Received: 10 February 2024 | Revised: 6 August 2024 | Accepted: 8 August 2024

DOI: 10.1111/vru.13428

ORIGINAL RESEARCH

WILEY

Intranasal *Linguatula serrata* (tongue worm) in canids and vulpids can be detected using computed tomography

Alice Birckhead[1] | **David Jenkins**[1] | **Shokoofeh Shamsi**[1] | **Richard Malik**[1,2] | **Ann Carstens**[1,3]

[1]School of Agricultural, Environmental and Veterinary Sciences, Charles Sturt University, Wagga Wagga, Australia

[2]Centre for Veterinary Education, University of Sydney, Sydney, New South Wales, Australia

[3]Department of Companion Animal Clinical Studies, Faculty of Veterinary Sciences, University of Pretoria, Onderstepoort, South Africa

Correspondence
Alice Birckhead, School of Agricultural, Environmental and Veterinary Sciences, Charles Sturt University, Locked Bag 588, Wagga Wagga, NSW 2678, Australia.
Email: abirckhead@csu.edu.au

Funding information
Australian Government Research Training Program Scholarship

Abstract

Linguatula serrata ("tongue worm") is a zoonotic intranasal parasite found globally in wild dogs, free-ranging dogs, some domestic dogs, and vulpids. Since there are no sensitive tests currently available, infections are underdiagnosed. This is a pilot observational prospective study aimed at determining whether nasal linguatulosis can be diagnosed using CT. The secondary aims were to evaluate radiography, rhinoscopy, and nasal egg swabs as methods in the diagnosis of tongue worms. Fifty-four wild canids and three vulpids euthanased by gunshot were sourced from pest-control officers. Cadaver heads were subjected to helical CT examination, nasal-swabbed for tongue worm eggs, and necropsied. Radiographs and rhinoscopy were performed on cadavers suspected to be infected based on preliminary CT examination. Tongue worms were retrieved at necropsy in 25 dogs and one fox. CT findings in animals with no nasal cavity ballistic damage were reviewed in six infected dogs and one infected fox. Adult female tongue worms were identified in 4 of 6 dogs and 1 of 1 fox as long, tubular, slightly heterogeneously attenuating structures in the mid to caudal nasal cavities. They were not clearly visible in CT scans when surrounded by nasal fluid, and small parasites (male and immature females) were not discernible. Radiographic findings were mild and nonspecific. One tongue worm was detected in 1 of 12 dogs examined rhinoscopically. Tongue worm eggs were found in swabs from 7 of 25 dogs. While small tongue worms could not be detected with CT, CT proved to be a useful diagnostic method for visualizing adult female tongue worms.

KEYWORDS
parasitic, Pentastomida, rhinitis

1 | INTRODUCTION

Linguatula serrata ("tongue worm") is a zoonotic intranasal pentastome parasite of canids and other carnivores worldwide in its distribution.[1] It is considered a "neglected" and underdiagnosed parasite, and its global prevalence is unknown.[1,2] Amongst domestic dogs, tongue worms have been found to be highly prevalent in stray dogs that routinely eat raw offal, such as in certain regions of Iran.[3,4] In south-eastern Australia, tongue worms are common in wild dogs.[5] Sporadic cases have been documented in domestic dogs in central and northern Europe and the

United States, particularly in imported stray dogs.[2,6–13] Single cases in Athens[14] and the United Kingdom[15] were diagnosed recently; a pet dog likely infected at a sheep property and another on a commercial raw meat diet (respectively). With increased foreign pet adoption and wildlife expansion, it has been suggested that tongue worms may be diagnosed more frequently in central and northern Europe.[2]

Tongue worm has an indirect life cycle. Herbivores, such as sheep, goats, cattle, buffalo, rabbits, and wallabies, are intermediate hosts.[16] Dogs, the definitive hosts, become infected after consuming raw offal from an infected herbivore through hunting or scavenging.[5] Hereafter, the nymphs migrate up the esophagus and nasopharynx from the stomach, maturing into adult tongue worms in the nasal cavities, where they survive for up to 2 years.[1,5] Females grow up to 15 cm in length, while males reach approximately 2 cm.[17] Females produce millions of eggs over their lifetime, which are expelled in nasal secretions or swallowed and passed in feces.[5] Infected dogs pose a zoonotic risk. Humans may develop visceral linguatulosis after accidentally consuming tongue worm eggs in contaminated food or water or through close interactions with infected dogs.[18]

Infected dogs may be asymptomatic or have nonspecific signs of mild to severe rhinosinusitis.[2,6] Diagnosis relies on the visualization of the parasite or its eggs. Detection of eggs in nasal secretions or stool samples is not reliable, as it requires the presence of a sexually mature female; it takes approximately 6 months for a female to become sexually mature, eggs are shed intermittently, and sometimes a male-only infection is present.[6,19] Tongue worms can be detected via rhinoscopy; however, they may not be reachable or may be missed if they are tightly coiled in the nasal passages.[6,14] In some cases, they are diagnosed after they are spontaneously expelled during coughing or sneezing.[12,14,20] In wild and stray dogs, tongue worms are usually diagnosed at necropsy.[4,5]

Diagnostic imaging may aid in the diagnosis of this parasite. CT is an excellent imaging modality for the visualization of the nasal cavities and paranasal sinuses and is often used as part of the diagnostic work-up for chronic nasal disease in dogs.[21] There is only one report describing CT findings in a dog that had coughed up an adult tongue worm. No other tongue worms were identified; secondary changes were visualized including left frontal sinusitis, left exophthalmos, and lesions consistent with oesophageal granulomas.[13]

This study aimed to evaluate CT as a modality for diagnosing linguatulosis in canids and vulpids and compare cross-sectional imaging to necropsy findings. The secondary aims were to describe the radiographic features of linguatulosis and assess the diagnostic value of rhinoscopy and nasal swabs for the detection of eggs. It was hypothesized that individual parasites could be identified using CT, particularly the larger adult females.

2 | MATERIAL AND METHODS

This was a pilot observational prospective study. Ethics exemption (A21475) was obtained from the Animal Care and Ethics Committee, Charles Sturt University (CSU). Wild canid cadavers and vulpids were sourced from vertebrate pest control officers in south-eastern and northern New South Wales (NSW) and the Australian Capital Territory (ACT), as per previous studies.[5,22] Canids and vulpids were trapped and shot between May 2021 and October 2023 as part of normal pest control procedures.

2.1 | Animals

The study population consisted of wild canid (dingoes [*Canis lupus dingo*] and dingo/dog hybrids) and red fox (*Vulpes vulpes*) cadavers. Following euthanasia, cadavers were decapitated, and heads were bagged and placed in a cooler bag and frozen within 12 h. Frozen heads were transported to CSU and stored in a freezer prior to examination. This included a minimum of 2 days in a −80°C freezer to inactivate *Echinococcus granulosus* eggs,[23] with which the cadavers were likely to be contaminated. Cadaver heads were thawed for 12–24 h prior to CT examination, with the noses pointing ventrally to provide drainage, thereby reducing residual nasal fluid.

