Full Paper

Nematodes belonging to the genus *Ternidens* (Strongyloidea: Chabertiidae) found in a talapoin, *Miopithecus talapoin*, imported for sale as a pet

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ABSTRACT. Reexamination of preserved nematode specimens collected from a talapoin, *Miopithecus talapoin*, which died at a pet dealer in Tokyo, and tentatively classified as *Globocephalus* sp. revealed four female adults and one fourth-stage larva belonging to the genus *Ternidens* (Strongyloidea: Chabertiidae). The adults closely resembled *T. deminutus*, the only species currently recognized in the genus. A brief morphological description was made with a discussion on its possible transmission to humans from the pet monkeys. This is the first report of *Ternidens* from primates imported for sale as pets in Japan.

KEY WORDS : *Miopithecus*, pet dealer, talapoin, *Ternidens*, zoonosis

Various primate species are reared for and kept as pets across Japan [8, 17]. These animals are close to humans phylogenetically and thus share many zoonotic pathogens with us, including helminth parasites. Yokoyama et al. [19] reported helminth parasites collected from 96 individual primates, belonging to 22 species of 5 families, which were imported to Japan as pets but died at pet dealers. The study reported 7 nematode, 1 trematode, 1 acanthocephalan and 1 pentastome species from 14 talapoins (*Miopithecus talapoin*). Among the nematodes reported in Yokoyama et al. [19], *Globocephalus* sp. was collected from 2 talapoins. Recently, we reexamined the preserved material from one of the two talapoins and realized that it was misclassified and should be assigned to the genus *Ternidens*. Material from the other talapoin could not be retrieved for analysis. Because many human infections with *Ternidens deminutus* – the only species within the genus – have been reported, we present a morphological description of these nematodes in the current manuscript to call attention to the potential veterinary and public health risks associated with infection.

MATERIALS AND METHODS

Nematodes collected from one talapoin and preserved in the Wild Animal Medical Center (WAMC), Rakuno Gakuen University (Accession No. As2565) were reexamined in this study. The talapoin was wild-caught and imported to Japan to be sold as a pet, but details such as its country of origin, duration of captivity, etc., were not available. Its carcass was frozen and transported to WAMC, where a necropsy was performed in July 2002. The methods of necropsy and collection of parasites are reported elsewhere [19]. Among the nematodes collected, those with a large buccal capsule comparable with that of *Globocephalus* were selected, cleared in a glycerol-ethanol solution by evaporating ethanol, and mounted on a glass slide with a 50% glycerol aqueous solution. They were observed under an Olympus BX50 microscope equipped with a differential interference contrast. The head of one fragmented worm was severed for en face observation.

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RESULTS

Four individuals with large buccal capsules were recognized among the examined material. They were all females and two of them were gravid while the remaining two were devoid of eggs in their uteri. One of the gravid females was fragmented, lacking its posterior body. In addition to these adult worms, one fourth-stage larva was also found.

Description

Ternidens* cf. *deminutus

(Nematoda: Strongyloidea: Chabertiidae: Chabertiinae)

(Figs. 1-3)

Adult (4 females): Body slender. Cephalic end tilted dorsally (Figs. 1A, 2B). Cuticle ornamented with transverse striations. Lateral alae absent. Cephalic end ellipsoidal, dorso-ventrally elongated, in apical view (Figs. 1B, 2A). Cephalic diameter narrower than cervical region (Figs. 1A, 1D, 2B). Corona radiata present: external circle composed of 24 to 26 elements (n=2); development of internal circle weak (Figs. 1B, 2A). Four cephalic papillae and two lateral amphids present (Figs. 1B, 2A). Buccal capsule thick-walled, connected to esophageal funnel (Figs. 1D, 1E, 2B). Three large tripartite esophageal teeth projecting into the buccal lumen from esophageal funnel being located in subdorsal and ventral positions; each tooth seen as Greek letter 'ω' (omega) when viewed apically (Figs. 1C-1E, 2B). Esophagus club-shaped, with thickest portion near posterior end, extending into intestine forming valve (Fig. 1A). Cervical groove present on ventral side at level of esophageal funnel, and excretory canal opening to it (Figs. 1A, 1D, 1E). Nerve ring located at junction between anterior and middle 1/3 of esophagus (Fig. 1A). Deirids minute, near level of nerve ring. Vulva located slightly anterior to anus (Fig. 1F). Ovejector developed, paired, opposed at origin then posterior arm turned anteriorly (Fig. 2C). Tail long conical, ending in dull tip (Fig. 1F). Uterine eggs ellipsoidal, thin-shelled. Measurements are compared with previous data in Table 1.

