Clinical spectrum of symptoms in cerebral Toxocariasis (Review)

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Abstract. Human helminth zoonosis is one of the most encountered helminthiases worldwide. Representative diseases include *Toxocara canis* and *Toxocara cati*, which are common nematodes prevalent in dogs and cats. The infiltration of these roundworms in the human body through contaminated food or nematode eggs could lead to central nervous system injury as the roundworms can cross the blood-brain barrier leading to neurotoxocariasis. Among the neurological and neuropsychological disturbances produced by Toxocara infection, in humans, the most representative are meningitis, encephalitis, myelitis and cerebral vasculitis, but asymptomatic central nervous system infection is probably the most prevalent. The present review examines the clinical symptomatology of neurotoxocariasis in case reports in the literature in the last 7 decades (1950-2020). The available evidence was retrieved from PubMed and Medline electronic databases. The present review reports the most prevalent clinical symptomatology in the cases of detected and diagnosed Toxocara infection with neuroinvasion. Thus, the present review aims to raise the awareness of neurological cases of Toxocara infection with the potential to at least establish differential diagnosis of neurotoxocariasis.

Contents

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1. Introduction

The incidence of parasitic infections remain prevalent disregarding the advancement in different countries. This increased incidence is generated partially by a rising number of travelers abroad and pet owners (1). In some countries, the food habits and preferences are varied and this factor can make humans in these countries more prone to this disease (1). Forms of toxocariasis in literature have been described after the ingestion of meat from chickens, cows and quails in Japan in adult patients with pulmonary and liver affections (1).

At the time of intrusion in the host gastro-intestinal system, the progression continues through the portal vein to the liver, where it can be cantonated, but also, with the possibility of by-passing the liver and continuing to migrate through the circulation in systemic organs, causing the manifest form of the disease depending on the concerned organ (1).

A categorical diagnosis of *Toxocara cati* or *Toxocara canis* infection can be established after the discovery of the larvae and eggs originating from the patient, but this situation is infrequent. Broadly, the diagnosis is determined in the hospital using the anamnesis of a history of eating uncooked meat, paraclinical laboratory exams hypereosinophilic syndrome with the existence of specific antibodies. The severity of this disease may be directly proportionate to the dose of inoculation (2). Glickman *et al* raised the concern about a high risk of potential infections with parasites from *Canis* and *Felids* in the situations of hunting and possessing hunting dogs inside human establishments (2).

Toxocara cati (*T. cati*) and *Toxocara canis (T. canis)* are the etiological factors of human toxocariasis. In addition, these ubiquitary zoonotic nematodes belong to the family Ascaridae (2). The adult parasites from *T. cati* and *T. canis* are located in the first part of the small intestine of the terminal host. *T. cati* and *T. canis* can be hosted in various types of paratenic beings such as humans, mammals, birds and rodents (3). The natural evolution of the presence of the larva in these organisms involves migration to certain tissues and organs of the hosts and long-term survival (3). This fact has been demonstrated by experimental studies on various animals such as chickens or mice, which have shown the migration of the pathogen in certain parts of the organism of the host (3).

2. Neuroinvasion in animals

Studies and experimental studies on animals have reported the presence of *T. canis* larvae in the brain, liver and other organs of the hosts, confirming migration of the larva in the organism of the host (3,4). Fenoy *et al* presented the theory that larvae are not always prevalent in histopathological lesions because of the motility of the larvae (5). Studies with animals have demonstrated that the most prevalent organ preferred by larvae in migration is the liver of the host, especially in the case of the chicken as the paratenic host (6,7).

Azizi *et al* demonstrated for the first time that following experimental infection with embryonated eggs in chicken with *T. cati*, the larvae had the capacity to migrate to other tissues and organs in the host besides the gastrointestinal tract. In this study, the migration of the larvae to the brain and liver of the hosts was reported along with the presence of mild infection. In addition, the research team recovered larvae from the brain and the liver of two chickens that were infected. The authors concluded by projecting an awareness of raw meat consumption, especially raw chicken brain and liver (8).

Studies involving mice infected with *T. canis*, reported 'congestion, thickening of arterioles, moderate inflammatory infiltrate and severe gliosis' (8,9). In addition, similar results related to the morphological aspects in toxocariasis were reported by Oryan *et al* in studies with chickens infected with *T. cati* (9).