2.2 | Imaging

All cadaver heads were subjected to CT examination using a 16-slice scanner (Toshiba Alexion Advance) at the Veterinary Clinical Centre, CSU. The heads were positioned in ventral recumbency. Images were acquired in the transverse plane using the following image acquisition parameters: helical scan mode, 120 kVP, 150 mAs, 0.5 mm thickness, 0.4 slice interval, 0.75 s/rotation, pitch of 0.688, and a 256 × 256 matrix. CT images were reconstructed using soft tissue and bone algorithms.

CT examination was also performed on three tongue worms (one large female, one small female, and one male) ex situ, which were retrieved at necropsy approximately an hour earlier. The parasites were placed on top of a plastic slip and the same CT parameters were used, as above. The following CT characteristics were recorded: Hounsfield units (average of three readings), body shape, and size.

Digital radiography (AGFA NX) was conducted on all dogs that appeared to be infected based on the initial CT examination and did not have nasal cavity ballistic damage. Left to right lateral, dorsoventral (DV) and intraoral DV views were taken. The exposure factors for the canids were 70 kVp/5 mAs (DV and right lateral views) and 60 kVp/2.5 mAs (intraoral DV views), and for the vulpid, 50 kVp/2 mAs and 50 kVp/2 mAs, respectively.

Normograde rhinoscopy was performed on nasal cavities of cadavers suspected to be infected based on initial CT examination on the proviso they did not have marked ballistic damage, using a 3.8 mm diameter flexible bronchoscope (Olympus BF type 3C160). Still images were taken of suspect tongue worms and of associated pathological changes.

2.3 | Imaging analysis

All CT images and radiographs were interpreted by a third-year diagnostic imaging resident and an ECVDI-certified radiologist, who were both aware of the necropsy findings, and a consensus opinion was reached. Images were reviewed using multiplanar reconstructions in soft tissue (W/L 400 60) and bone windows (W/L 1500 300) using RadiAnt DICOM viewer software (Medixant).

The resident categorized the infected cadavers into three groups: free of nasal cavity ballistic damage, mild ballistic damage, and marked ballistic damage. Mild ballistic damage was defined as when one to two small metallic pellet fragments were present; and marked, as when several metallic pellet fragments and/or paranasal fractures were present. Dogs in the latter group were excluded from further imaging analysis.

The following CT findings were recorded: the presence of suspect tongue worm(s), parasite location (left or right nasal cavity, frontal sinus or nasopharynx), approximate length and maximum width, and its attenuation in Hounsfield units (HU; measured by using a hand-drawn region of interest and averaging three readings). When there was a clear difference between the interior and exterior of the parasite, average HU units were recorded for both. For location within the nasal cavity, rostral was defined as nares to teeth 105/205, middle as 106/206–108/208, and caudal was from the level of 109, caudally. It was also noted whether the parasite was situated within the ventral, middle, or dorsal third of the nasal cavity. For the approximate length of the parasite, the ruler tool was used, and when the shape folded, the shape was followed as closely as possible, and partial linear measurements were summed.

Other nasal changes were recorded, including the presence of soft tissue fluid attenuating material, whether it was unilateral or bilateral, and location (rostral, mid, or caudal nasal cavity and/or involvement of the frontal sinuses). The fluid was graded as scant, mild (filling up to 1/3rd of the nasal cavity), moderate (filling up to 2/3rds), or marked (all of the nasal cavity). The presence of turbinate destruction and paranasal bone lysis were also recorded.

2.4 | Nasal swabs and necropsy examination

Following the CT scans, cotton-tipped swabs of each nasal vestibule were collected, placed in saline, in labeled Eppendorf tubes, and stored in the fridge or freezer. To determine egg counts, the swabs were stirred vigorously in a saturated sodium nitrate solution (Chem Supply) in a Fecalizer egg flotation device (United States Plastic Corporation). More solution was added until a positive meniscus was formed. A cover slip was placed on the meniscus, and light microscopy (Olympus BH-2) at ×100 and ×400 magnification was used to count and verify the identity of the eggs (by size, shape, and hooks in the embryonated eggs).[5]

The necropsy technique followed that described by Shamsi et al.[5] consists of bisecting the heads sagittally with a hatchet and hammer and thoroughly examining each nasal cavity. Any identified parasites were retrieved and placed in 70% ethanol. Nasal turbinates/conchae were then removed and flushed with water over a 300 μm sieve to collect any remaining parasites. Parasite identification was carried out by a co-author (D.J.) based on its location in the nasal cavity and its distinctive flattened body and broad anterior end.[17] Number and sex (based on size and morphology) of parasites retrieved from each nasal cavity were recorded. The size range of the parasites was documented. Where possible, the parasite location was recorded (caudal, middle, rostral nasal cavity), and the parasite was photographed in situ to allow direct comparison with CT findings.

For the last groups of cadavers (15 dogs, 2 foxes) the CT scans were reviewed prior to the necropsies, and the location of any suspect tongue worms were documented (using the cadaver dentition as landmarks). A Dremel hobby drill (DREMEL 3000) was used to perform an osteotomy precisely over the identified location. This was done to better visualize the parasites in situ, and was followed by routine necropsy as described above.

TABLE 1 Summary of necropsy and nasal swab results.

Number of infected dogs/total dogs	25/54
Number of infected foxes/total foxes	1/3
Total number of tongue worms (female, male)	128 (49, 79)
Number of tongue worms per dog, range (median)	1–21 (3)
Number of dogs positive on nasal swab (egg number range per nasal cavity)	7 (0–67)

3 | RESULTS

3.1 | Necropsy examination and nasal egg swab findings

A total of 54 canid and 3 vulpid cadaver heads were examined by CT and necropsy: 37 from south-eastern NSW, 3 from the ACT, and 17 from northern NSW. Twenty-five of 54 dogs and 1 of 3 foxes were found to be infected with tongue worms at necropsy, with a total of 128 parasites retrieved (Table 1). All infected cadavers were from south-eastern NSW and the ACT. Nasal swabs were positive in 7 of 25 infected dogs; no eggs were recovered from the infected fox. Egg numbers per nasal vestibule ranged from 0 to 12 in six dogs and 67 in one dog (Table 1). Six of the egg-negative dogs had male-only infections.

3.2 | CT characteristics of tongue worms ex situ

Female tongue worms were visible using bone and soft tissue algorithms in both bone and soft tissue windows. Male tongue worms were, however, not detectable in the soft tissue window when the soft tissue algorithm was used. Tongue worms have dorsoventrally flattened bodies with narrower and rounder posterior ends. The body shapes ranged from saucer- to crescent-shaped to oval when viewed transversely (Figure 1).

