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Commensal Brown Rat *(Rattus norvegicus)* as a carrier of potential zoonotic parasites in the urban area of Bosnia and Herzegovina

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Summary

Commensal rats are highly adaptable to coexisting with human populations, often relying on human dwellings and immediate access to food, water, shelter and space. We present the case of an adult commensal brown rat, *Rattus norvegicus*, that was found in an urban area of Sarajevo (Bosnia and Herzegovina). Histopathological examination revealed numerous eggs of *Calodium hepaticum* in the liver parenchyma and coprological examination identified species of the class Cestoda (*Rodentolepis* spp., *Hymenolepis diminuta*) and the class Nematoda (*Trichuris muris, Nippostrongylus brasiliensis* and *Strongyloides ratti*). Haematological parameter analysis was conducted using the “Idexx ProCyte Dx” cell counter and biochemical parameters of the rat's serum were tested. Haematocrit, haemoglobin content and erythrocyte indices (MCV, MCH) were decreased and moderate quantities of spherocytes were present (4.95 %). The total number of leukocytes was within the physiological range, with minimally increased values of monocytes and neutrophils and decreased values of eosinophils. The results of the morphometric examinations were in the expected range for adult rats. This case report highlights the public health risk posed by commensal rats if systematic rodent control measures are not

Schlüsselwörter: kommensale Nagetiere, Sarajevo, Helminthen, Zoonosen.

Zusammenfassung

Die kommensale Wanderratte *(Rattus norvegicus)* als Überträger potenzieller zoonotischer Parasiten in einem Stadtgebiet von Bosnien und Herzegowina

Kommensale Ratten sind sehr anpassungsfähig und sind oft auf menschliche Behausungen und leichten Zugang zu Nahrung, Wasser, Unterkünften und mehr angewiesen. Im vorliegenden Fallbericht wird die Untersuchung einer ausgewachsenen kommensalen Wanderratte, *Rattus norvegicus*, die in einem städtischen Gebiet von Sarajevo (Bosnien und Herzegowina) gefunden worden war, beschrieben. Zahlreiche Eier von *Capillaria hepatica* wurden im Leberparenchym entdeckt. Bei den koproskopischen Untersuchung wurden Arten aus den Klassen Cestoda (*Rodentolepis* spp., *Hymenolepis diminuta*) und Nematoda (*Trichuris muris, Nippostrongylus brasiliensis* und *Strongyloides ratti*) nachgewiesen. Die Analyse der hämatologischen Parameter wurde mit dem Zellzähler "Idexx ProCyte Dx" durchgeführt und eine Analyse der biochemischen Parameter des Serums der untersuchten Ratte wurde vorgenommen. Hämokrit, Hämoglobingehalt und Erythrozytenindizes (MCV, MCH) waren vermindert, ebenso waren Sphärozyten (4,95 %) mäßig vorhanden.

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fully implemented. It should serve as a guide for future research on the population of commensal rats in the cities of Bosnia and Herzegovina, aimed at a detailed identification of parasitic zoonotic pathogens.

Abbreviations: ALP = alkaline phosphatase; ALT = alanine transaminase; GGT = gamma-glutamyl transferase; HCT = haematocrit; HE = haematoxylin and eosin; MCV = mean corpuscular volume; MCHC = mean corpuscular haemoglobin concentration; MHC = mean haemoglobin concentration; SEOV = Seoul orthohantavirus; TBIL = total serum bilirubin

Die Gesamtzahl der Leukozyten lag innerhalb der physiologischen Grenzen, mit minimal erhöhten Werten der Monozyten und Neutrophilen und verringerten Werten der Eosinophilen. Die Ergebnisse der morphometrischen Untersuchungen stimmten mit den Referenzwerten für ausgewachsene Ratten überein. Dieser Fallbericht verdeutlicht das Risiko für die öffentliche Gesundheit, das von kommensalen Ratten ausgeht, wenn systematische Maßnahmen zur Nagetierbekämpfung nicht vollständig umgesetzt werden. Die Ergebnisse dieses Fallberichts sollten letztendlich als Leitfaden für zukünftige Forschungsstudien zur Population kommensaler Ratten in den Städten von Bosnien und Herzegowina dienen, mit dem Ziel der weiteren detaillierten Identifizierung parasitärer Zoonoseerreger.

Introduction

Brown and black rats (*Rattus norvegicus* and *Rattus rattus*) are among the most widespread urban wildlife species (Himsworth et al. 2014; Blasdell et al. 2022). They perform several ecological tasks that are beneficial for the environment, including soil excavation, biotic recovery facilitation, insect control and seed and spore dispersal (Rabiee et al. 2018). However, they are also responsible for substantial economic damage in agricultural areas and represent a potential threat to human health due to their ability to transmit and spread zoonotic agents, such as viruses, bacteria and parasites (Easterbrook et al. 2007; Meerburg et al. 2009; Panti-May et al. 2015; Blasdell et al. 2022).