In a study by Oryan *et al* with chicken infected with *T. cati*, the authors discovered, after 240 days after the inoculation of the larvae eggs, larvae recovery in 3 chicken brains and also modifications as hemorrhages and infiltrations (mostly lymphocytic, less eosinophilic) located in the meninges and also in the vessels in cerebral parenchyma and in the region of the cerebellum. The brain infection was mild, without any impairment of behavioral pattern observed in the infected chickens. Furthermore, histopathological changes were found in the organs of all the infected chickens (9).

In addition, Janecek *et al* reported similar structural brain damage in the cerebrum of *T. canis*-infected mice with the presence of activated microglia and focal accumulation of phagocytic cells (10). Similarly, Othman *et al* reported many *T. canis* larvae scattered in brain tissues of the infected group of mice inducing vascular congestion but without inflammatory infiltrate (11).

In a study by Pegg, common flies were infected with eggs of *T. canis* and afterwards, Beagle puppies were fed with the flies, after being treated with antihelminthics. From the puppies in the group, 80% became infected with *T. canis* after ingestion of the flies. Larvae and eggs were collected from various tissues of the dogs. This study has enormous importance in considering flies as sources of infection with *T. canis* not only for dogs, but as well as humans (12).

3. Neuroinvasion in humans

Neurotoxocariasis is a severe disease that has been associated with a decrease in mental activity, social changes and neurodegenerative diseases. The importance of the disease is determined by its ubiquitous spread as a zoonosis generated by *T. canis* or *T. cati* (9-11).

Toxocariasis in humans is produced by the presence in the digestive system of eggs in the embryonate stage or the tissues of hosts that contain the infective larvae. Humans develop the infectious disease after consumption of embryonated eggs coming from soil (geophagia, pica) or in the case of contact with dirty hands, raw vegetables, or larvae from undercooked or raw meat consumption (9-11). Present in the human body, the larvae begin their exodus using the blood flow to migrate to various organs in the body.

Toxocariasis can be categorized into four main stages: Asymptomatic-the most prevalent phase, visceral, ocular and neurotoxocariasis. The factors that contribute to the stage of the disease include: The quantity and quality of the infection, the patient's immune response and the concerned organs (9-11).

Toxocariasis that is located in the nervous system is a chronic disease that may recur for a considerable amount of time and may interfere with the functions of the nervous system, characterized by a decrease in cognitive capacity, neuropsychological impairment, depression, behavioral alteration and neurodegenerative diseases (11-13).

As a consequence of this localization, the treatment of neurotoxocariasis is difficult and consists of many challenges, as drugs destined to treat this disease have variable effects. In addition, effective treatment must take into consideration the difficulty of penetrating the blood-brain barrier, and on the other hand, the treatment can sometimes cause more detrimental effects than the disease itself due to allergic responses that may occur during treatment (11). Another challenge in the treatment of neurotoxocariasis is the fact that the treatment combines anti-inflammatory drugs to reduce the generalized inflammatory reaction, which also decreases the effectiveness of treatment on the pathogenic larvae, especially taking into consideration the fact that the immune reactions occur in the brain; thus, it is difficult to eradicate this disease.

The cells mainly involved in the defense process against the penetration of pathogens and parasites into the brain are astrocytes, which also modulate neuroinflammation. Through these processes, astrocytes maintain homeostasis in the brain (11). Taking into consideration the disruptions that occur in the neurotoxocariasis pathology, it is assumed that the function of astrocytes is impaired (11).

4. Case reports from the literature

The clinical intensity and type of manifestations in neurotoxocariasis are related to the quantity of the larvae that penetrate the blood-brain barrier and also are related to the severity of the destruction and inflammatory response (11). The clinical manifestations of neurotoxocariasis are distributed on a broad extent, generating varied syndromes: Encephalitis, seizures, brain vasculitis, extramedullary space-occupying lesion and meningitis (9-12).

