play an important role in the biological cycle of many parasites of pets. Among the endoparasites identified in Greece which could be transmitted to dogs and/or cats from colloquially rodents are *Spirocerca lupi*, Ascaridae namely *Toxocara canis*, *Toxascaris leonina* in dogs and *Ancylostoma caninum*, *A.braziliense*, *Trichinella spiralis*, *Echinococcus granulosus*, *Toxoplasma gondii*, *Cryptosporidium* spp and *Leihsmania* spp, while cats can be infested by *Toxocara cati*, *Toxascaris leonina*, *Ancylostoma tubaeformae*, *A.braziliense*, *Aelurostrongylus abstrusus* and *Taenia taeniaformis*, *Toxoplasma gondii*, *Cryptosporidium* spp and *Leihsmania* spp. The route of infection of pet includes in many cases ingestion of parasite infested rodents. A number of these parasites are also of great Public Health importance because they are causing zoonotic diseases. Because of the large numbers of rodents in some areas and their role in transmitting diseases in man and animals, rodenticide programs are performed by individuals or state agencies. Rodenticides are chemical and non-chemical compound which are used to eliminate rodents. However, attention should be paid on their use and manufacturer's instructions should be strictly followed because of the risk of accidental poisoning of pets and children. It can be conclude that prudent rodent control is essential in the prevention of parasite infection of pets and the transmission of zoonotic parasite to humans.
Keywords: *Rodenticides, parasites, dog, cat, zoonosis*

ΠΕΡΙΛΗΨΗ. Είναι γνωστό ότι τα ποντίκια και άλλα τρωκτικά παίζουν ένα σημαντικό ρόλο στο βιολογικό κύκλο πολλών παρασίτων των ζώων συντροφιάς. Μεταξύ των παρασίτων τα οποία έχουν ανευρεθεί στην Ελλάδα, αρκετά είναι τα ενδοπαράσιτα τα οποία μπορούν να μεταδοθούν στους σκύλους μέσω των τρωκτικών όπως το *Spirocerca* lupi, οι ασκαρίδες (*Toxocara canis*, *Toxascaris leonina*), τα ανκυλόστομα (*Ancylostoma caninum* και *A.braziliense*),το νηματώδες *Trichinella spiralis*, το κεστώδες *Echinococcus granulosus* και τα πρωτόζωα *Toxoplasma gondii*, *Cryptosporidium* spp and *Leihsmania* spp ενώ οι γάτες μπορεί να μολυνθούν από τα νηματώδη: *Toxocara cati*, *Toxascaris leonina*, *Ancylostoma*

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tubaeformae, *A.braziliense*, *Aelurostrongylus abstrusus* το κεστώδες *Taenia taeniaformis* και τα πρωτόζωα *Toxoplasma gondii*, *Cryptosporidium* spp *Leihsmania* spp. Η μόλυνση των κατοικίδιων ζώων μέσω των μολυσμένων τρωκτικών προϋποθέτει την καταβρόχθιση τους ή την στενή επαφή με αυτά, ενώ πολλά από αυτά τα παράσιτα έχουν μεγάλη σημασία για τη Δημόσιας Υγεία επειδή προκαλούν σοβαρές ζωονόσους. Λόγω του ότι σε ορισμένες περιοχές ο αριθμός των τρωκτικών είναι μεγάλος και η δυνατότητα τους να μολύνουν άλλα ζώα αλλά και τον άνθρωπο είναι σημαντική, εκτελούνται τόσο από ιδιωτικούς όσο και από κρατικούς φορείς διάφορα προγράμματα για την εξάλειψη τους με τη χρήση τρωκτικοκτόνων δολωμάτων. Τα τρωκτικοκτόνα είναι κατάλληλες χημικές ή μη ουσίες, που χρησιμοποιούνται για την εξόντωση των τρωκτικών. Ωστόσο, θα πρέπει να δοθεί μεγάλη προσοχή στη σωστή χρήση και στη αυστηρή τήρηση των οδηγιών του κατασκευαστή τους, διότι υπάρχει μεγάλος κίνδυνος δηλητηρίασης των κατοικίδιων ζώων αλλά και παιδιών. Είναι φανερό ότι η σωστή καταπολέμηση των τρωκτικών, συμβάλλει σημαντικά στην πρόληψη των παρασιτικών μολύνσεων τόσο στα κατοικίδια ζώα όσο και στον άνθρωπο.