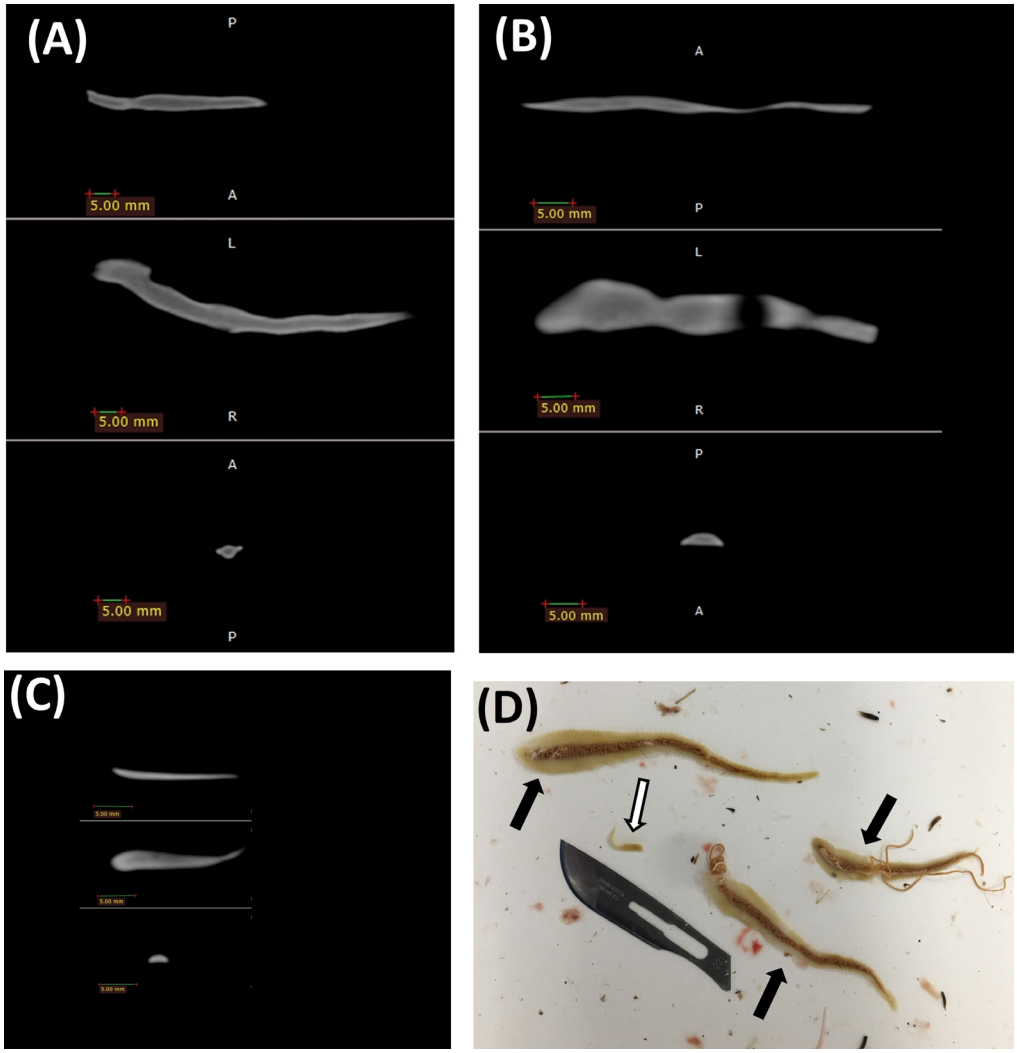

FIGURE 1 Bone window CT images of two female tongue worms (A and B) and a male tongue worm (C). Sagittal, dorsal, and transverse views are included, from top to bottom, respectively. The transverse views are obtained at the cranial third of the body. Note: Only part of the female tongue worms are visible in the sagittal and dorsal planes due to the body's undulation. D, Photograph of tongue worms retrieved at necropsy, for comparison. Black arrows, female tongue worms; white arrow, male tongue worms. A No. 22 scalpel (length = 5.5 cm) has been included for scale.

TABLE 2 CT imaging findings of tongue worm ex situ.

Tongue worm	Female 1	Female 2	Male
Size (L × H[a] × W[a])	80 × 3.4 × 6.2 mm	43 × 1.8 × 1.8 mm	16.5 x 0.8 × 2.4 mm
Average attenuation (HU)	Exterior: 364 Interior: Head: 10 Mid body: 140 Posterior end: 492	Exterior: 377 Interior: 178	375

Abbreviations: H, height; HU, Hounsfield units; L, length; W, width.
[a]Measured at head; widest part of the body.

Females were mildly heterogeneous in attenuation with a thin (up to 1 mm thick) mineral attenuating rim (see Table 2). Internally, Female 1 (larger female) ranged from an average of 10 HU at the head to 140 HU at the midbody and 492 HU at the posterior end. Female 2 (smaller) was generally denser (average of 178 HU), with no clear difference noted between the head and the body. The male tongue worm was relatively homogeneous, with an overall average attenuation of 375 HU; no difference was seen between its interior and exterior.