Table 1. Morphometric comparison of adult female *Ternidens* collected from primates (in mm unless otherwise stated).

Species Host Locality Source	*T.* cf. *deminutus* *Miopithecus talapoin* Japan Present worms	*T. deminutus* *Gorilla gorilla* Africa Railliet and Henry (1905) [13]	*T. deminutus* *Cercopithecus cephus*, etc. Republic of the Congo Diaouré (1964) [4]	*T. simiae* Unidentified monkey Sulawesi (Indonesia) Yamaguti (1954) [18]
Worm length	6.48-7.09	11.7	8.5-11.9	9.9-10.5
Width in midbody	0.22-0.31	0.65	0.48-0.60	0.42
Cephalic diameter	0.15-0.16		0.14-0.17	0.18
No. external corona radiata elements	24-26	22	20-23	23-24
Buccal capsule length	0.16-0.17		0.21	0.15
Buccal capsule width	0.17-0.18		0.17	0.174-0.18
Esophageal teeth length, μm	81-100		85	90-100
Esophagus length	0.62-0.65	0.86	0.72	0.77-0.81
Esophagus width	0.12-0.17	0.25	0.26	0.20-0.24
Nerve ring*	0.34-0.38		0.42	0.39
Deirids*	0.35-0.38		0.42	0.56
Ventral groove/ excretory pore*	0.18-0.21		0.22	0.25
Vulva**	0.58-0.75	0.68	0.62	0.53-0.61
Anus**	0.23-0.24	0.27	0.22	0.25
Eggs, μm	55-63 × 30-38	60-65 × 38-40	62-72 × 36-40	69-78 × 36-45

* Distance from cephalic extremity. ** Distance from caudal extremity.

