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EPIDEMIOLOGICAL AND CLINICAL IMPORTANCE OF CANINE DIOCTOPHIMOSIS

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Abstract

Dioctophimosis is an endoparasitism in dogs caused by *Dioctophyma renale*, a nematode with an indirect life cycle and high zoonotic potential. Infection in dogs occurs through ingestion of transitional/paratenic hosts containing infective larvae. The preferred site of parasitism is the right kidney, although the parasite may also be ectopically localized in subcutaneous tissue, internal organs, peritoneum, and mediastinum. Since dogs are usually infected with a small number of parasites, the disease is asymptomatic, making the diagnosis of this disease in clinical veterinary practice rather difficult. In addition, as dogs are usually infected with a small number of parasites, the disease is asymptomatic, which makes the diagnosing of this disease in clinical veterinary practice difficult. The long prepatent period, lasting three to five months, makes it impossible to diagnose the disease in dogs younger than six months. Clinical suspicion of dioctophimosis in dogs is established on the basis of anamnestic/epizootiologic data and the clinical picture, while the final diagnosis is made *ante mortem* or *post mortem* on the basis of reliable diagnostic parameters and methods. The most practical application in routine diagnosis of canine dioctophimosis is the detection of *D. renale* eggs in urine sediment. When dioctophimosis is suspected in

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carnivores, the differential diagnosis should exclude urinary capillariosis, feline polycystic nephropathy, leptospirosis, renal fibrosis, and nephritis of various etiology. The outcome of treatment is uncertain and includes surgical removal of the affected kidney or drug therapy with avermectin derivatives. Prophylaxis consists of preventing contact of dogs with potential transitional hosts and controlling the feeding of their heat-untreated meat. Because of the potential risks that *D. renale* may have on the health of dog owners, education on the etiopathogenesis and means of occurrence, maintenance, and spread of this nematode is necessary.

Key words: *Dioctophyma renale*, dog, kidneys, clinical significance, public health

EPIDEMIOLOŠKI I KLINIČKI ZNAČAJ DIOKTOFIMOZE PASA

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Kratak sadržaj

Dioktofimoza je endoparazitoza pasa koju prouzrokuje *Dioctophyma renale*, nematoda sa indirektnim životnim ciklusom i visokim zoonoznim potencijalom. Infekcija pasa nastaje ingestijom prelaznih/paratenih domaćina koji u sebi sadrže infektivne larve. Predilekciono mesto parazitiranja je desni bubreg, uz mogućnost ektopične lokalizacije parazita u supkutanom tkivu, unutrašnjim organima, peritoneumu i medijastinumu. Pošto su psi uglavnom inficirani malim brojem parazita, oboljenje protiče asimptomatski, što u kliničkoj veterinarskoj praksi otežava dijagnostiku ovog oboljenja. Dug prepatentni period, koji traje od tri do pet meseci, onemogućava dijagnostiku oboljenja kod pasa mlađih od šest meseci. Klinička sumnja na diok-

tofimozu kod pasa postavlja se na osnovu anamnestičkih/ epizootioloških podataka i kliničke slike, dok se precizna dijagnoza utvrđuje ante mortem ili post mortem na osnovu pouzdanih dijagnostičkih parametara i metoda. Najveću praktičnu primenu u rutinskoj dijagnostici dioktofimoze pasa ima nalaz jaja *D. renale* u sedimentu urina. Kod sumnje na dioktofimozu mesojeda diferencijalno dijagnostički treba isključiti urinarnu kapilariozu, policističnu nefropatiju mačaka, leptospirozu, fibrozu bubrega i nefritise različite etiologije. Lečenje je neizvesno i podrazumeva hirurško uklanjanje promenjenog bubrega ili medikamentoznu terapiju derivatima avermektina. Profilaksa je zasnovana na sprečavanju kontakta pasa sa potencijalnim prelaznim domaćinima i kontrolisanje ishrane njihovim termički neobrađenim mesom. Zbog potencijalnih rizika koje *D. renale* može imati po zdravlje vlasnika pasa, neophodna je edukacija o etiopatogenezi i mogućnostima pojave, održavanja i širenja ove nematode.