The first case of neurotoxocariasis was reported in 1951 by Beautyman and Woolf (13), in the case of a child with clinical and pathological findings of a neurological disorder caused by an encapsulated larva recovered from serial sections of the brain at autopsy (the child's death was due to poliomyelitis) that was firstly wrongly assumed to be *Ascaris lumbricoides*. In 1956, Nichols (14) described the morphological features of Toxocara and Beautyman and Woolf (13) concluded that in

their case report the child presented with *T. canis*, rather than the initial larvae believed. As the response of the infection with these zoonotic agents, at the molecular level, there appears a demyelination of the nerve fibers. In observations in mice, it was demonstrated that *T. canis* has a higher prevalent inclination of migration in the central motor system than *T. catis* (10). The terminology of neurotoxocarosis was first introduced in the literature in 2007 (15).

In a case report by Marx *et al* (16), a 2-year-old girl presented with impairment of gait and ataxic gait, dysarthria, nystagmus, hyperreflexia of the lower limbs, cutaneous plantar reflex in extension bilaterally, nuchal rigidity and Brudzinski sign. Cerebrospinal fluid (CSF) analysis showed pleocytosis with the predominance of lymphocytes. Magnetic resonance was suggestive for acute disseminated encephalomyelitis, but the laboratory analysis tests of the blood and CSF showed the presence of antibodies against *T. canis*. This case report was the first case reported in an article of neurotoxocariasis with acute disseminated encephalomyelitis pattern images in magnetic resonance imaging (MRI).

The systemic symptomatology may be absent in most cases, but regarding the neurological symptomatology, the most prevalent are: Deterioration in the motor area, seizures of the epileptic type and impairments in the neuropsychological area (17).

The eating patterns of individuals are particularly important because of the prevalence of human ingestion of animal raw organs, especially the liver and brain, a situation reported by Morimatsu *et al* in a familial case of ingestion of raw chicken liver that presented visceral larva migrans caused by *T. canis* larvae. Both patients in this family presented with mainly systemic and pulmonary signs and symptomatology, but one of the patients also presented neurological symptoms in anamnesis, before admission to the hospital which included posterior headache and neurologic abnormality of the front of the right arm of 3-week duration (18).

In a case report by Goffette *et al*, a woman presented with the following neurological findings: Subacute weakness located in the right leg and dysesthesia located in the right Th8-Th10 dermatomes; the cerebrospinal fluid findings showed eosinophilic pleocytosis and also the levels of *T. canis* were more significant in the CSF than in the blood (19).

Mikhael *et al* presented a case of an 18-month-old male who was admitted twice to the hospital; firstly with inconclusive diagnosis and laboratory findings, being probable a case of visceral larva migrans. At the second admission, the child presented with ataxia and went into status epilepticus repeatedly and became comatose. The patient's exitus came after 3 days. The pathological findings showed *T. canis* larvae in the brain and other organs. Numerous granulomatous inflammatory regions located both in the white and gray matter were found in both cerebral hemispheres, cerebellum and brain stem and also, observed parts of the larvae were found in these regions (20). Table I summarizes the results from the literature regarding the cases of cerebral toxocariasis in chronological order (13,16-19,20-51).

5. Conclusions

The specificity of the clinical manifestations of neurotoxocariasis has not been clearly determined, but the clinical manifestations reflect in an insightful way the provenience of the lesions located in the central nervous system. In the literature, a prevalence of male gender has been reported among cases of neurotoxocariasis, with 75% of the cases cited with a mean age of 42.5±15.5 (52); compared with cases of visceral larvae migrans that are more prevalent among children (53).

The cerebral localization was most prevalent in Europe and subsequently America with reference to the geographical classification. A few cases of encephalic localization were reported in Asia, in contrast to the large number of cases of spinal cord localization reported in this area (54).

The most encountered form of debut in neurotoxocariasis is the isolated myelitis that is prevalent in approximately 70% of the cases (52,54,55). The symptoms are represented by sensory and motor impairments, mostly being located in the lower limbs and usually being followed by autonomic dysfunction. In a study by Lee *et al*, 33 patients that presented with atopic myelitis were positive for the Toxocara excretory-secretory antigens in immunological tests, developing a new branch of research and differential diagnosis for the patients that present with unusual cases of myelitis (56). In a study by Lee *et al* in 2010, the authors investigated retrospectively the MRI findings of visceral larva migrans of neurotoxocariasis located in the spinal cord of 8 patients, and the authors found only one patient that presented a migration of lesion (56). Furthermore, in a study by Jabbour *et al* that contained the examination of 17 patients with myelitis due to *T. canis* infection, only one lesion in the spinal cord revealed characteristic MRI spinal cord imaging (42). These three studies on myelitis caused by Toxocara infection represent a number of 56 cases, about half of all cases of neurotoxocariasis reported in the literature. Moreover, most cases of myelitis due to Toxocara infection were diagnosed in Korea and Japan and several cases were reported in Western countries (52,54,55).