Λέξεις ευρετηρίασης: *Μυοκτόνες ουσίες, έλμινθες, σκύλος, γάτα, ζωονόσος*

INTRODUCTION

Rodents are mammals of the order Rodentia and exist everywhere in the earth except Antartica (Lund, 1994; Reid, 1997; Nowak, 1999; Myers & Armitage, 2004). Over of 40% of the mammalian species belong to this order (Myes, 2000) which is about 2.277 species (Wilson and Reeder, 2005). Common rodents worldwide include mice, rats, squirrels, porcupines, beavers, Guinea pigs and hamsters (Rodent Encyclopedia, 2007) while some species among them are pests, eating seeds stored by people and spreading diseases (Meerburg et al, 2009). Rodents take part in many ecosystems and have an important role because of their rapid reproduction, their role as food for predators and their contribution to the seed dispersal as well as multiple pathogen vectors. The most important commensal rodents for the health of companion animals and humans in Greece are the brown rat (*Ratuus norvegicus*), the roof rat (*Rattus rattus*) and the house mice (*Mus musculus*).

The purpose of this review is to identify the importance of rodents in dogs and cats with emphasis on those with zoonotic potential, the rodent control and the benefits of rodent control in pet and Public Health.

RODENTS AS HOSTS OF ENDOPARASITES OF DOGS AND CATS

Among the endoparasites identified in Greece which could be transmitted to dogs and/or cats from colloquially rodents are *Spirocerca lupi, Ascaridae* namely *Toxocara canis, Toxascaris leonina* in dogs and *Ancylostoma caninum, A.braziliense, Trichinella spiralis* and *Echinococcus granulosus* while cats can be infested by *Toxocara cati, Toxascaris leonina, Ancylostoma tubaeformae, A.braziliense, Aelurostrongylus abstrusus* and *Taenia taeniaformis.*

a) *Spirocerca lupi*

Spirocercosis is a, rather infrequent in Greece, parasitic disease caused by the nematode *Spirocerca lupi* (esophageal worm) which has as final hosts dogs, foxes, wild canids and occasionally cats and wild felids while coprophagus beetles are the intermediate hosts (Haralabidis et al, 1988, Mylonakis et al 2001, Taylor et al, 2007, Zajac and Conboy, 2012). Many vertebrates such as rodents, birds, insectivores and reptiles act as paratenic hosts (Taylor et al, 2007, Zajac and Conboy, 2012). When an infected intermediate host is ingested by a paratenic host (rats, mouse) this animal carries the parasite as encysted third stage larvae in the viscera. If infected rodents are ingested by a final host (dog and very rarely cat) the larvae are liberated, penetrate the stomach wall and migrate via the celiac artery to the thoracic aorta in three months. Then, they migrate to the wall of esophagus (or in other organs) where they form granuloma and they mature three months later (Taylor et al, 2007). Infection is usually subclinical. The most frequent clinical symptoms are difficulty in swallowing, regurgitation, vomiting, dyspnea, occlusion or perforation of the esophagus, aortic stenosis, aneurysm or rupture of the aorta, sudden bleeding, hematemesis, hemoptysis, tumor formation in the surrounding tissues, esophageal sarcoma, cachexia, and sudden death (Mylonakis et al, 2008, Mylonakis et al, 2012).

b) Ascaridae (*Toxocara canis, Toxascaris leonina, Toxocara cati*)