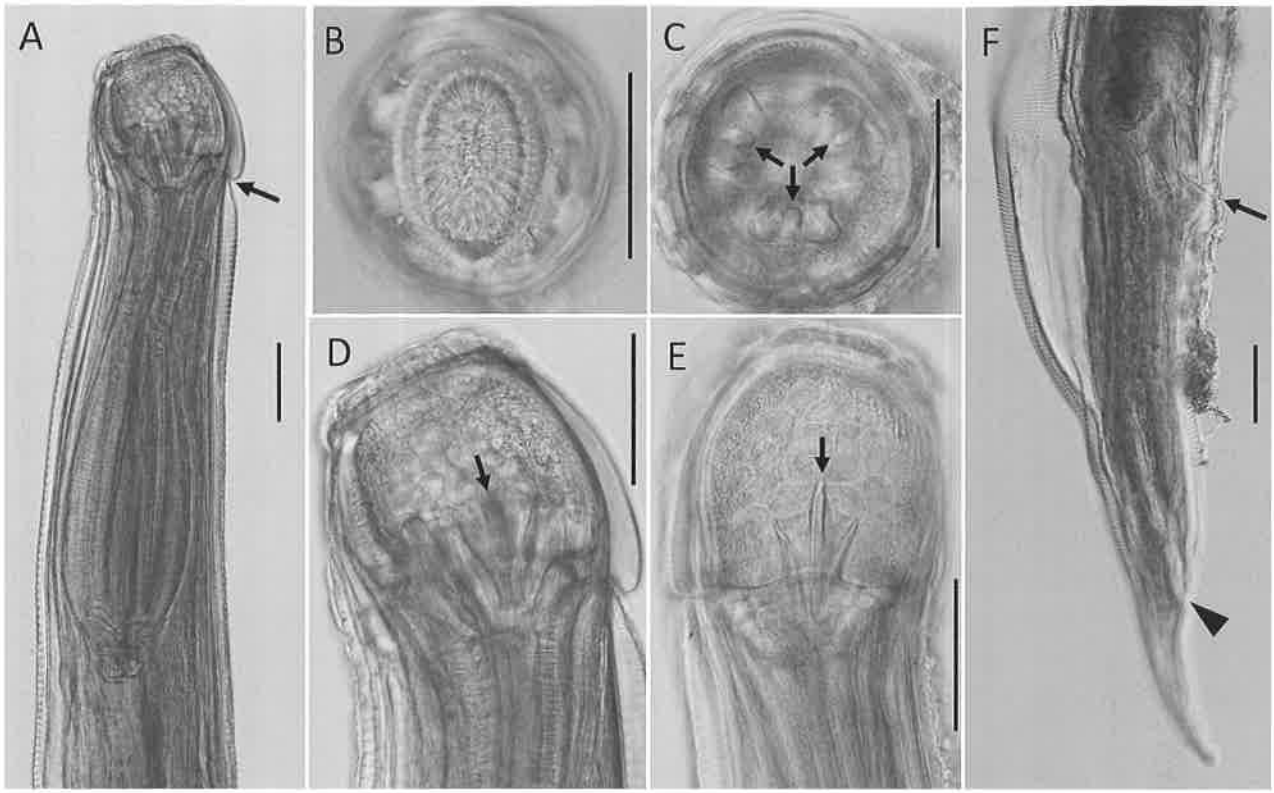

Fig. 1. Female *Ternidens* cf. *deminutus* collected from a talapoin imported to be sold as a pet in Japan. A: Anterior end, right lateral view. Arrow indicates position of excretory pore. B–E: Cephalic extremity, apical views showing corona radiata of mouth (B) and teeth (arrows) at bottom of buccal capsule (C); right lateral (D) and ventral (E) views showing tricuspid teeth (arrows). F: Posterior end, right lateral view, showing vulva (arrow) and anus (arrowhead). Scale bar: 100 μm.

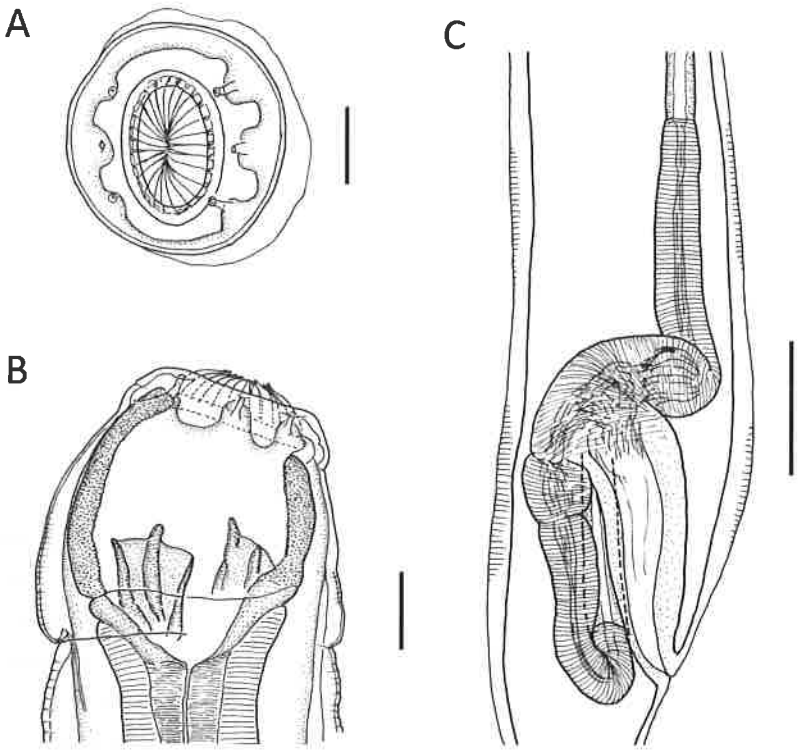

Fig. 2. Line drawings of female *Ternidens* cf. *deminutus* collected from a talapoin imported to be sold as a pet in Japan. A, B: Cephalic extremity, apical (A) and left lateral (B) views. C: Ovejector, right lateral view. Scale bars: 50 μm for A and B; 100 μm for C.