The cerebral localization of Toxocara infection is revealed through presentation of meningitis, encephalitis, meningoencephalitis, encephalomyelitis, and meningoencephalomyelitis, but cerebral abscesses have been reported in several cases (56,57). Encephalic and meningeal toxocariasis implication is correlated with a large area of clinical symptoms containing headache, seizures, focal deficits, confusional state, and cognitive impairment, the presence of fever not being mandatory (56,57).

Another important factor to be taken into consideration as a symptom of neurotoxocariasis is the presence of epileptic seizures, as demonstrated in a study by Luna *et al* (57). Another theory targets the implication of neurological disorders that are evolving in a paraclinical frame of high Toxocara seropositivity (58,59). Depressive symptoms, mental confusion, cognitive impairment and even schizophrenia have been reported to be prevalent among patients with neurotoxocariasis (60,61). Furthermore, in a study by Hotez, the significance of infections is viewed as a factor that causes lower academic achievement between students that come from rural areas, due to the presence of the effects that infections have on the human brain (62). In light of all of the cases presented, awareness must be maintained concerning the implications of Toxocara infection on the

Table I. Case reports of patients with neurotoxocariasis from the literature in chronologic order.

Case no.	Author(s) (year)	Title	Type of publication	Sample	Findings	(Refs.)
1	Beautyman and Woolf (1951)	Ascaris larva in the brain in association with acute anterior poliomyelitis	Case report	1	A case of a child infected with *T. canis* revealed poliomyelitis at autopsy.	(13)
2	Mikhael *et al* (1974)	*T. canis* infestation with encephalitis	Case report	1	An 18-month-old male presented with status epilepticus and died afterwards. The autopsy showed encephalitis due to infection with *T. canis*.	(20)
3	Gould *et al* (1985)	Toxocariasis and eosinophilic meningitis	Short report	1	A case of mild eosinophilic meningitis due to *T. canis* infection in an 11-year-old girl, who presented with positive meningeal signs.	(21)
4	Russegger and Schmutzhard (1989)	Spinal toxocaral abscess	Case report	1	A 55-year-old woman presented with acute paraparesis, after a long period of back pain. A spinal abscess of granulomatous type was identified and removed in the laminectomy located in the T7-11 area and serum toxocara enzyme was positive.	(22)
5	Fortenberry *et al* (1991)	Visceral larva migrans producing static encephalopathy in an infant	Case report	1	A 10-month-old boy presented multiple times at the hospital, firstly being diagnosed with a probable Epstein-Barr infection. Afterwards, he presented with lethargy, inability to walk or stand, poor coordination and hyperreflexia in the lower extremities and developed recurrent seizures. CT investigations showed increasing ventriculomegaly. The meningeal biopsy showed eosinophilic meningoencephalitis and also showed at the brain biopsy: Granulomatous inflammation with giant cells. Subsequently presented cortical blindness, recurrent seizures and spastic quadriparesis.	(23)
6	Villano *et al* (1992)	A rare case of *T. canis* arachnoidea	Case report	1	A case of *T. canis* arachnoidea located in the cervical zone.	(24)
7	Sommer *et al* (1994)	Adult *T. canis* encephalitis	Case report	1	A 48-year-old developed ataxia, rigor and neuropsychological impairment after being infected with *T. canis*. Diffuse and defined white matter lesions were prevalent at CT and MRI scans and also, at angiography, multiple occlusions of middle cerebral artery branches were obvious.	(25)

Table I. Continued.