Ključne reči: *Dioctophyma renale*, pas, bubrezi, klinički značaj, javno zdravlje

INTRODUCTION

Dioctophyma renale (giant kidney worm) is a widely spread nematode that parasitizes dogs in tropical and subtropical regions and tends to spread to other geographical areas (Taylor et al., 2007; Eiras et al., 2021).

The parasite is predominantly localized in the right kidney of dogs but can also parasitize in subcutaneous tissues, mediastinum, peritoneum, and internal organs when it causes an ectopic form of the disease (Taylor et al., 2007; Angelou et al., 2020; Greer et al., 2021). During the indirect developmental cycle and migration of larval stages, *D. renale* causes nonspecific symptoms in the form of lumbar pain, dysuria, hematuria, and general disturbances (Gherman, 2013; Russo et al., 2022). The above clinical manifestations are the result of high intensity infections where death due to renal failure is possible (Taylor et al., 2007; Paras et al., 2018).

Larval forms of the parasite cause trauma by migrating through individual tissues and organs - stomach, duodenum, liver, abdominal cavity (Ferreira et al., 2010). Adults inflict chemical damage to infected tissues and organs and, by mechanical action, cause compression and atrophy of the renal parenchyma (Russo et al., 2022) and obstruction of the ureter with subsequent hydronephrosis (Angelou et al., 2020).

In Serbia, there are conditions for the occurrence, maintenance, and spread of this helminthiasis in carnivores and humans related to the presence of infected intermediate/paratenic hosts (oligochaetes, frogs, and fish) and susceptible true hosts (martens, ferrets, foxes, cats, and dogs) in the mentioned epizootic area (Ignjatović, 2022).

There are numerous reports from Serbia related to the problem of intestinal, cardiorespiratory, and ocular parasitic infections in domestic carnivorous animals (Gajić et al., 2014; Ilić et al., 2015; Stepanović et al., 2015; Hadži-Milić et al., 2016; Ilić et al., 2017; Ristić et al., 2020; Stepanović et al., 2020; Ilić et al., 2021) and wild carnivores (Ilić et al., 2012; Ilić et al., 2016; Ilić et al., 2016a; Ilić et al., 2020). Apart from the recent reports on the discovery of *Capillaria* plica species in foxes (Aleksić et al., 2020) and urinary capillariasis in dogs (Ilić et al., 2021a), in previous research in Serbia, not enough attention has been devoted to the study of urinary parasitoses in domestic carnivores.

The aim of this paper is to provide new information on the etiopathogenesis of *D. renale* and point out the need to investigate the occurrence of this parasite in wild and domesticated carnivores in Serbia. The proposed studies are of particular importance because *D. renale* may pose a threat to human health. Since dioctophimosis was diagnosed in dogs in Greece in 2019, the exacerbation of the effects of global warming could be an important predisposing factor for the occurrence of this zoonosis in carnivores in Serbia.

ETIOPATHOGENESIS

Dioctophyma renale (Goeze, 1782) belongs to the Animalia kingdom, Nematoda phylum, Enoplea class, Dorylaimia subclass, Dioctophymatida order, Dioctophymatina suborder, Dioctophymatoidea superfamily, Dioctophymatidae family, Dioctophymatinae subfamily, and *Dioctophyma* genus (Gherman, 2013).

Morphological characteristics of the causative agent

Adult forms of the parasites have a cylindrical bright red body covered with a thin cuticle. Sexual dimorphism is clearly prominent. Females are longer (100-103 cm) and thicker (6-12 mm) compared to males, whose length is about 35 cm, and thickness 3-5 mm. At the anterior end of the body there is a hexagonal shaped mouth, surrounded by 12 papillae arranged concentrically in two rows (Figure 1A). The tale of female parasite is narrow and ends bluntly, while vulva has posterior appearance about the end of oesophagus. The tail

of the female parasite is narrow and ends bluntly, while the vulva is directed backwards over the end of the oesophagus.