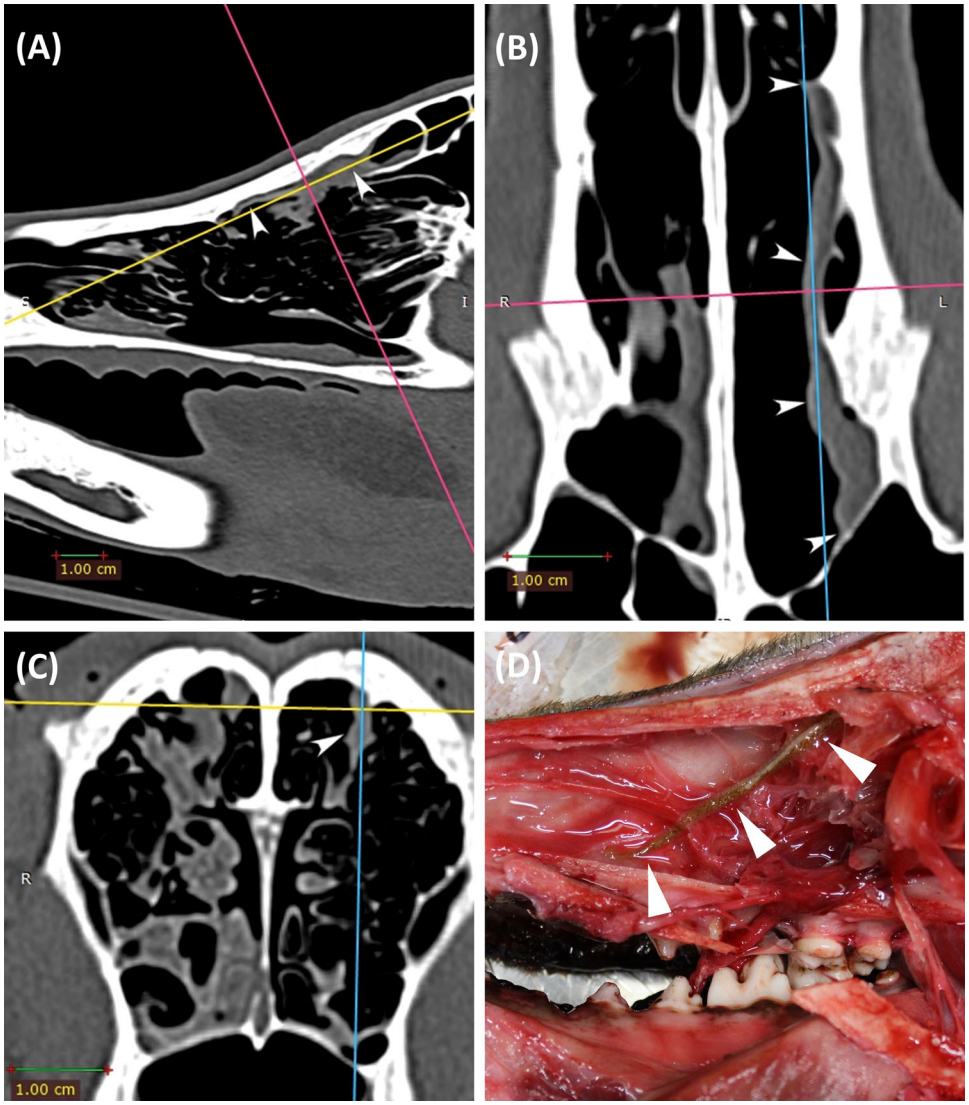

FIGURE 2 Sagittal (A), dorsal (B), and transverse (C) bone window CT images of the head, with the image axis aligned with the dorsal aspect of the frontal bone/body of the tongue worm. White arrows point to the female tongueworm. Note: A second female tongue worm is partially visible in the right nasal cavity in B and C. D, Female tongue worm photographed in situ (white arrows) in the same dog, following removal of the nasal turbinates. Note: The tongue worm had been pulled with forceps slightly rostrally and ventrally prior to the photograph, and the photograph was flipped to the orientation of the sagittal CT image.

3.3 | CT findings in the canid cadavers

Six of the infected dogs and the infected fox had no nasal cavity ballistic damage, seven had mild damage, and 12 infected dogs had marked ballistic damage; the latter were excluded from imaging analysis.

3.3.1 | CT identification of tongue worms in dogs with no nasal cavity ballistic damage

A total of nine structures consistent with the appearance and attenuation of female tongue worms were identified using CT in 4 of 6 infected dogs and in 1 of 1 infected fox (see Figures 2 and 3). Male tongue worms or small immature females could not be observed clearly on CT in any of the cadavers. The structures consistent with adult female tongue worms ranged from 2.6 to 5.2 cm long and varied in attenuation from an average of 66 to 144 HU internally and 262 to 350 HU externally (refer to Table 1, S1). They were not clearly distinguishable from nasal fluid or nasal turbinates, due to being of similar HU. The main identifying feature of the adult female tongue worm was its elongated form, which was much longer than that of any accumulated nasal fluid. The thin mineral attenuating rim of the females was visible but was subtle and of similar thickness and density to the surrounding nasal turbinates (attenuation of nasal turbinates ranged from 50 to 800 HU).

All identified female tongue worms were located within the dorsal aspect of the mid to caudal nasal cavities and sometimes extended to the ventral third (in the fox and one dog). Three tongue worms appeared to extend into the rostral aspect of the frontal sinuses.

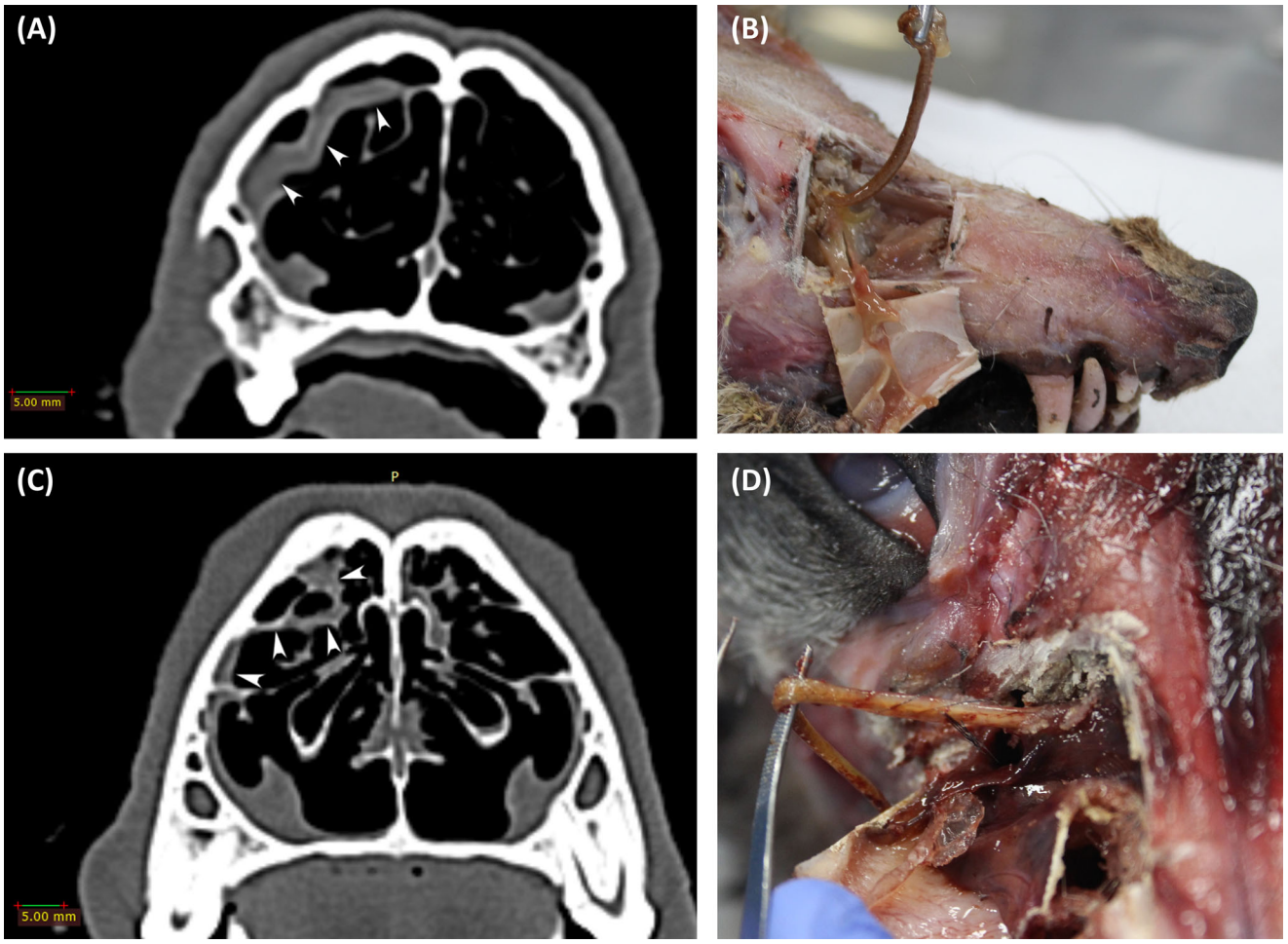

FIGURE 3 A and C, Transverse bone window CT images of the head of a fox and a dog, respectively. A female tongue worm (white arrows) was present in the mid-to-caudal right nasal cavity of both animals, confirmed at necropsy. B and D, Photographs taken at necropsy following osteotomies at these sites, showing the female tongue worms being retrieved. For the CT images, the left is on the right.

Multiplanar reconstruction was required to detect the female tongue worms due to their undulations between the nasal turbinates. In three canid cadavers, the tongue worms were rostro-caudally orientated and most clearly visible in the dorsal plane when the image axis was parallel to the dorsal aspect of the frontal bone (Figure 2). In the fox and a smaller canid head, the female tongue worms were more vertically orientated and most clearly seen in the transverse plane (Figure 3). The two image evaluators preferred the bone window over the soft tissue window for parasite identification.