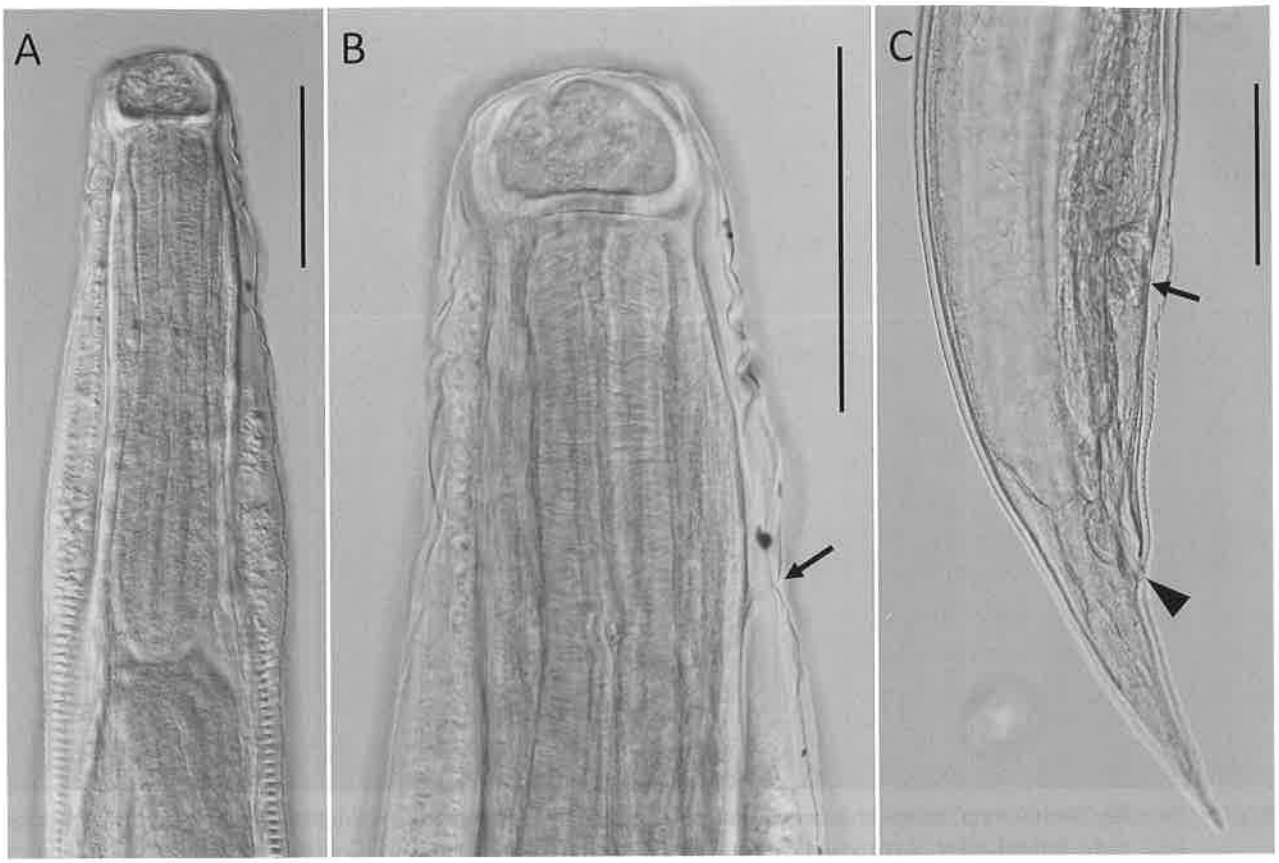

Fig. 3. Female fourth-stage larva of *Ternidens* cf. *deminutus* collected from a talapoin imported to be sold as a pet in Japan. A: Anterior end, right lateral view. B: Magnified view of anterior end. Arrow indicates position of excretory pore. C: Posterior end, right lateral view, showing primordial vulva (arrow) and anus (arrowhead). Scale bar: 100 μm.