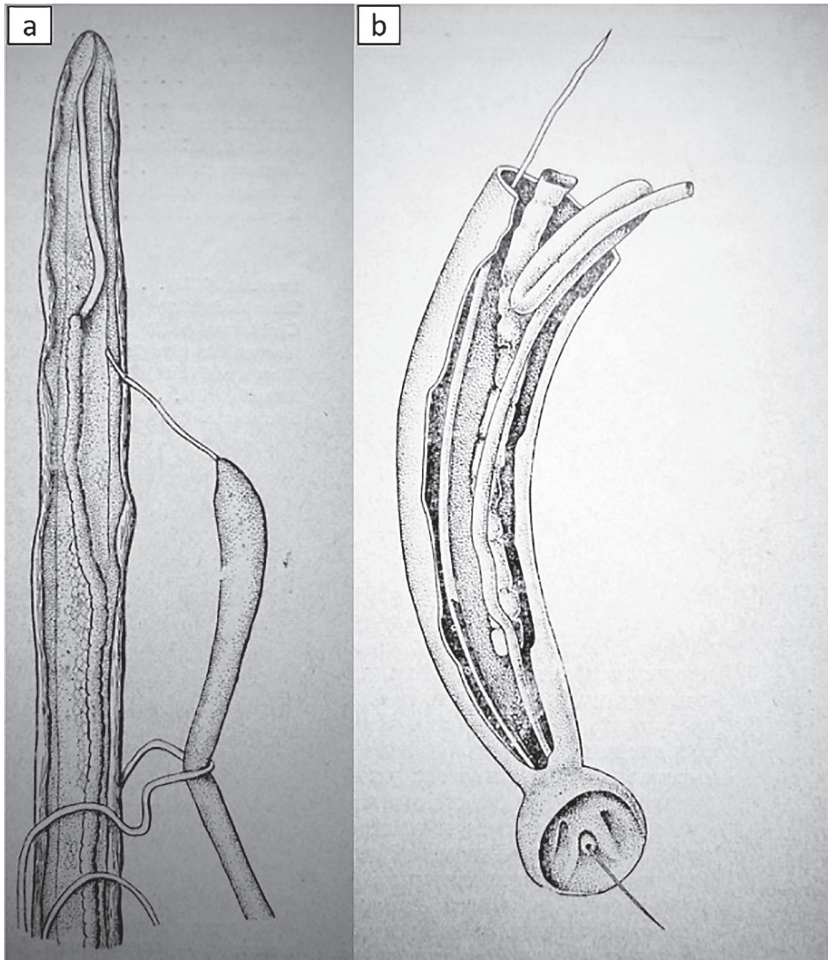

Figure 1. *Dioctophyma renale*: A) anterior side of female body (Goeze, 1782 by Лукасяк, 1930); B) posterior side of male body (Goeze, 1782) (described in Караманова 1968)

At the posterior end of the body of the male worm there is a bell-shaped copulatory bursa with one spicule (Figure 1B and 2). The eggs are oval, yellowish, 74-84 μm in size, unembryonated at the moment of hatching, containing two blastomeres. The egg membrane is thick with one mucoid structure at both poles (Taylor et al., 2007; Gherman, 2013).

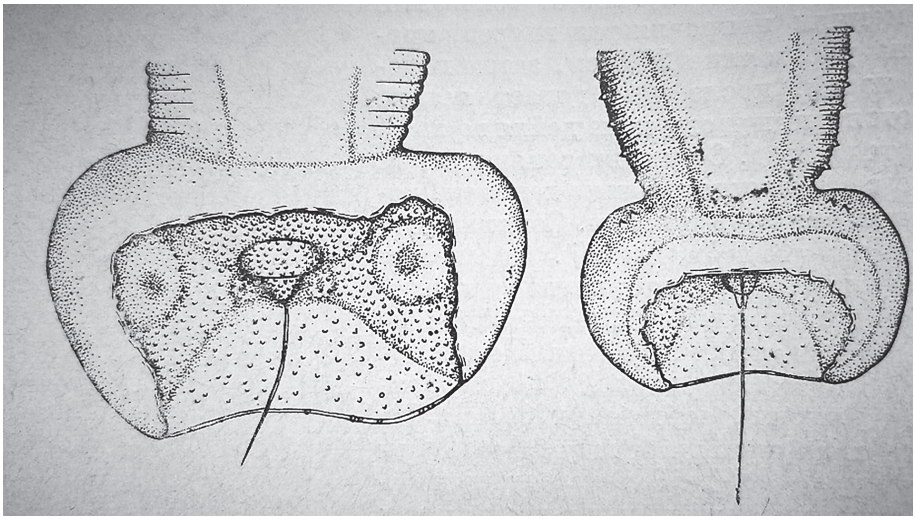

Figure 2. Copulatory bursa of adult male worm *D. renale* (Goeze, 1782 by Стефански, 1928) (described in Караманова 1968)