At necropsy, the four canine and one vulpid cadavers were confirmed to be infected with a total of 21 tongue worms: 13 females and 8 males. In the other two infected dogs, no structures consistent with tongue worms were seen on CT, but at necropsy, two males and a small female tongue worm were retrieved. The female tongue worms ranged in length from 4 to 9 cm; the shorter measurements obtained on CT would be explained by the folded nature of the tongue worms in the nasal turbinates. The males ranged from 14 to 22 mm in length. In regard to the five female tongue worms that were not seen on CT, some of them were found adjacent to one another at necropsy and were likely not distinguishable in CT slices due to border effacement with one another (Figure 4A) or with a small amount of surrounding nasal mucus/exudate.

All infected dogs and the fox had scant to mild fluid to soft tissue attenuating material within their nasal cavities. The material was often bilateral and within the caudal nasal cavities. Four dogs had nil to scant amounts of fluid attenuating material within their frontal sinuses. The other two dogs had unilateral ballistic damage to the frontal sinuses with a mild amount of fluid/soft tissue attenuating material present. No turbinate destruction or paranasal bone lysis was observed in any of the heads.

3.3.2 | CT identification of tongue worms in dogs with mild nasal ballistic damage

All infected dogs with mild nasal ballistic damage had a moderate amount of fluid attenuating material within their nasal cavities, hindering tongue worm visualization (Figure 5D). Only one structure consistent with a female tongue worm was identified in the caudo-dorsal nasal cavity of one dog. Necropsy confirmed the presence of a

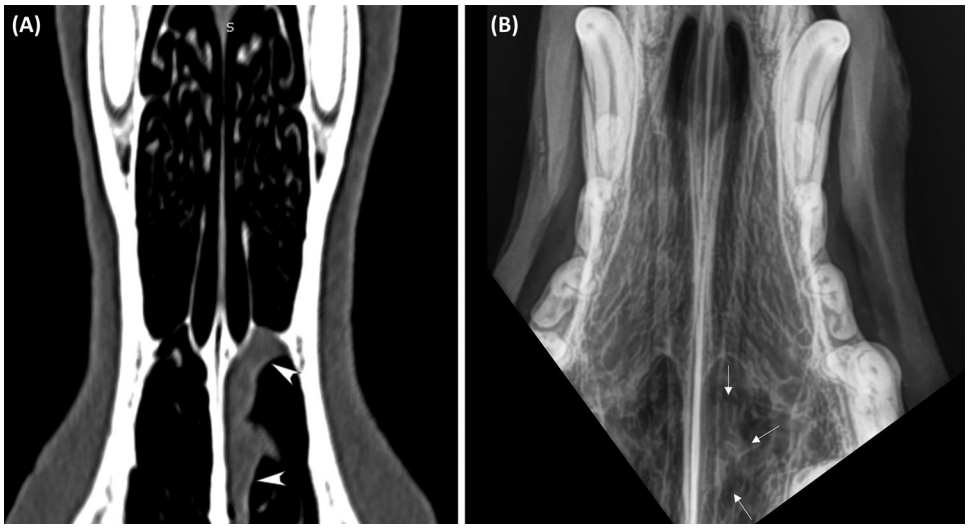

FIGURE 4 Dorsal (A) bone-window CT image and intraoral DV radiograph (B) of the nasal cavities of the same dog. Arrows point to a female tongue worm; the radiograph shows a mild increased soft tissue opacity. Note: A second female tongue worm was suspected to be border effacing with its mid aspect. The Left is on the right.

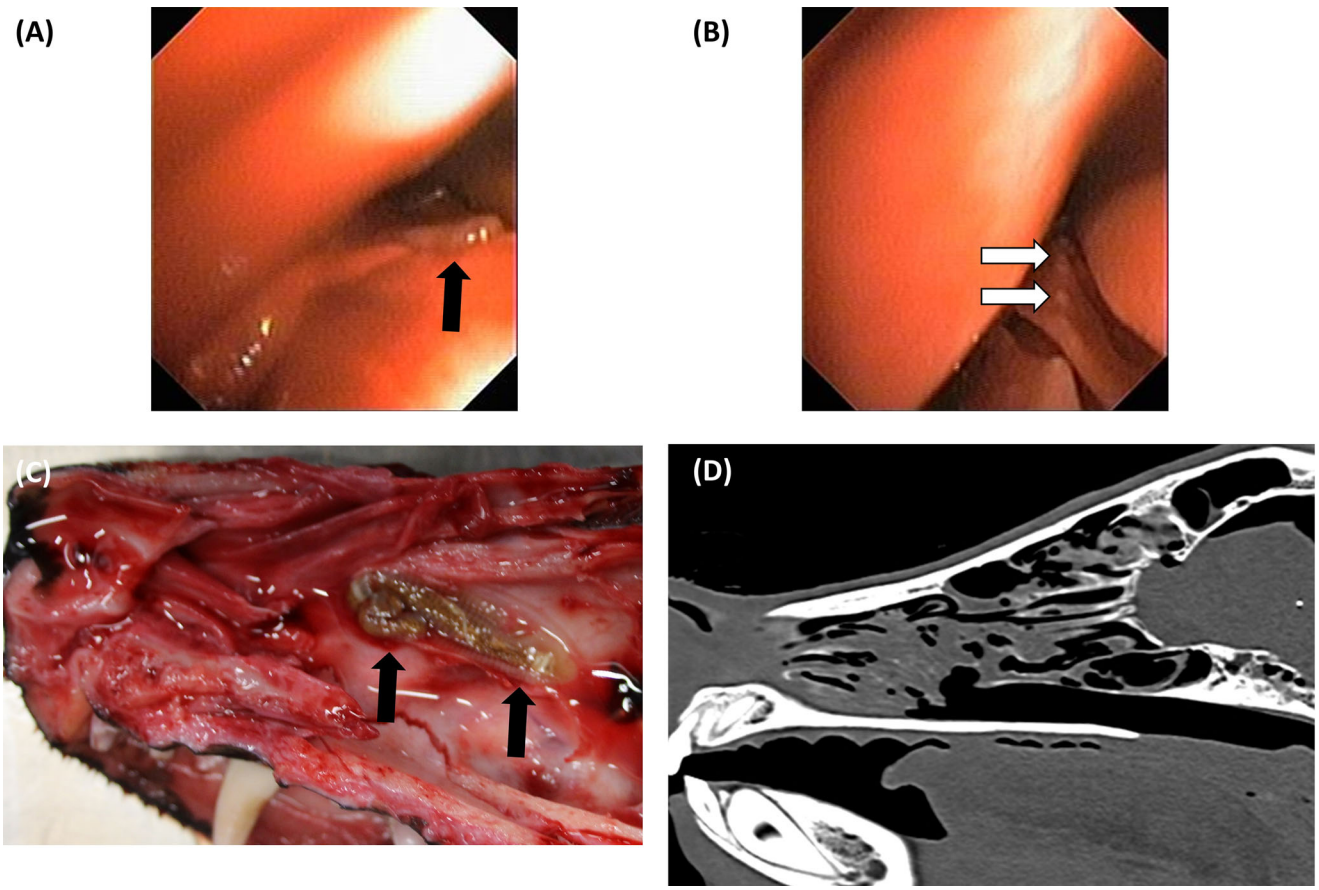

FIGURE 5 A and B, Rhinoscopy images of the left nasal cavity of an infected cadaver, showing the posterior end of a large female tongue worm (arrow, A) and small focal nodules in the adjacent mucosa (arrows, B). C, A female tongue worm was confirmed at this location at necropsy (arrow). D, Sagittal bone window CT image of the same dog. This cadaver had mild nasal ballistic damage and a moderate amount of nasal fluid; the tongue worm border was effaced with the fluid and was not visible. Note: Necropsy photograph flipped to the orientation of the sagittal CT image.

further 15 tongue worms (six female and nine male) in these dogs, with one female in the nasopharynx and the others in the nasal cavities.