Toxocariasis of dog is a very frequent (Lefkaditis et al, 2004, Lefkaditis et al, 2005, Lefkaditis et al, 2009) and worldwide distributed parasitosis (Taylor et al, 2007, Zajac and Conboy, 2012) of dog and fox caused by the nematode *Toxocara canis*. It is a zoonosis of high public health importance causing two main syndromes in man, the ocular larvae nigrans (OLM) and the viscera migrans syndrome (VLM) (Weese and Fulfor, 2011, Kantere 2014). The parasite is transmitted by four routes; via ingestion of eggs, transplacentaly, lactogenetic and by consumption of infested paratenic hosts. Rodents act as paratenic hosts carrying the third stage larvae in their tissues after previous ingestion of infective eggs. When a dog ingests an infected rodent their encysted larvae are released from the tissues and migrate directly to the gastrointestinal tract where they mature 39-42 days post infection (Hershell, 1978 – διαγραφή, Taylor 2007). In this way of canine infection, the clinical signs derive from the digestive system (Lefkaditis et al, 2005) and depend on the number of ingested larvae. A low parasitic burden is usually asymptomatic, while heavily infected animals are often presented with severe emaciation, vomiting (sometimes the vomit contains adult parasites), diarrhea (mucous), poor coat appearance, anemia, potbelly appearance, rare bowel occlusion and in very large number of parasites death can occur (Urguhart et al, 2000, Taylor et al, 2007, Zajac and Conboy, 2012) .

Toxocariasis of cat is common (Lefkaditis et al, 2014) cosmopolitan parasitosis caused by the infection by the nematode parasite *Toxocara cati*. Cats can aquire the infection via galactogenic route, or by licking infective eggs or finally by somatic larvae from paratenic hosts such as mice and rats. Therefore, in domestic cats are less likely to be infected because of the limited possibility to hunt and consume pray rodents. In the case of hunting cats there is increased likelihood of infection via hunting and consequent cannibalism of those rodents which have the second stage larvae encysted in their skeletal muscle or the liver (Urguhart et al, 2000, Taylor et al, 2007). After the consumption of the prey paratenic host, larvae are released in the stomach of the cat and stay in the stomach wall for about six days, then they enter the stomach contents, where they molt to the fourth stage larvae. These larvae migrate to the intestinal lumen and after about 14 days mature to adult parasites without further migration (Urguhart et al, 2000, Taylor et al, 2007). Since the majority of feline toxocariasis is acquired either by the milk of the dam or by ingestion of paratenic host, there is no migratory phase therefore the clinical signs are usually confined to the intestine, presented as pot belly appearance, diarrhea, poor coat and failure to thrive (Taylor et al, 2007). Toxascariasis of dog and cat caused by the nematode parasite *Toxascaris leonina*, which is of low prevalence in Greece (Lefkaditis et al, 2004, Lefkaditis et al, 2009, Lefkaditis et al, 2014), can affect dog and cat while rodents act as paratenic hosts. The infective third stage larvae are consumed as infectious elements with the prey by the mice and spread to all their tissues where remain infectious for up to 5 months. When a dog or cat eats an infested mouse the larvae develop into adults in the small intestine of the final host in about two months. Only a heavy parasitic burden can cause clinical signs as vomiting and diarrhea in infested animals (Urguhart et al, 2000, Taylor et al, 2007). Since the two main reservoirs of infection are larvae in the rodents and eggs from the environment any action as rodenticides can reduce the prevalence of this nematode parasitosis.

c) *Ancylostoma caninum. A. braziliense* and *A. tubaeforme*

Ancylostomosis of dog is a rather uncommon zoonotic disease (Lefkaditis et al, 2004, Lefkaditis et al, 2009) caused more frequently by the nematode parasite *Ancylostoma caninum* (common name, canine hookworm) or rarely by *A. braziliense*. Final host of this parasite are dog, fox and occasionally man. Dogs can acquire the infection via oral ingestion, skin penetration of larvae, sometimes lactogenic while infection via paratenic host seems to be an important route of infection (Taylor et al, 2007). Rodents act as paratenic hosts for this parasitosis. When a dog eats a rodent the larvae which are encysted in the tissues of paratenic host (Taylor, 2007) are released in the stomach of dog and migrate directly to the intestine where without any other migration they molt to the fourth stage larvae about 3 days after infection. In young dogs, the worms need about 16-18 days to mature and they live for about 6 months. *Ancylostoma* is a very voracious parasite in the intestine with a pathogenicity strongly depended on its abundance (Barr and Bowman, 2006). A small number of parasites are usually well tolerated without causing any clinical symptoms (Barr and Bowman, 2006). Heavy infections

are followed by bloody diarrhea, melena, anemia caused by blood loss, cachexia and poor coat appearance. Death caused by acute blood loss and acute onset of anemia have also been reported in heavily contaminated puppies (Urguhart et al, 2000, Taylor et al, 2007).