Livestock farms are frequently inhabited by commensal rats, which represent potential sources of infectious pathogens. The rats can pose risks to farm structures and animals, potentially leading to economic losses by damaging property and affecting livestock. The rodents find food and shelter on farms, especially during extremely cold or hot periods of the year (Berentsen et al. 2015; Ebani 2022). Poultry farms, in particular, are often targeted by rats, which spoil eggs, egg trays and poultry feed. The presence of rats also leads to decreased poultry productivity (Kandhwal 2009). Not only do rats cause high mortality rates, primarily by preying on young chicks, they also disrupt production by breaking and/or consuming eggs and by disturbing birds with their movements and noises (Rao & Sakthivel 2015).

Most major cities and towns in both high-income and low and middle-income countries are facing an increasing threat from rat populations. Wild rats have colonized urban ecosystems globally and their presence has become a danger, serving as the gateway for the emergence of up to 60 zoonotic diseases (Taylor et al. 2008; Fatima et al. 2018; Katica et al. 2019a). So-called commensal rats are highly adaptable to coexisting with human populations, often relying on human habitats and immediate access to food, water, shelter and space (Tung et al. 2013). Wild rats transmit infectious agents to humans and animals through direct contact and indirectly by contamination of food with urine, hairs and faeces (Islam et al. 2021). Commensal rats often carry bacterial pathogens known to cause acute gastroenteritis in humans, including atypical enteropathogenic *Escherichia coli, Clostridium difficile* and *Salmonella enterica enterica*, as well as agents of infections associated with undifferentiated febrile illnesses, such as *Bartonella* spp., *Streptobacillus moniliformis* and *Leptospira interrogans* (Firth et al. 2014).

Recent research (Castel et al. 2023) has confirmed the circulation of hantaviruses, including Seoul orthohantavirus (SEOV), in wild rat populations in West Africa, posing a potential zoonotic risk. The range of SEOV could rapidly expand and human transmission may increase due to the shift in host preference from the common brown rat (*R. norvegicus*), which is currently invading Africa, to the more widespread black rat (*R. rattus*). These pests often carry and may transmit fleas, ticks and other blood-feeding arthropods, which have the potential to spread vector-borne pathogens, such as *Borrelia burgdorferi* (Ebani 2022). Commensal rats can also serve as reservoirs for helminths of zoonotic public health significance that cause echinococcosis, taeniasis, trichinellosis, schistosomiasis, filariasis, opisthorchiasis and hymenolepiasis. Some gastrointestinal helminths in commensal rodents pose threats to public health (Waugh et al. 2006; Hancke et al. 2011; Khan et al. 2022), including the zoonotic species *Rodentolepis nana, Hymenolepis diminuta* and *Calodium hepaticum* and the potentially zoonotic species *Moniliformis moniliformis* and *Raillietina* sp. (Stojčević et al. 2004; Waugh et al. 2006; Easterbrook et al. 2007; Hancke et al. 2011). Rodents also serve as intermediate or paratenic hosts for zoonotic parasites such as *Echinococcus multilocularis, Toxocara* spp. and *Toxoplasma gondii* (Reperant et al. 2009). Rats carry infectious agents with zoonotic potential in some Western European countries (McGarry et al. 2015; Galán-Puchades et al. 2018), although there have been no studies in Bosnia and Herzegovina and its surrounding regions. We now report an investigation of the presence of potential zoonotic endoparasites within the specimen examined, by means of morphometric, haematological, histopathological and parasitological analysis.

Ethics committee approval

This study was approved by the Ethics Committee of the Veterinary Faculty, University of Sarajevo, under registration number 07-03-1072-2/23, Bosnia and Herzegovina.

Case description

An adult commensal brown rat, *R. norvegicus*, was captured using a Tomcat Rat Snap Mechanical Trap (Power Townsend Company, USA) in the basement of a public institution in the heart of Sarajevo as part of routine sanitary and pest control measures (Fig. 1). The animal was caught alive and exhibited highly agitated behaviour. The anaesthetic ketamine hydrochloride + xylazine was administered subcutaneously (80 mg/kg ketamine-HCl+10 mg/kg xylazine) (Bhatia et al. 2022). Peripheral blood was collected from the *V. caudalis* for haematology and biochemistry two hours after the rat was caught. The animal was then euthanized and a *post-mortem* examination performed. During the necropsy, a gross examination of the entire body and internal organs was performed and tissue and faeces samples were collected for pathological, morphometric and parasitological analysis.