3.4 | Radiology findings of the infected dogs

In the four dogs and the one fox that had female tongue worms identified on CT, subtle findings were identified using plain radiography in one dog and in the fox. In these cadavers, a focal, longitudinal area of soft tissue opacity was seen on the intraoral DV view at the level of the fourth maxillary premolars that corresponded to a female tongue worm on CT (Figure 4).

3.5 | Rhinoscopic findings

Twelve infected dogs and one fox were examined rhinoscopically. Examination in the fox was limited by the small size of the nares; only the right nasal cavity was able to be examined and no tongue worms were identified. In the dogs, only one female tongue worm was visualised on rhinoscopy and confirmed by later dissection. This dog had small mucosal nodules just the rostral of the identified tongue worm (Figure 5). Similar small mucosal nodules were noted on endoscopy in six of the infected dogs.

4 | DISCUSSION

The primary objective of this study was to determine whether CT was useful for diagnosing nasal linguatulosis in dogs. Further objectives were to document the radiological characteristics of linguatulosis and to evaluate the diagnostic value of rhinoscopy and nasal swabs for tongue worm eggs. The results of the study partly supported the hypothesis, with adult female tongue worms visible on CT when there was minimal nasal fluid present. Male tongue worms and small immature female tongue worms were not detectable. Radiological findings of linguatulosis were mild and nonspecific. Rhinoscopy and superficial nasal swabs subjected to flotation were found to be relatively insensitive methods for diagnosing tongue worms.

There are few reports documenting the CT features of intranasal parasites. *Eucoleus boehmi* (Nematoda: Capillariidae) infection was described in two canine case reports, with CT findings consistent with rhinitis. The nematodes, which are approximately 15–30 mm long, were not visible on CT and were subsequently diagnosed by rhinoscopy.[24,25] CT characteristics of nasal myiasis have been described in people,[26,27] deer,[28] and camels.[29] Larvae were observed as multifocal fluid to soft tissue attenuations. Badawy and Elmadawy[29] concluded in camels that whilst nasal myiasis may be confused with nonspecific rhinitis on CT, a distinguishing feature was that nasal myiasis commonly occurred in the ventral nasal concha whereas nonspecific rhinitis was generally diffuse.

In our study, adult female tongue worms were evident using CT when there was minimal nasal fluid around them. A main identifying feature was their elongated form, which was often seen spanning and folding between the nasal turbinates in the caudodorsal nasal cavity. Multiplanar reconstruction was required to appreciate the elongated structures, which is not dissimilar to identifying some intranasal foreign bodies.[30] The primary author generally found it helpful to align the image axis with the dorsal aspect of the frontal bone when visualizing rostrocaudally directed parasites. In the fox and a smaller canid head, the parasites were more vertically orientated, and the transverse plane was most useful. If the tongue worms are coiled and not "stretched out," they could be confused with focal nasal fluid or soft tissue attenuating material. Male tongue worms and immature females were not identified on CT due to their small size, and it was not possible to distinguish them from focal areas of nasal exudate.

Adult female tongue worms ranged in density from fluid (10 HU) to soft tissue to mineral (up to 492 HU) and were surrounded by a thin, mineral-attenuating rim; their chitinous exoskeleton likely explains the latter.[31,32] Male tongue worms were more homogeneous and had a higher density overall, possibly related to volume averaging associated with their small size. Tongue worms were border-effaced by nasal fluid and nasal turbinates. Differentiating between structures of a similar density is a limitation of CT and explains why the tongue worms were not always visible.[33]

The infected dogs all had a small amount of fluid to soft tissue attenuating material in their nasal cavities, particularly caudally. This may reflect a combination of rhinitis and postmortem change. The general CT characteristics of linguatulosis were benign, with no evidence of destructive or invasive disease. Possible differential diagnoses for nasal linguatulosis are nonspecific rhinitis, foreign body rhinitis, and other intranasal parasites (such as nasal myiasis[34] and nasal leeches[35]). Features helpful for prioritizing linguatulosis in the differential diagnosis include: (1) history: dogs from an environment where the parasite is endemic and/or they have the opportunity to ingest it (2) location of the pathological process: predominantly in the mid- and caudal nasal cavities; and (3) presence of mature female tongue worms: visible as long, undulating, tubular structures on CT. In comparison, nonspecific rhinitis tends to be diffuse, and chronic foreign-body rhinitis is typically unilateral; furthermore, focal turbinate destruction may be noted around the foreign body.[30,33]

The pathological changes that occur with linguatulosis in dogs are described in only a few publications and have ranged from no change to mild changes and to multifocal regions of mucosal hemorrhage, ulceration, and inflammation.[4,22,36,37] Interestingly, in a canine case of nasal carcinoma, *L. serrata* nymphs were found within the neoplastic mass and were surrounded by cystic structures, granulomatous nodules, and fibrous tissue.[38] It was postulated that the neoplasm occurred secondary to a severe inflammatory reaction to the nymphs. The association between chronic inflammation and neoplasia is well documented,[39] such as fracture-associated sarcomas in dogs,[40] injection site sarcomas in cats,[41] and *Spirocerca lupi* (Nematoda: Spirocercidae) induced oesophageal neoplasia in dogs.[42]

Histopathological findings of nasal linguatulosis have been described in a small number of wild canids in Australia.[22] All five dogs had large amounts of mucus within their nasal cavities, and

one had multifocal mucosal erosions and hemorrhage. The foci were well-defined, expanded the interstitium and submucosa, and resembled small polyps; some were considered to reflect prior parasite attachment sites. A limitation was that cadavers had been frozen and thawed, which is known to degrade tissue architecture.[43] In the current study, small mucosal nodules were observed endoscopically in seven of the infected dogs, possibly reflecting the aforementioned pathological changes. However, histopathology was not performed, as it was logistically not possible to obtain fresh samples.

Only one tongue worm was identified using rhinoscopy of the 12 infected dogs examined. The low detection rate was likely explained by the location of the large female tongue worms in the caudal nasal cavity and nasal fluid, and postmortem change hindered their visibility. Additionally, a more thorough rhinoscopic examination would be possible using a smaller rhinoscope than the one used. Tongue worm eggs were identified on nasal swabs in 7 of 25 infected dogs, which is likely due to intermittent egg shedding and some having male-only infections.[6,19]

This study has several limitations. Feral canids and vulpids from tongue worm endemic areas were utilized; the authors suspect undiagnosed cases occasionally occur in rural domestic working dogs and dogs used for pig hunting in south-eastern Australia. The subjects had been euthanized by gunshot, and only a small number of animals had no nasal cavity ballistic damage. Not all tongue worms could be visualized in situ at necropsy, which meant direct comparison with CT findings was not always possible. Reviewing CT scans prior to necropsy and performing targeted osteotomies proved a better method for visualizing female tongue worms in situ (this was done in the last cadaver group). Necropsy changes and freeze-thawing would have contributed to some nasal fluid, and fluid associated with rhinitis may also have drained out during the thawing process. Therefore, no strong conclusions could be made about the associated rhinitis/rhinosinusitis. Also, the freeze and thawing process may have reduced the number of eggs retrieved by nasal swabs. Tongue worms have been known to leave the nasal cavity after euthanasia,[44] and thus, more tongue worms may have originally been present in the cadavers.