Life cycle

Adult forms of *D. renale* are mainly localized in the renal pelvis of the right kidney, while secondary forms can be found in the renal parenchyma, subcutaneous tissue, and abdominal cavity (Gherman, 2013). The prepatent period lasts for approximately 135-155 days, and the complete life cycle is completed in 2 years (Ferreira et al., 2010). Adult female worms hatch eggs, which are ejected- by the urine of infected animals. At an optimal temperature of 25-30^{0}C, first stage larvae (L1) are developed in intermediate hosts for about one month. Low temperatures significantly extend this period (Freitas, 1980).

This parasite has a complex life cycle that includes the presence of intermediate and paratenous hosts. The first intermediate hosts are aquatic oligochaetes (*Lumbricus variegatus*), in which the larvae of the first and second stages are formed (L2). There are three different ways of continuing the transmission. In the first case, infective third (L3) and fourth stage (L4) larvae are formed in the same host. In second, paratenous hosts (fish or frogs) *per os* ingest oligochaetes containing first larval stage forms, which develop in infectious larvae in tissues. A third way of transmission occurs when fish or frogs eat crayfish species from the *Cambarus* genus where infected oligochaetes parasites are present (Angelou et al., 2020).

Dogs become infected by ingesting some intermediate hosts (oligochaetes, fish, or frogs), which contain infective larvae. In the pathogenesis of dioctophimosis, the most important event is the migration of larval forms of parasites, which penetrate the intestinal wall and then reach the abdominal cavity, from where they migrate to the kidneys. The primary place of localization and maturation of the parasite into its adult form is the right renal pelvis, due to its anatomical connection with the duodenum (Ferreira et al., 2010). The adult forms of *D. renale* live for 3 years in a definitive host, while eggs in optimal environmental conditions can survive for 5 years (Angelou et al., 2020).

During the migration through various organs of the infected dog, *D. renale* causes mechanical damage, especially in the right kidney by parenchymal compression. Apart from the mechanical effects, parasites have esophageal glands, whose secretion of lipolytic and proteolytic enzymes causes chemical damage to infected tissues and organs (Russo et al., 2022).

GEOGRAPHICAL DISTRIBUTION AND EPIZOOTIOLOGICAL CHARACTERISTICS OF *D. RENALE*

Dioctophyma renale is very widespread in tropical and subtropical regions with a tendency to spread to other geographical areas. This phenomenon mainly occurs due to transport of dogs from endemic areas where they get infected by eating meat from intermediate hosts containing infective larvae (Measures, 2001; Russo et al., 2022). It is most commonly diagnosed in North and South America, Asia, and sporadically in Europe (Taylor et al., 2007). According to the literature, *D. renale* has not been diagnosed in Africa and Oceania yet (Acha and Szyfres 1986; Measures, 2001).

The highest prevalence of dioctophimosis is found in mammals from South America (37-42.1%), where the disease has been reported in thirty-three countries with most clinical cases in Argentina (1,414). Due to tropical ecosystems, which are suitable for the coexistence of intermediate and definitive hosts, there is an increasing likelihood of the occurrence, maintenance, and spread of the infection, while humidity and suitable temperature favourably affect the development and vitality of eggs (Russo et al., 2022).

Although the disease in dogs is sporadically present in Europe, the reported prevalence in Poland is 10.5%, indicating a risk of spreading to surrounding countries (Eiras et al., 2021). Dioctophimosis has not yet been diagnosed in dogs from Serbia. Sporadic cases in some countries in Europe, whose number is continually rising, sudden climate changes, increased commercial and uncommercial dog transport worldwide are the factors which contribute to preconditions for occurrence of this parasitosis in Serbia as well (Ignjatović, 2022).

Infection in humans by this nematode is described in Australia (Fernando, 1983) and other countries, including Austria, Bulgaria, Chile, Korea (Eiras et al., 2021), Indonesia (Sardjono et al., 2009), Greece (Katafigiotis et al., 2013), India (Venkatrajaiah et al., 2014), Thailand (Beaver and Khamboonruang, 1984), Iran (Norouzi et al., 2017), and Serbia (Nikolić Svetozarević et al., 2001), while cases of *D. renale* infections in mammal animals haven't been reported (Eiras et al., 2021). It is believed that human cases in these countries are of autochthonous origin, unlike recently diagnosed cases of subcutaneous dioctophimosis in Chinese people (one woman and one man) in Japan (Urano et al., 2001; Tokiwa et al., 2014; Tanaka et al., 2020).