Case no.	Author(s) (year)	Title	Type of publication	Sample	Findings	(Refs.)
8	Komiyama *et al* (1995)	Optic neuritis in cerebral toxocariasis	Case report	1	A 21-year-old woman presented with convulsions, fever and developed meningeal signs and cerebellar ataxia. Serologic and CSF analysis were positive for *T. canis* infection. CT and MRI revealed swelling and a lesion of the right optic nerve.	(26)
9	Magnaval *et al* (1997)	Human Toxocara infection of the central nervous system and neurological disorders: A case-control study	Case control study	27	A group of 27 patients with positive immunodiagnosis of toxocariasis with *T. canis*, from CSF and serum, but without the existence of any symptoms analyzed considering the risk factors. The following were found as adjuvants in the infection with *T. canis*: Rural area, dog owning and dementia.	(27)
10	Strupp *et al* (1999)	Meningomyelitis in a case of toxocariasis with markedly isolated CSF eosinophilia and an MRI-documented thoracic cord lesion	Case report	1	A 45-year-old man presented with weakness of both quadricep muscles and gait disturbances. At spinal MRI a prevalent thoracic lesion was revealed. Anti-*Toxocara canis* antibodies were present in serum.	(28)
11	Goffette *et al* (2000)	Eosinophilic pleocytosis and myelitis related to *T. canis* infection	Case report	1	*T. canis* infection-induced myelitis and CSF analysis showed eosinophilic pleocytosis.	(19)
12	Richartz and Buchkremer, (2002)	Cerebral toxocariasis: A rare cause of cognitive disorders. A contribution to differential dementia diagnosis	Case report	1	A 65-year-old woman presented with depression and cognitive impairments. The CSF presented pleocytosis with marked eosinophilia and a positive serology for *T. canis*. After following treatment, the patient's cognitive symptoms improved.	(29)
13	Dousset *et al* (2003)	Cerebral vasculitis due to *T. canis* (or *catis*) origin	Case report	1	Cerebral vasculitis was reported secondary to infection of *T. canis*.	(30)
14	Moreira-Silva *et al* (2004)	Toxocariasis of the central nervous system: With report of two cases	Review of literature with case report	2	Two 5-year-old children were admitted presenting infection with Toxocara larvae. The girl presented paralyses of the VI, VII and XII cranial nerves and paralyses of both superior and inferior members with the meningeal signs positive. Meanwhile, the boy presented palsy of the inferior limbs, with a diagnosis of possible transverse myelitis. The CSF in both cases, presented pleocytosis with marked eosinophilia and a positive serology for Toxocara larvae, both in serum and CSF.	(17)

Table I. Continued.

Case no.	Author(s) (year)	Title	Type of publication	Sample	Findings	(Refs.)
15	Bächli *et al* (2004)	Cerebral toxocariasis: A possible cause of epileptic seizure in children	Case report and review of the literature	1	A 11-year-old girl presented with a generalized epileptic seizure; CT scan revealed a cystic lesion in the parietal lobe. After the lesion was removed tests revealed positive for *T. canis* infection.	(31)
16	Eberhardt *et al* (2005)	Eosinophilic meningomyelitis in toxocariasis	Case report and review of the literature	1	A 39-year-old patient presented with positive Lhermitte's sign 3 weeks before the admission. MRI of the cervical spine revealed a T2 hyperintense intramedullary signal formation between C2-T1. CSF tests showed Toxocara infection.	(32)
17	Dauriac-Le Masson *et al* (2005)	*T. canis* meningomyelitis	Case report	1	A 32-year-old woman presented with ascending weakness and paresthesiae in the lower limbs. MRI showed a contrast-enhancement at Th9 level. *T. canis* antibodies were higher in the CSF than in blood.	(33)
18	Gorgulu *et al* (2006)	Postoperative cerebral abscess formation caused by *Toxocara canis* in a meningioma cavity	Case report	1	A 56-year-old woman that had a right parietal meningioma removed by operation, presented with left-side hemiparesis. Cranial MRI revealed a formation located in the tumor cavity and after it was removed the diagnosis was of a *T. canis* abscess.	(34)
19	Morimatsu *et al* (2006)	Familial case of visceral larva migrans after ingestion of raw chicken livers: Appearance of specific antibody in Appearance of specific antibody in bronchoalveolar lavage fluid of the patients	Case report	2	Two related patients infected with *T. canis* through food; one of them presented occipital headache and neurological dysfunction located in the front of the right arm of 3-week interval.	(18)
20	Maiga *et al* (2007)	Presentation of cerebral toxocariasis with mental confusion in an adult	Case report and review of the literature	1	A 73-year-old man presented with confusion and subsidiary developed meningoencephalitis. Immunodiagnosis in both serum and CSF was positive for Toxocara.	(35)
21	Marx *et al* (2007)	Toxocariasis of the CNS simulating acute disseminated encephalomyelitis	Case report	1	After *T. canis* infection, MRI was similar to acute disseminated encephalomyelitis. Presence of ataxic gate, lower limb hyperreflexia, Babinski sign bilaterally, nuchal rigidity, Brudzinski sign.	(16)
22	Helbok *et al* (2007)	Rare case of *T. canis* cerebral vasculitis	Case report	1	*T. canis* infection-induced cerebral vasculitis	(36)