Fourth-stage larva (1 female): Body slender, tapering to both extremities. Length 3.5 mm, width 135 μm. Cuticle striated transversely. Cephalic extremity slightly tilted dorsally (Figs. 3A, 3B) Cephalic diameter 71 μm. Buccal capsule developed, simple, 43 μm long by 65 μm wide (Figs. 3A, 3B). Esophagus club-shaped, lacking funnel and teeth (Figs. 3A, 3B). Nerve ring 170 μm and excretory pore 153 μm from cephalic extremity (Fig. 3B). Deirids not seen. Primordial vulva present under cuticle anterior to anus, 340 μm from caudal extremity (Fig. 3C). Tail long conical, 160 μm long (Fig. 3C).

Taxonomic summary

Host: *Miopithecus talapoin* (Schreber, 1774) (Primates: Cercopithecidae).

Site of infection: Intestine.

Locality: Tokyo, Japan.

Specimens deposited: Meguro Parasitological Museum, Tokyo, MPM Coll. No. 21467.

Remarks. In having a large globular buccal capsule, well-developed corona radiata and Type II ovejector, the present species is classified as a member of the subfamily Chabertiinae of the family Chabertiidae [11]. Within this subfamily, the worms could be assigned to the genus *Ternidens* Railliet et Henry, 1909 because the cephalic diameter is narrower than the cervical region, the buccal capsule has similar width and depth and the esophageal teeth are large and tripartite, projecting into the buccal cavity [11]. *Ternidens deminutus* (Railliet et Henry, 1905) is the type species of the genus [13]. Some additional species have been proposed for this genus. In 1954, *Ternidens simiae* Yamaguti, 1954 was described from a monkey (*Macaca* sp.?) in Celebes (Sulawesi) of Indonesia [18]. However, it was later synonymized with *T. deminutus* [4]. Today, it is generally regarded that *Ternidens* is a monotypic genus.

The morphology of the present worms generally coincided with that of *T. deminutus*. Although the measurements were generally smaller than those reported by the previous researchers (Table 1), this discrepancy could be due to the non-gravid state of half of the females examined here. The fragmented worm, of which the head was used for en face observation, also had slightly more numerous elements of the external corona radiata than those in previous reports (Table 1). The fourth-stage larvae of *T. deminutus* were previously recorded from nodules in the intestinal wall of *Macaca mulatta* but without description [2]. In the absence of male adult worms, as well as the lack of DNA sequence data, strict species identification is withheld in the present work.

DISCUSSION

Ternidens deminutus was first described based on specimens obtained by autopsy of a human on Mayotte, an island in the Mozambique Channel [13]. The worm was first assigned to the genus *Triodontophorus* but later transferred to a new genus, *Ternidens* [14]. Subsequently, this nematode was collected from various apes and monkeys, namely, chimpanzees (*Pan troglodytes*), western gorillas (*Gorilla gorilla gorilla*), baboons (*Papio* spp.), sooty mangabeys (*Cercocebus atys*), guenons (*Cercopithecus* spp.), grivets and vervet monkeys (*Chlorocebus* spp.) and macaques (*Macaca* spp.) of Africa and Asia including some Asian islands [3, 6]. However, the talapoin had not previously been recorded to be a host of *Ternidens* [3]. Human cases of *Ternidens* infection have been reported, mostly from South and Southeast Africa, especially from Zimbabwe and its neighboring countries where up to 87% prevalence was recorded in some communities in the 1970's [3, 5, 6]. In the definitive hosts, it inhabits the wall of the colon, producing ulcers and cystic nodules [3, 6]. Patients experience abdominal pain, and pseudotumors and abscesses were suspected clinically [3, 6]. *Ternidens* is also surmised to ingest host blood, causing anemia [3, 6]. Two cases of human infections were recorded in Suriname, South America, where *Ternidens* infection in nonhuman primates has not been recorded [9]. Recently, the first Asian case was diagnosed in Thailand based on the worm in pathological sections of an abscess attached to the terminal ileum [7]. However, the accuracy of this identification has been questioned [3].