The intensity of infection is quite variable and depends on host species and localization of helminths in their organism. High intensity infection considered to be the one with at least twenty adult forms of parasite per one individual (Eiras et al., 2021).

Despite the fact that high temperatures are appropriate for egg development, dioctophimosis is also present in areas with colder weather, which is suitable for intermediate hosts. Other factors like the pH value of an area, salinity of water surfaces, and mobility of intermediate hosts can be responsible for the growing prevalence of dioctophimosis in the mentioned regions (Pedrassani et al., 2009).

Primary environmental contaminants are affected carnivores who eject eggs by the urine. Secondary sources of contamination are intermediate hosts, in which larvae are developed from eggs and continue the life cycle of the parasite (Gherman, 2013).

The factors like ways of keeping and feeding animals, weather disasters (floods) can significantly increase the risk for occurrence of the infection. That is especially true for dogs who live in yards and have close contact with watercourses and are fed raw fish or frogs. Since immunosuppression occurs due to frequentative pregnancies (especially in stray bitches), females are more commonly affected than males. However, males are more territorial with regard to females, and infected prey is more accessible to them. Despite the stated assumptions, gender and age predisposition for dioctophimosis isn't defined in dogs (Pedrassani et al., 2017).

Lack of reports on the prevalence of *D. renale* infections in animals from different regions is a result of insufficient epidemiological studies or the low prevalence and complex life cycle of the parasite (Eiras et al., 2021).

CLINICAL DIAGNOSTIC PARAMETERS OF DIOCTOPHIMOSIS IN CARNIVORES

Long prepatent period (3-5 months) complicates diagnosis of the disease in dogs under six months of age. Clinical suspicion of dioctophimosis in dogs can be established on the basis of anamnestic or epizootiological data and a clinical picture.

Anamnestic and epizootiological data

During the collection of anamnestic data, it is significant to ask dog owners about feeding habits, contact with water surfaces or aquatic animals (such as frogs or fish), and the possibility of roaming around without owner's supervision (Russo et al., 2022).

The data on lifestyle and quality of life of carnivores collected from owners and available data on climate parameters, transport of dogs and cats in endemic areas of dioctophimosis, or buying pets from risky epizootiological localities, could be very significant for raising suspicion about this nematode (Ignjatović, 2022).

Clinical picture

Nonspecific clinical symptoms of dioctophimosis are not sufficient to make a f diagnosis, but they may serve to raise a reasonable suspicion of this disease.

In the clinical picture of dioctophimosis, signs of renal insufficiency are dominant (Gherman, 2013). Symptoms depend on the intensity of the infection and the localization of the causative agent. In low-grade infections, the disease is asymptomatic because one kidney is affected while the other compensates for its impaired function. Then non-specific clinical symptoms like fever, convulsions, abdominal distension, inappetence, and consequently loss of body mass are dominant. In high-grade infections, animals experience haematuria at the end of urination, and pyuria, while the abdomen is painful on palpation in the renal region (Russo et al., 2022).

In the case of an ectopic form of disease, oedema can occur in the inguinal region (it looks like a stab wound with a fistula containing *serohemorrhagic* exudate), proliferation of surrounding tissue (due to chronic peritonitis), and urethral obstruction (the consequences of which are anuria, uremic coma, and death) (Taylor et al., 2007; Paras et al., 2018).

Haematological analysis in the affected dog shows anaemia, eosinophilia, and lymphopenia, while microscopic examination of the blood smear reveals toxic granulation of neutrophils. These findings suggest the presence of acute inflammation. Blood biochemistry results indicate increased blood urea nitrogen and creatinine values. On physicochemical examination, the urine sample is blurred, red, with an alkaline pH value of 8 and contains proteins. After the centrifugation, there is a large amount of urinary sediment (Gherman, 2013; Russo et al., 2022).

A valid *ante mortem* diagnosis is established by parasitological examination of urine sediment, ultrasonography, contrast radiography, computerized tomography, and serological methods of diagnostics (indirect ELISA).