Table I. Continued.

Case no.	Author(s) (year)	Title	Type of publication	Sample	Findings	(Refs.)
23	Keller *et al* (2008)	Possible intrafamilial transmission of Toxocara causing eosinophilic meningitis in an infant	Case report	1	A 7-month-old infant presented with eosinophilic meningitis, with Toxocara antibodies present in both blood and CSF.	(37)
24	Kinčeková *et al* (2008)	Complicated cerebral toxocariasis in a 4-year-old child	Case report	1	A 4-year-old boy presented with loss of voluntary movement coordination, deterioration of walk and afterwards became comatose. At the CT scan multiple hypodense lesions were present in fronto-parietal region. The blood test revealed positive *T. canis* antibodies.	(38)
25	Scheid *et al* (2008)	Cognitive dysfunction, urinary retention, and a lesion in the thalamus-possible toxocariasis of the central nervous system	Case report	1	A 45-year-old man with a 7-year history of unexplained neurologic signs and symptoms, including cognitive impairment. MRI revealed a cystic lesion in the left thalamus. Blood and CSF analyses were positive for *T. canis*.	(39)
26	Salvador *et al* (2010)	Pediatric neurotoxocariasis with concomitant cerebral, cerebellar, and peripheral nervous system involvement	Case report and review of the literature	1	A 5-year-old boy presented impairments in gait, balance, and motor coordination and subsidiary meninginism. Eosinophilic meningoencephalitis was suspected and serological tests were positive for *T. canis*.	(40)
27	Singer *et al* (2011)	Severe meningoencephalomyelitis due to CNS toxocariasis	Case report	1	A 44-year-old woman was admitted with epileptic seizure and developed after paraplegia with pyramidal signs and sensory impairments. Spinal MRI revealed signs of myelitis and cerebral MRI revealed a slight leptomeningeal enhancement. Blood and CSF analyses were positive for Toxocara.	(41)
28	Jabbour *et al* (2011)	*T. canis* myelitis: Clinical features, MRI findings, and treatment outcome in 17 patients	Case reports	17	A total of 17 cases of isolated Toxocara myelitis. Clinical presentation included sensory, motor, and autonomic dysfunction, usually located in the lower limbs. All patients tested positive for *T. canis* antibodies in the blood and CSF.	(42)
29	Park *et al* (2012)	Eosinophilic myelitis in the cervical cord mimicking intramedullary cord tumor	Case report	1	A 55-year-old man presented with paresthesias located in the left upper limb. At MRI a nodule in the C5 area was evident. Toxocariasis antigen was positive.	(43)

Table I. Continued.