Ancylostomosis of cat is a very frequent parasitosis (Lefkaditis et al, 2014) caused by the nematode *Ancylostoma tubaeforme* or rarely by *A. braziliense*. Rodents can act as paratenic hosts for this parasitosis (Bowman et al, 2002). Similarly to the situation in dogs, other routes of infection include skin penetration, oral ingestion and galactoenic infection. The cat "hookworm" *A. tubaeforme* regularly occurs in stray cats and in domestic ones particularly those roaming out and having the ability to hunt. Mild infested animals are usually asymptomatic while in heavy infections anemia and diarrhea are the more frequent reported symptoms (Urguhart et al, 2000, Barr and Bowman, 2006, Taylor et al, 2007).

d) *Trichinella spiralis*

Cats and dogs acquire the infection of *Trichinella spiralis* (Trichinosis) via their prey such as rats and other rodents. When a dog or a cat eats row meat that contains encysted *T. spiralis* second stage larvae, these are released in the stomach and develop into adults in the small intestine of host after few days where they live only 4 to 6 weeks (Taylor et al, 2007). Trichinosis is an important zoonosis in Greece (Boutsini et al, 2014) but a not important parasitosis for dogs and cats (Weese and Fulford, 2011). In all infected mammals diarrhea and fever in the first phase occurs, while later in the second phase with the encysted larvae in the muscles, rigid, stiff movements, marked eosinophilia and respiratory difficulties occur (Barr and Bowman, 2006).

e) *Aelurostrongylus abstrusus*

Aelurostrongylosis of cat is a cosmopolitan rare parasitosis of cat caused by the nematode *Aelurostrongylus abstrusus* (common name, cat lungworm). Final host of this parasite is the cat, intermediate hosts are many terrestrial mollusks (snails, slugs), while paratenic hosts include rodents, birds, amphibians and reptiles (Taylor et al, 2007). When a rodent eats an infected mollusk the third stage larvae are developed, which after their ingestion by a hunter cat, are released in the alimentary tract of cat and migrate to the lungs by the blood and lymphatic stream where they molt to adults and remain in the alveolar ducts and the terminal bronchioles (Urguhart et al, 1996, Bowman et al, 2002). The prepatent period is about 30-40 days. Light infected cats are usually asymptomatic. Sometimes, a chronic cough, sneezing, wheezing, tachypnea and fever are presented. Clinicopathological abnormalities such as leukocytosis and eosinophilia have been also reported in infected cats (Barr and Bowman, 2006).

f) *Echinococcus granulosus*

Echinococcosis is a very important zoonotic parasitosis caused by the cestode *Echinococcus granulosus*. Among other hosts, mouse and rats can act as intermediate hosts for this dangerous parasite. Rodents among other intermediate hosts can contribute to the spread of this zoonotic parasite (Taylor et al, 2007, Weese and Fulford, 2011). Another species of the genus Echinococcus, *Echinococcus multilocularis* is also of great public health importance (Weese and Fulford, 2011).

g) *Taenia taeniaeformis*

The feline tapeworm is a very common (Lefkaditis et al, 2014) cosmopolitan parasitosis caused by the cestode *Taenia taeniaeformis* with intermediate host rodents. Any cat with the ability to roam and hunt can acquire the infection therefore the spread of parasite depends on the prevalence of rodents. An infected cat infests the environment with about 4 mature proglotids daily containing approximately 2000 eggs. Rodents are infected by grazing pasture contaminated with infected cat feces. After 42 days of their ingestion from an intermediate host (mouse, rat) eggs develop to the metacestode *Cysticercus fasciolaris* into the liver (Bowman, 1999, Bowman et al, 2002, Barr and Bowman, 2006, Taylor et al, 2007). In the liver of mouse or rat this bladder worm is coiled up neatly in a cyst (Verheyen et al, 1978-διαγραφή, Bowman et al, 2002).