Parasitological diagnostics from urine sediment

Eggs detection in the urine of an affected dog represents the gold standard in diagnosing this nematode. The urine sample obtained by cystocentesis or catheterisation is centrifuged on 400 spins in 5 minutes with the aim of getting the sediment. After that, the sediment is examined by optical microscope using 40x magnification, and based on morphological characteristics of eggs, *D. renale* can be diagnosed (Figure 1). An advantage of this method is low price, high specificity and sensitivity. However, eggs absence cannot eliminate suspicion of this disease with certainty, especially in cases of ectopic forms, the absence of females, or presence of male adults (Pedrassani et al., 2017). Eiras et al. (2021) report about the rare but possible finding of eggs in animal faeces, which seems to be a result of urine contamination.

Ultrasonography

Ultrasonography is a fast, effective, and non-invasive technique for diagnosing multifocal circulatory structures that represent longitudinal and transversal sections of a parasite located in the right kidney. Within the ultrasonographic diagnostics it is useful to apply doppler ultrasonography technique that can detect reduction or complete absence of its signal, indicating tissue damage potentially caused by the presence of parasite (Pedrassani et al., 2017; Eiras et al., 2021; Russo et al., 2022).

Native radiography

Native radiography does not provide valid results, and therefore it is applied in combination with contrast urography, which detects deviations in kid-

ney size, shape, and topography. Based on the elimination of contrast medium, the preservation of kidney function is estimated, which is a significant parameter for the selection of an adequate therapy procedure (Eiras et al., 2021; Russo et al., 2022).

Computerised tomography

CT scanner is a valid method of diagnostics. Due to its cost, it is primarily used in human medicine, and rarely in affected dogs. Circulatory structures with contrast medium deposits in peripheral parts of tissue are considered positive findings (Eiras et al., 2021).

Serological methods

In cases of ectopic forms of disease, absence of *D. renale* eggs in urine, or presence of immature females or only males, alternative diagnostic procedures for detecting dioctophimosis include indirect ELISA as well. This test has high specificity of 93 %, it consists of soluble antigens that are obtained by extraction from oesophagus of parasite and it is based on specific antibodies (IgG) detection in blood serum (Pedrassani et al., 2017).

Post mortem diagnosis is established on the basis of parasitological sections and histopathology examinations (Ferreira et al., 2010).

Parasitological section

Since the infections by *D. renale* nematode in cats and dogs are usually low intensity, pathomophological changes could be less prominent or are completely absent.

In high intensity infections, necropsy has the following findings: thicker kidney capsule, connective tissue infiltration with signs of cystic degeneration. As a result of compressive atrophy on transversal sections, thinned regions of cortex and medulla are common. As a result of urethral obstruction by adult parasite forms, the renal pelvis is highly dilated due to hydronephrosis and filled with haemorrhagic exudate. Due to compensatory hypertrophy and glomerulonephritis, left kidney is bigger compared to the right (Hallberg, 1953; Angelou et al., 2020).

Ectopic migration often occurs when larvae or adult helminth forms are found in the abdominal cavity (Shahbazi et al., 2017), causing peritonitis and perihepatitis (Taylor et al., 2007), or rarely in the thoracic cavity, like perforation

of the mediastinal part of the pleura (Russo et al., 2022). Interference of parasites around hepatic lobes is possibly resulting in capsule erosions, bleeding and rupture (Angelou et al., 2020). In cases of extrarenal localization, larval forms can be encysted in subcutaneous tissue, the spleen, the uterus, the mammary gland, the ovaries, the scrotum, and the testes (Greer et al., 2021), when necropsy is the most appropriate method (Ferreira et al., 2010; Eiras et al., 2021).

In some cases of dioctophimosis, subcutaneous changes are reported. Bitencourt Vidal et al. (2021) report on the accidental finding of nodular structures in the inguinal region of cats, during routine spaying. Parasitological examination of nodular content established the presence of *D. renale*, while histopathological findings confirmed granulomatous inflammation.

Histopathological findings

Histopathological examination of damaged kidney reveals cortical and medullar atrophy, complete loss of tubular structures, intensive fibrosis and diffuse glomerular sclerosis (Oliveira et al., 2021), neovascularization, hyperaemia, mononuclear cell infiltration (Hallberg, 1953), and dystrophic calcification and metaplastic changes of epithelial cells of the renal pelvis (Russo et al., 2022).