Further studies are required to assess the CT characteristics of linguatulosis. Imaging live dogs is necessary because it avoids the problems of postmortem changes and ballistic damage. It also enables contrast CT to be performed, which may highlight nasal/paranasal pathology and be useful for detecting tongue worm-induced esophageal granulomas.[13] Studies on the diagnostic value of rhinoscopy for nasal linguatulosis in live dogs, are also warranted. Vigorous nasal flushing under general anesthesia could be a means of retrieving more eggs and possibly small and large tongue worms.

In conclusion, this is the first study reporting on the CT findings of intranasal tongue worms in wild canids and vulpids. CT proved useful for detecting adult female tongue worms in nasal cavities with minimal fluid. Male tongue worms and immature females were not detectable; therefore, negative imaging findings cannot exclude infection in at-risk dogs. Rhinoscopy and nasal egg swabs were relatively insensitive, but combined with nasal washings, they may be a useful diagnostic tool for nasal linguatulosis.

LIST OF AUTHOR CONTRIBUTIONS

Category 1

(a) Conception and design: Birckhead, Jenkins, Malik, Carstens, Shamsi
(b) Acquisition of data: Birckhead, Jenkins
(c) Analysis and interpretation of data: Birckhead, Carstens

Category 2

(a) Drafting the article: Birckhead
(b) Reviewing article for intellectual content: Birckhead, Jenkins, Shamsi, Malik, Carstens

Category 3

(a) Final approval of the completed article: Birckhead, Jenkins, Shamsi, Malik, Carstens

ACKNOWLEDGEMENTS

The authors thank Kelsey Jensen for performing the CT and radiographic examinations, Dr. Diane Barton for helping with the initial necropsies, and Cassie Hartshorn and Natalie McCaig for assisting with the rhinoscopy. The authors also thank the vertebrate control officers of the North Coast and South East NSW Local Lands Services for collecting the fox and wild dog heads used in this study. We also acknowledge the funding support received from the Australian Government Research Training Program Scholarship.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data used in this study are available from the corresponding author upon reasonable request.

PREVIOUS PRESENTATION OR PUBLICATION DISCLOSURE

The preliminary research findings were presented at the HDR & Honours Symposium, Charles Sturt University, 2023. An abstract was presented at ANZCVS Science Week, 2024.

REPORTING CHECKLIST DISCLOSURE

No EQUATOR network checklist or other reporting checklist was used.

ORCID

Alice Birckhead https://orcid.org/0009-0002-5644-4236
Ann Carstens https://orcid.org/0000-0002-2462-4323

REFERENCES

1. Tabaripour R, Keighobadi M, Sharifpour A, et al. Global status of neglected human *Linguatula* infection: a systematic review of published case reports. *Parasitol Res*. 2021;120(9):3045-3050. doi:10.1007/s00436-021-07272-y
2. Berberich M, Grochow T, Roßner N, et al. *Linguatula serrata* in an imported dog in Germany: single-case or emerging disease? *Vet Parasitol Reg Stud Reports*. 2022;30:100717. doi:10.1016/j.vprsr.2022.100717