Case no.	Author(s) (year)	Title	Type of publication	Sample	Findings	(Refs.)
30	Fukae *et al* (2012)	Longitudinal myelitis caused by visceral larva migrans associated with *T. cati* infection	Case report	1	A 42-year-old man presented with thoracic dysesthesia. At MRI, focal enhancement at the Th5 level was discovered. *T. cati* antigen was positive.	(44)
31	Lompo *et al* (2012)	*T. canis* cerebral vasculitis revealed by iterative strokes	Case report	1	A 49-year-old man presented with right ACA infarction and multiple segmental stenoses in encephalic arteries, in a context of hypereosinophilia. Subsidiary, the patient presented left pontine hemorrhagic stroke. The serum and CSF analysis revealed infection with *T. canis*. Diagnosis was *T. canis* cerebral vasculitis.	(45)
32	Choi *et al* (2013)	Obstructive hydrocephalus due to CNS toxocariasis	Case report	1	A 46-year-old man presented with headache, diplopia, and visual impairments. Funduscopic examination revealed optic disk swelling in both eyes. Brain MRI scan revealed hydrocephalus and leptomeningeal enhancement at the prepontine cistern, left cerebellopontine angle cistern and bilateral cerebral hemisphere. Serologic and CSF analysis were positive for *T. canis* infection.	(46)
33	Fellrath and Magnaval (2014)	Toxocariasis after slug ingestion characterized by severe neurologic, ocular, and pulmonary involvement	Case report	1	A 71-year-old male presented with confusion, memory and balance impairment, and scalp hyperesthesia. The brain MRI revealed subcortical ischemic lesions. Serum analysis revealed Toxocara infection.	(47)
34	Sick and Hennerici (2014)	Isolated eosinophilic meningitis in Toxocariasis	Case report	1	A young man presented with isolated eosinophilic meningitis, which resulted from infection with *T. cati*.	(48)
35	Hiramatsu *et al* (2015)	*T. canis* myelitis involving the lumbosacral region	Case report	1	A 60-year-old man presented weakness and dysesthesia in the lower limbs. The MRI findings showed lumbosacral hyperintensities and nodules in the lumbar spinal cord area. Anti-Toxocara antibodies were present both in blood and CSF.	(49)
36	Kwon (2015)	Toxocariasis: A rare cause of multiple cerebral infarction	Case report	1	A 39-year-old man presented with right leg weakness. Brain MRI revealed small embolic acute ischemic lesions in both cerebral hemispheres, temporooccipital lobes of both PCA territory, and left cerebellar hemisphere. Serologic results revealed positive infection with *T canis*.	(50)

Table I. Continued.

Case no.	Author(s) (year)	Title	Type of publication	Sample	Findings	(Refs.)
37	Abir *et al* (2017)	Toxocariasis of the central nervous system	Article with case reports	2	A 45-year-old man had a 3-month history of symptomatology of weakness and personality change; at the neurological examination, the patient presented frontal and pyramidal syndrome. At CT scan was revealed the presence of bilateral lesions located in the capsulo-lenticular area. A 66-year-old woman presented with both motor and sensory impairments in the lower limbs. Upon neurological examination, spastic paraparesis and superficial sensory impairment below the T10 level and hypoesthesia in the lower limbs were present. The spinal MRI revealed lesions in the cervical and lumbar areas. The blood and CSF investigations were positive for Toxocara infection in both patients.	(51)

T. canis, *Toxocara canis*; *T. cati*, *Toxocara cati*; CSF, cerebrospinal fluid; CT, computed tomography; MRI, magnetic resonance imaging.

whole organism, but especially in the nervous system. It is extremely important to consistently consider infection with Toxocara as a differential diagnosis.

Neurotoxocariasis represents a rare diagnosis. It is possible to be underdiagnosed especially due to the vague and wide-ranging characteristics of the symptomatology aggravated by an insufficiency of supporting diagnostic investigations. This is also the reason why MRI investigation has become so important and vital in this disease. Therefore, a classification of brain imaging conclusions have been described in connection with neurotoxocariasis, firstly being assessed by computed tomography and currently with the aid of magnetic resonance imaging (63). Regardless of the obvious significance of interpretation of neuroimaging conclusions, only several clinicians use MRI to diagnose and evaluate neurotoxocariasis (63).

MRI could represent the most accessible aid for evaluating the efficacy of treatment and to pursue the evolution of the disease, facts that alternatively could be otherwise challengeable or unattainable, particularly for patients which present sporadic seizures. In an article by Rüttinger and Hadidi (63), which assessed the importance of MRI in neurotoxocariasis, it was concluded that gadolinium-enhanced MRI could be significantly valuable for determining the requirement of treatment, as well as to assess a disrupted blood brain-barrier to an active inflammation.

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Authors' contributions

ADA, AEG and AZS conceived and designed the review. AZS, AEG and ADA performed the literature research. ADA, AEG, AP, DCJ, AZS and DDA were involved in the interpretation of the findings in the literature. ADA, AZS, AEG and DDA were involved in the writing of the manuscript. All authors have read and approved the final manuscript.

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The authors declare that they have no competing interests.

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