Due to clinical significance of this disease and increasing prevalence during last decade in dogs of surrounding countries, the list of differential diagnosis of dioctophymiasis needs to include the following: nematode *Capillaria plica* (Ilić et al., 2021), chronic nephritis, renal fibrosis and functional kidney disorders of different etiology (Gherman, 2013), as well as polycystic kidney disease of cats and canine leptospirosis (Mesquita et al., 2014).

THERAPEUTIC AND PROPHYLACTIC APPROACH

The most common approach in therapy of dioctophimosis is surgical removal of pathologically changed kidney. In cases of extrarenal localization, laparoscopy is used for larval removal and adult nematode forms. In cases of rare finding of *D. renale* in both kidneys, the only therapeutic method is helminths' extraction from renal pelvises, with uncertain prognosis and survival time from six months to three years (Greer et al., 2021; Eiras et al., 2021).

Medication therapy is extremely limited and uncertain, but avermectine derivatives that can be used are moxidectine and doramectine (Russo et al., 2022). One of effective therapeutic protocols implies intramuscular application of 5 % enrofloxacine (1 ml/10 kg) for five days, then doramectine (1 ml/20 kg) for three days. Seven days later, tablets of enrofloxacine are applicated for

three days *per os* and doramectine injection once a week (Eiras et al., 2021).

Greer et al. (2021) designed a protocol that, beside diagnostic methods, also gives information about treatment options for affected dogs according to the results of specialized clinical examination methods (Figure 3). If urinalysis detects *D. renale* eggs, a patient is a candidate for surgical removal of the affected kidney. Before this invasive intervention, it is necessary to examine blood biochemistry parameters that indicate the degree of preservation of kidney function (blood urea nitrogen, creatinine, and electrolytes). If they are within reference values, the patient undergoes surgical intervention and after the surgery is treated with moxidectine (2,5 mg/kg monthly). If kidney function isn't preserved, euthanasia is justified. When there is absence of eggs in urine sediment, ultrasonography is performed. If adult parasite forms are found in the renal pelvis, the previously mentioned procedure is implemented.

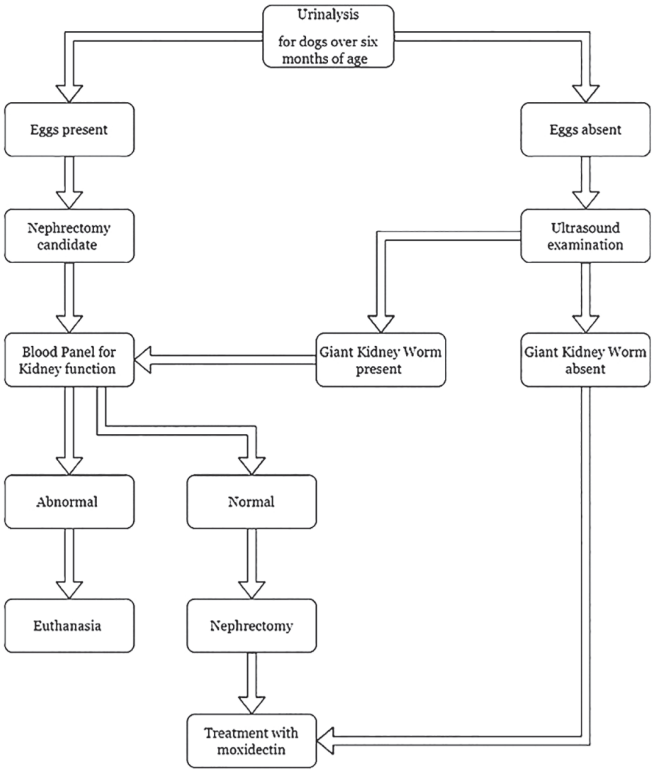

Figure 3. Protocol for diagnosing and treating dogs older than six months infected by *D. renale* (Greer et al., 2021)

Experimental investigations indicate that fungal proteases and chitinases extracted from *Pochonia chlamydisporia* have a harmful effect on the causative agent's eggs. Eiras et al. (2021) suggests the potential possibility of biological control of dioctophimosis and the need for additional investigations.