3. Hajipour N, Tavassoli M. Prevalence and associated risk factors of *Linguatula serrata* infection in definitive and intermediate hosts in Iran and other countries: a systematic review. *Vet Parasitol Reg Stud Reports*. 2019;16:100288. doi:10.1016/j.vprsr.2019.100288
4. Oryan A, Sadjjadi SM, Mehrabani D, et al. The status of *Linguatula serrata* infection of stray dogs in Shiraz, Iran. *Comp Clin Pathol*. 2008;17(1):55-60. doi:10.1007/s00580-007-0707-x
5. Shamsi S, McSpadden K, Baker S, et al. Occurrence of tongue worm, *Linguatula cf. serrata* (Pentastomida: linguatulidae) in wild canids and livestock in south-eastern Australia. *Int J Parasitol Parasites Wildl*. 2017;6(3):271-277. doi:10.1016/j.ijppaw.2017.08.008
6. Macrelli M, Mackintosh A. Tongue worm (*Linguatula serrata*) infection in a dog imported into the United Kingdom from Romania. *Vet Rec Case Rep*. 2022;10(2):e281. doi:10.1002/vrc2.281
7. Mitchell S, Bell S, Wright I, et al. Tongue worm (*Linguatula* species) in stray dogs imported into the UK. *Vet Rec*. 2016;179(10):259-260. doi:10.1136/vr.i4829
8. Nagamori Y, Ramachandran A, Kuzma C, et al. A zoonotic parasite, *Linguatula serrata*, infection in a dog imported from Ethiopia to the United States. *Vet Parasitol Reg Stud Reports*. 2019;16:100273. doi:10.1016/j.vprsr.2019.100273
9. Sievänen M, Pohjoismäki J, Saari S, et al. The first *Linguatula serrata* case in an imported dog in Finland. *Vet Parasitol Reg Stud Rep*. 2021;26:100654. doi:10.1016/j.vprsr.2021.100654
10. Marchetti V, Macchioni F, Gori E, et al. *Linguatula serrata* (Pentastomida: linguatulidae) infection in a paucisymptomatic greyhound imported from Romania to Italy: a case report and literature overview. *Open Vet J*. 2023;13(8):1044-1055. doi:10.5455/OVJ.2023.v13.i8.12
11. Springer A, Fiedler H, Raue K, et al. *Linguatula serrata*-Befall bei einem importhund aus Rumänien. *Tieraerztliche Praxis Ausgabe K: Kleintiere-Heimtiere*. 2018;46(04):260-264. doi: 10.15654/TPK-170651
12. Thomas M. *Linguatula serrata* in an imported Romanian street dog. *Vet Rec*. 2018;182(4):112-113. doi:10.1136/vr.k356
13. Villedieu E, Sanchez RF, Jepson RE, et al. Nasal infestation by *Linguatula serrata* in a dog in the UK: a case report. *J Small Anim Pract*. 2017;58(3):183-186. doi:10.1111/jsap.12611
14. Dimzas D, Morelli S, Colombo M, et al. Unusual parasitoses in urban dogs: urinary capillariosis and linguatulosis, cases report. *Vet Parasitol Reg Stud Reports*. 2024;47:100949. doi:10.1016/j.vprsr.2023.100949
15. Campbell E, Jones A. Tongue worm in an untravelled dog in the UK. *Vet Rec*. 2023;192(8):337-338. doi:10.1002/vetr.2979
16. Barton DP, Porter M, Baker A, et al. First report of nymphs of the introduced pentastomid, *Linguatula serrata*, in red-necked wallabies (*Notamacropus rufogriseus*) in Australia. *Aust J Zool*. 2019;67(2):106-113. doi:10.1071/ZO20017
17. Shamsi S, Barton DP, Zhu X, et al. Characterisation of the tongue worm, *Linguatula serrata* (Pentastomida: linguatulidae), in Australia. *Int J Parasitol Parasites Wildl*. 2020;11:149-157. doi:10.1016/j.ijppaw.2020.01.010
18. Oluwasina OS, Thankgod OE, Augustine OO, et al. *Linguatula serrata* (Porocephalida: linguatulidae) infection among client-owned dogs in Jalingo, North Eastern Nigeria: prevalence and public health implications. *J Parasitol Res*. 2014;2014. doi:10.1155/2014/916120
19. Otranto D. Diagnostic challenges and the unwritten stories of dog and cat parasites. *Vet Parasitol*. 2015;212(1-2):54-61. doi:10.1016/j.vetpar.2015.06.002
20. Ioniță M, Mitrea IL. *Linguatula serrata* (Pentastomida: linguatulidae) infection in dog, Romania: a case report. *AgroLife Sci*. 2016;5(2):85-89.
21. Saunders JH, Van Bree H, Gielen I, et al. Diagnostic value of computed tomography in dogs with chronic nasal disease. *Vet Radiol Ultrasound*. 2003;44(4):409-413. doi:10.1111/j.1740-8261.2003.tb00477.x
22. Shamsi S, Loukopoulos P, McSpadden K, et al. Preliminary report of histopathology associated with infection with tongue worms in Australian dogs and cattle. *Parasitol Int*. 2018;67(5):597-600. doi:10.1016/j.parint.2018.05.011
23. Public Health Agency of Canada. Pathogen Safety Data Sheets: Infectious Substances—*Echinococcus granulosus*. 2011; Accessed 29 April 2022. https://www.canada.ca/en/public-health/services/laboratory-biosafety-biosecurity/pathogen-safety-data-sheets-risk-assessment/echinococcus-granulosus-pathogen-safety-data-sheet.html
24. Alho AM, Mouro S, Pissarra H, et al. First report of *Eucoleus boehmi* infection in a dog from Portugal. *Parasitol Res*. 2016;115(4):1721-1725. doi:10.1007/s00436-016-4932-6
25. Baan M, Kidder AC, Johnson SE, et al. Rhinoscopic diagnosis of *Eucoleus boehmi* infection in a dog. *J Am Anim Hosp Assoc*. 2011;47(1):60-63. doi:10.5326/JAAHA-MS-5707
26. Duque CS, Mosquera CA, Abreu CE. Radiologic findings in nasopharyngeal myiasis. *Otolaryngol Head Neck Surg*. 2004;131(2):272-273. doi:10.1016/j.otohns.2004.06.573
27. Duque CS, Mosquera CA, Casiano RR, et al. Radiologic findings in sinonasal myiasis. *Otolaryngol Head Neck Surg*. 2006;135(4):638-639. doi:10.1016/j.otohns.2005.04.012
28. Fidalgo LE, Lopez-Beceiro AM, Vila-Pastor M, et al. Use of computed tomography as a non-invasive method for diagnosing cephenemyiosis in roe deer (*Capreolus capreolus*). *Med Vet Entomol*. 2015;29(1):110-113. doi:10.1016/j.otohns.2004.06.57310.1111/mve.12087
29. Badawy AM, Elmadawy RS. Computed tomographic features of the camel nasal myiasis. *J Adv Vet Res*. 2015;5(2):47-52.
30. Moreno-Aguado B, Carrera I, Holdsworth A, et al. CT findings in 20 dogs and six cats with confirmed nasal foreign bodies. *Vet Radiol Ultrasound*. 2020;61(4):417-426. doi:10.1111/vru.12832
31. von Vaupel Klein C. *Treatise on zoology- anatomy, taxonomy, biology. The crustacea*. Brill; 2015;
32. Killiny N, Brodersen CR. Using x-ray micro-computed tomography to three-dimensionally visualize the foregut of the Glassy-Winged Sharpshooter (*Homalodisca vitripennis*). *Insects*. 2022;13(8):710. doi:10.3390/insects13080710
33. Lafuma F, Baudin Trehiou C, Bernardin F, et al. Computed tomography may be helpful in discriminating grass awn foreign body rhinitis from non-foreign body rhinitis in dogs. *Vet Radiol Ultrasound*. 2021;62(5):533-540. doi:10.1111/vru.12981
34. Heath AC, Johnston C. Nasal myiasis in a dog due to *Oestrus ovis* (Diptera: oestridae). *N Z Vet J*. 2001;49(4):164. doi:10.1080/00480169.2001.36226
35. Singh M, Kumar A, Kumar A, et al. Case report: endoscope-assisted bilateral nasal leech retrieval in a dog. *Front Vet Sci*. 2022;9:881581. doi:10.3389/fvets.2022.881581
36. Ehrenford FA, Newberne JW. An aid to clinical diagnosis of tongue worms (*Linguatula serrata*) in dogs. *Lab Anim Sci*. 1981;31(1):74-76.
37. Hajipour N, Tavassoli M, Eslamlo AA, et al. Investigation of histopathological changes caused by adult stage of *Linguatula serrata* in dog. *Comp Clin Pathol*. 2018;27(3):717-720. doi:10.1007/s00580-018-2656-y
38. Bordicchia M, Falcioni D, Scarpona S, et al. Nasal carcinoma in a dog with *Linguatula serrata* infection. *Vet Rec Case Rep*. 2014;2(1):e000015. doi:10.1136/vetreccr-2013-000015
39. Schottenfeld D, Beebe-Dimmer J. Chronic inflammation: a common and important factor in the pathogenesis of neoplasia. *CA Cancer J Clin*. 2006;56(2):69-83. doi:10.3322/canjclin.56.2.69
40. Morrison WB. Inflammation and cancer: a comparative view. *J Vet Intern Med*. 2012;26(1):18-31. doi:10.1111/j.1939-1676.2011.00836.x
41. Hartmann K, Day MJ, Thiry E, et al. Feline injection-site sarcoma: ABCD guidelines on prevention and management. *J Feline Med Surg*. 2015;17(7):606-613. doi:10.1177/1098612X15588451
42. Pazzi P, Kavkovsky A, Shipov A, et al. *Spirocerca lupi* induced oesophageal neoplasia: predictors of surgical outcome. *Vet Parasitol*. 2018;250:71-77. doi:10.1016/j.vetpar.2017.11.013

43. Baraibar MA, Schoning P. Effects of freezing and frozen storage on histological characteristics of canine tissues. *J Forensic Sci*. 1985;30(2):439-447.
44. Sinclair KB. The incidence and life cycle of *Linguatula serrata* (Frohlich 1789) in Great Britain. *J Comp Pathol*. 1954;64(4):371-383. doi:10.1016/s0368-1742(54)80038-5

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Birckhead A, Jenkins D, Shamsi S, Malik R, Carstens A. Intranasal *Linguatula serrata* (tongue worm) in canids and vulpids can be detected using computed tomography. *Vet Radiol Ultrasound*. 2024;65:793–803. https://doi.org/10.1111/vru.13428