h) *Toxoplasma gondii*

Toxoplasmosis is an important worldwide parasitosis caused by the obligatory intracellular, protozoan parasite *Toxoplasma gondii*. Felids, wild and domesticated are the final host of this common parasitosis, while all warm-blooded animals, birds and human are the intermediate hosts. Rodents are an important and common carries of Toxoplasmosis (in a study, Webster and MacDonald -1995, estimate the prevalence of Toxoplasmosis of wild rats from farms in England in 35%) because they usually can eat infected cat feces or raw meat (modes of transmission). *T. gondii* affects the brain of infected rodents and change their behavior; it

makes a rat to act like trying to capture by a cat. It must be pointed that infected rats retain normal defensive behavior to non-feline predator odor and normal performance on memory, anxiety, fear and social tasks (Vyas et al, 2007; Lamberton et al, 2008). The parasite doesn't simply take away all fear and inhibition from rats, those still were afraid of light and big, open spaces, but specifically targets one fear pathway in rats, it takes away the fear of predator odors only (Berdoy et al, 2000; Webster et al, 2006; Vyas et al, 2007; Kaushik et al, 2014). This specific preference for cat odor is likely an adaptive manipulation by *Toxoplasma*, increasing infected rat predation rates and facilitating *Toxoplasma* transmission to the cat (Kaushik et al, 2014).

i) *Cryptosporidium spp*

Wild rodents from different habitats, by their widespread distribution, may provide a possible source of infection throughout the environment by contamination of water and soil. Cryptosporidiosis in rodents caused by the coccidian *Cryptosporidium spp* and can affect dog, cat other animals and human via fecal-oral route (Glaberman et al, 2002; Xiao and Fayer, 2008), is acute and self-limiting in immunocompetent hosts but life threatening in immunocompromised individuals (Xiao et al, 2004). Rodents, which are abundant and widespread, have been considered reservoirs of cryptosporidiosis in humans dog, cat and farm animals. Previous studies based on oocyst morphology showed that many wild rodents might serve as hosts of *Cryptosporidium parvum*-like and *C. muris*-like parasites (Chalmers et al, 1997; Torres et al, 2000; Bajer et al, 2002). The spread of this infection is greater in wild rats originated from farms (Webster and MacDonald, 1995) than those from other areas (Foo et al, 2007; Feng, 2010). Humans and animals can acquire *Cryptosporidium* infection through direct contact with infected individuals or contaminated fomites or by consumption of contaminated food or water (Glaberman et al, 2002; Xiao and Fayer, 2008). Rodents, which are abundant and widespread, have been considered reservoirs of cryptosporidiosis in humans and farm animals. Previous studies based on oocyst morphology showed that many wild rodents might serve as hosts of *Cryptosporidium parvum*-like and *C. muris*-like parasites (Chalmers et al, 1997; Torres et al, 2000; Bajer et al, 2002). The reported prevalence rates of *Cryptosporidium* in rodents ranged from 5.0% to 39.2% (Foo et al, 2007; Feng, 2010).

k) *Leishmania infatum*

Leihsmaniasis caused by a biphasic protozoan of the genus *Leishmania* which complete its life cycle in two hosts, the sand fly, where exist the extracellular promastigote form and a mammal where the intracellular amastigote form develops. Dog play the main role as a reservoir of this zoonotic disease (for human also) but a variety of other domestic (cat including) or wild animals act as a reservoir for this parasitosis (Ashford, 1996, Colwell et al, 2011). Many rodent species has recorded to be infected by *Leishmania spp* (Zulueta et al, 1999, De Lima et al, 2002, Di Bella et al, 2003, Oliveira et al, 2005, Neiva, 2005, Junior, 2010, Campino and Maya, 2010, Psarulaki et al, 2010, Papadogiannakis et al, 2010, Helhazar etal, 2013) so, a large number of rodents in some endemic areas consists a risk factor for the spread of this protozoan infection in dog and cat.

APPLICATION OF RODENTICIDES AND THEIR INFLUENCE ON PET ENDOPARASITES

Rodenticides (also called rat poison) are chemicals which are used to eliminate rodents. However, rodenticides can sometimes accidentally cause secondary poisoning to children, pets and wildlife. An effective rodenticide must be tasteless and odorless in lethal for rodent concentrations. A first single dose is usually sufficient to kill while they also have a delayed effect, because of the usual behavior of rodents to taste a small bit, wait for some minutes and if they do not get sick, they continue eating.