In Japan, Tanaka et al. [16] obtained adults of *T. deminutus* from crab-eating macaques (*Macaca fascicularis*) reared at the Japan Monkey Center and gave a description of its eggs, but made no mention as to the morphology of the adults. Kagei and Asano [10] also recorded eggs of *Ternidens* sp. from 3 out of 10 chimpanzees imported for experimental use and observed infective larvae cultured using a filter paper technique from positive feces. However, the infective larvae they obtained differed from those of *T. deminutus* by having a spear-like structure at the cephalic end, a straight intestinal lumen and clear striations on the sheath [3, 6, 12]. As such, it seems that their worms were actually *Necator*. The present case may be the first demonstration of *Ternidens* from monkeys to be sold as pets in Japan. The import of monkeys for the pet trade was prohibited in Japan from 2005 by Article 54 of the Infectious Diseases Prevention Law. Nevertheless, some pet monkeys imported before 2005 may still survive today. Moreover, domestic-bred pet monkeys are also sold and reared [8, 17]. Because of low host specificity and the zoonotic nature of *T. deminutus*, it may be necessary to survey the prevalence of this nematode in pet monkeys across Japan.

Diagnosis of *Ternidens* infection has traditionally been done by detection of eggs during fecal examination. The egg shape resembles that of the hookworm eggs, but is slightly larger (70–90 × 40–60 μm) [6]. However, smaller size has been also recorded (see Table 1) and hence it may be difficult to identify *T. deminutus* eggs by the size alone. Tanaka et al. [16] stated that the eggs of *T. deminutus* were 'irregularly elliptical' and one pole was more pointed than the other. Nevertheless, such differences in pole shape have not been reported by other researchers [3, 6]. It is probable that this discrepancy is due to the fact that the eggs were collected from the uterus by Tanaka et al. [16]. The third-stage larvae raised in fecal culture provide clearer diagnostic characteristics, such as the zigzagged lumen of the intestine and the elongated sphincter cells between the posterior end of the esophagus and the intestine [12]. It has also been demonstrated that the internal

transcribed spacer genes (ITS) of nuclear rDNA are suitable diagnostic markers of *T. deminutus* [15].

If a pet monkey harbors *Ternidens*, prevention of transmission to the pet owners may be necessary. However, the exact life history of *Ternidens* remains unknown [1]. It is apparent that the eggs hatch in moist soil and the larvae develop into the third-stage filariform larvae, which maintain the cuticle developed during the second-stage as a sheath [5]. Nevertheless, the mode of infection remains unknown. Attempts to infect baboons and human volunteers through ingestion of filariform larvae or cutaneous inoculation made during the 1920's and 1930's were unsuccessful [see 1, 3, 6]. The involvement of some terrestrial invertebrates, such as termites, acting as paratenic hosts has been suggested but has not yet been demonstrated [1, 3]. Thus, further studies on the life histories of *Ternidens* are required.

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ペット用に輸入されたタラポアンから得られた *Ternidens* 属線虫（円虫上科：シャベルティア科）

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要約：輸入され、東京の動物商で飼育されていたペット用のサル、タラポアン *Miopithecus talapoin*（霊長目：オナガザル科）が死亡し、その剖検により得られ、暫定的に *Globocephalus* sp. とされていた線虫について再検討したところ、*Ternidens* 属（円虫上科：シャベルティア科）の雌成虫と雌4期幼虫であることが示された。成虫は現在本属で唯一認められている *T. deminutus* に近似していた。虫体の形態を記載し、本種がペットのサルから人に感染する可能性について考察した。わが国においてペット用のサルから *Ternidens* が検出されたのはこれが初例である。
キーワード：人獣共通感染症、タラポアン、*Ternidens*、ペット、*Miopithecus*