Control of dioctophimosis is accompanied by the use of general prophylactic measures that are educational for owners because specific measures like vaccination aren't available. Due to the high zoonotic potential of *D. renale* nematode, prevention of infection is especially important for stray dogs because of their uncontrolled movement and contact with ecosystems that represent the source of this parasitosis (Gherman, 2013; Russo et al., 2022). It is necessary to limit the movement of pet dogs or keep them monitored and under supervision in order to avoid contact with water courses, which are habitats for intermediate and paratenic hosts for *D. renale*. It is required to limit the feeding of dogs with raw fish, amphibians, or other intermediate hosts (Gherman, 2013; Russo et al., 2022).

The therapeutic prophylactic approach is very limited by the progressive development of parasitic resistance to some anthelminthic chemical groups.

SIGNIFICANCE OF *DIOCTOPHYMA RENALE* NEMATODE FOR PUBLIC HEALTH

Humans can become infected with the *D. renale* nematode after eating raw fish or frogs containing infective larvae or by ingesting aquatic oligochaetes of the Annelida genus (Chauhan et al., 2016). Due to its nonspecific clinical presentation and rarely diagnosed cases of the disease, this parasite is often neglected in human medicine (Yang et al., 2019). The disease is common in people from Asia (China, Indonesia, Iran, Thailand, and Japan), Europe (Greece and Serbia), North America, and Australia. Most cases are diagnosed in China, which is attributed to their traditional diet and consumption of raw meat (Yang et al., 2019).

Previous studies have found a slightly higher prevalence in males compared to females (59.5% and 40.5%) (Perera et al., 2021). Nematodes can survive in the kidneys for up to five years and cause obstruction, hydronephrosis, and destruction of the renal parenchyma (Chauhan et al., 2016). Affected patients usually have nonspecific symptoms suggestive of nephritis: Haematuria and pain in the lumbar region, while fever, abdominal pain, anaemia, and loss of body mass are less commonly reported. More severe cases are confirmed to be fatal (Perera et al., 2021).

The diagnosis of dioctophimosis in humans is made on the basis of the detection of eggs and adult forms of *D. renale* in a urine, parasitological dissection, and histopathological examination of infected tissue from the right kidney. This finding is explained by the fact that the right kidney is closer to the stomach. According to Yang et al (2019), the parasite presence in the renal pelvis destroys the integrity of the renal tissue and leads to metaplastic changes. This is the reason why the parasite finding is related to the occurrence of renal tumours. The occurrence of ectopic parasitism should not be neglected when *D. renale* larvae are localized in the subcutaneous tissue and retroperitoneal cavity and adult forms are localized in the thoracic cavity, causing inflammatory nodules and skin papules characterized by marked pruritus (Yang et al., 2019). The first diagnosed case of subcutaneous dioctophimosis in a Chinese man who has lived in Japan for 15 years was confirmed by molecular identification of *D. renale* larvae (Tokiwa et al., 2014).

There is still no adequate treatment protocol for human patients, and nephrectomy is considered too invasive. Although there are confirmed successful treatments with ivermectin and albendazole, the use of anthelminthics is still not accepted as a safe therapeutic option. Therefore, in human clinical practice, it is desirable to include this parasitosis in the list of differential diagnoses for patients with nonspecific symptoms such as haematuria and lumbar pain (Yang et al., 2019). The most effective way of prevention is to avoid eating raw fish or frog meat (Chauhan et al., 2016).

Thus far, one case of dioctophimosis has been reported in Serbia in a person who consumed minced fish meat during a trip. Upon his return to Serbia, the patient exhibited the following symptoms: fever, haematuria, dysuria and pain in the lumbar region. The diagnosis was confirmed after surgical intervention and pathohistological examination of the extirpated material (Nikolić Svetozarević et al., 2001).

CONCLUSION

From a veterinary point of view, dioctopimosis has a high value in clinical practice because dogs are usually affected by only a few parasites. The fact that the disease is often asymptomatic complicates its diagnosis. For this reason, only a reasonable suspicion can be made during the clinical examination of dogs, while it is essential to include the disease in the list of differential diagnoses of urinary tract diseases in carnivores. Because of the high zoonotic potential of the *D. renale* nematode, effective control and management of this helminthosis is crucial. It is also necessary that all fields of human and veterinary medicine work closely together within the concept of "one health".

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All authors (IT, IN, JMN, DD, NK) contributed to manuscript design, performed literature searches, wrote and revised the article, and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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