The family of rodenticides includes mainly anticoagulants and other chemicals such as metal phosphides, those which cause hypercalcemia, and other chemical poisons while alternative (non-chemical) poisons have been also developed. Anticoagulants have a chronic effect and death of rodents usually occurs after one or two weeks after ingestion of the lethal dose.

Influence of rodenticides on the prevalence of endoparasitosis in pets

Because of the large numbers of rodents in some areas, their behavior, their diet and the possibility to transfer diseases in man and animals rodenticide programs performed by privates or the state. Those programs carried out in order to reduce the total cost of society from the presence of rodents; loss of food storage, infrastructure and building damages, envi-

ronmental damage, losses in productivity and most importantly animal and Public Health risks.

The great majority of poisons lead to the death for the rodents that consumed not immediately but hours or days after the meal in their burrows, so poisoned dead rats or mice are not a risk factor for the transmission of parasitic diseases in other animals. The major positive effect of rodenticides for the spread of endoparasitic (and other) diseases is the decrease or disappearance of the population of rodents in an area and by this way the decrease of the risk of the transmission for those parasitoses where rodents act as intermediate or paratenic host.

For example, parasites of cats where rodents act as paratenic or intermediate host for the parasite are less likely to be transmitted to cats in the absence of rodents When young kittens start hunting and share the prey rodents with their dams they can acquire the zoonotic infection. So, any decrease of the number of rodents in the urban or rural areas even throw rodenticides decreases the spread of parasites.

Wild cats but also domestic (when, have the ability to run away from houses and hunt) are the main predators of rats and mice. Hunting cats can consume prey mice and rats which could transfer to those very important zoonotic agents such as *Toxocara* (Dubinsky et al, 1995), *Trichinella* (Hirvela-Koski et al, 1985) and other parasites as *Toxascaris, Aelurostrongylus, Taniae, Toxoplasma, Cryptosporidiosis, Leihsmania* and very rarely *Spirocerca* (Taylor et al, 2007). Application of control measure against rodents, like the use of rodenticides, decrease the possibility of eating infected rodents by the cat.

CONCLUDING REMARKS

Mice and other rodents are well known to play an important role in the biological cycle of many parasites of pets. The route of infection of pet includes in many cases ingestion of parasite infested rodent. A number of these parasites are also of great Public Health importance because they are causing zoonotic diseases.

Since rodents can serve as hosts and source of infection for pets and humans, their control is vital to reduce risk of transmission.

Rodenticides or colloquially rat poisons are chemicals intended to kill rodents but have the risk of secondary poisoning for other animals, human and wild life and for this aspect special care must take place when using these products, to follow the manufacturer's recommendations and prevent access by pets and children. With the advent of new non-chemical and more environmental friendly rodenticides the rodent control seems to become less dangerous without compromise more effectiveness.

Table 1. Common helminthes of pets and the role of rodents in their biological cycle

Pet animal	Parasite	Role of rodents
Dog, cat	*Spirocerca lupi*	Paratenic host
Dog	*Toxocara canis, Toxascaris leonina*	Paratenic host
Cat	*Toxocara cati, Toxascaris leonina,*	Paratenic host
Dog	*Ancylostoma caninum. A. braziliense*	Paratenic host
Cat	*A. tubaeforme, A. braziliense*	Paratenic host
Dog, cat	*Trichinella spiralis*	Intermediate host
Cat	*Aelurostrongylus abstrusus*	Paratenic host
Dog	*Echinococcus granulosus*	Intermediate host
Cat	*Taenia taeniaeformis*	Intermediate host

Table 2. Main categories of rodenticides and mode of action.

Rodenticide	Mode of action
Anticoagulants- (warfarin, coumatetralyl, difenacoum, brodifacoum, flocoumafen, bromadiolone, diphacinone, chlorophacinone, pindone	Blocking of the vitamin K cycle
Metal phosphides – (Zinc phosphide, aluminium phosphide, calcium phosphide)	The acid in the digestive system of the rodent reacts with the phosphide to generate the toxic phosphine gas
Causing Hypocalcaemia – (Calciferols (vitamins D), cholecalciferol (vitamin D_3) and ergocalciferol (vitamin D_2)	Disturbing calcium and phosphate homeostasis

Graphic abstract

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