Haematological and biochemical blood tests

Peripheral blood samples were collected by puncture of the *V. caudalis* into 3 ml vacutainer tubes containing ethylenediaminetetraacetic acid (EDTA) and gel. The puncture site was pre-disinfected with standard disinfectants (0.2 % chlorhexidine spray). Haematological parameters were measured using the "Idexx ProCyte Dx" cell counter. We used non-haemolyzed serum to determine biochemical parameters, obtained by centrifuging the whole blood of the rat in a microcentrifuge for three minutes at 10,000 revolutions per minute. Table 1 presents the results.

We also performed a blood smear examination and quantified poikilocytic erythrocytes on previously prepared peripheral blood smears. After air-drying following standard laboratory practice, the smears were stained using the Giemsa method. Poikilocytes were assessed semi-quantitatively (Christopher et al. 2014; Katica et al. 2019b). On each stained smear, 2,000 erythrocytes were counted and characterized at a microscopic magnification of 1000x. Poikilocytes were identified based on standard morphology and counted in representative monolayer fields where approximately half of the erythrocytes were in contact but not overlapping. The number and type of poikilocytes were expressed as a percentage of the total number of erythrocytes. Poikilocytosis was classified as follows: absent (0 %), rare (0.05–0.5 %), mild (>0.5–3 %), moderate (>3–10 %) and severe (>10 %). Microscopic assessments were also conducted in a similar manner to evaluate the presence of morphological changes in leukocyte cells (Harvey 2001) and the results are given in Table 1. We verified the leucogram using a binocular light microscope (Motic Type 102 M) at a magnification of 900x, utilizing the peripheral blood smears. We photographed the most representative microscopic fields containing erythrocytes with altered forms and the most prevalent specific leukocyte cells (Fig. 2).

Morphometric investigations of the digestive tract

The entire thoraco-abdominal organs were extracted and separately weighed (Nahita 5021 laboratory balance, max. load 600 g, resolution 0.1 g). The small intestine and large intestine segments were measured with ruler and thread.

Fig. 1: *Rattus norvegicus* and a "Tomcat Rat Snap" mechanical trap (Power Townsend Company, USA) / *Rattus norvegicus* und eine mechanische „Tomcat Rat Snap" Schlagfalle (Power Townsend Company, USA)

Tab. 1: Haematological and biochemical parameters of the peripheral blood / Hämatologische und biochemische Parameter des peripheren Blutes der untersuchten Ratte

Parameters	Results	Reference interval	Red Blood Cell Morphological Changes	Results Poikilocytes in %*	Parameters	Results	Reference interval[1]
Red blood count ($x10^{12}/l$)	8.21	7.34–8.85[2]	Ovalocytes	0.25	Glucose (mmol/l)	6.50	5.21–10.87
Haematocrit (%)	41.8	44.9–51.7[2]	Dacryocytes	0.15	Creatinine (μmol/l)	81	0–35.36
Haemoglobin (g/dl)	13.6	14.7–17.3[2]	Annulocytes	0.95	Urea (mmol/l)	13.0	/
Mean corpuscular volume (fl)	50.9	46–57[3]	Echinocytes	8.4	BUN/ Creatinine	40	/
Mean corpuscular haemoglobin (pg)	16.6	18.6–20.7[2]	Stomatocytes	0	Phosphorus (mmol/l)	2.60	1.29–3.29
Mean corpuscular haemoglobin concentration (g/dl)	32.5	31.3–34.4[2]	Sickle cells	0	Calcium (mmol/l)	2.40	1.92–3
White blood count ($x10^9/l$)	9.48	6.63–20.35[2]	Schistocytes	0.2	Total protein (g/l)	69	57–80
Platelets ($x10^9/l$)	443	804–1282[3]	Target cells	0	Albumin (g/l)	29	12–42
			Acanthocytes	0.15	Globulins (g/l)	40	27–56
			Spherocytes	4.95	Albumin/ globulins	0.7	/
			Reticulocytes	0	ALT (U/l)	211	1–22
Leucogram			Codocytes	0	ALP (U/l)	183	46–245
Neutrophiles ($x10^9/l$)	5.81	1.31–5.01	Intra-erythrocytic inclusions		GGT (U/l)	0	0–1
Lymphocytes ($x10^9/l$)	2.00	1.96–9.47	Erythrocontes	0	TBIL (μmol/l)	9	0–6.84
Monocytes ($x10^9/l$)	1.63	0.00–1.11	Heinz´ corpuscles	0	Cholesterol (mmol/l)	1.84	2.33–5.87
Eosinophiles ($x10^9/l$)	0.04	0.00–0.22	Howel-Jolly corpuscles	0	Amylase (U/l)	>2500	/
Basophiles ($x10^9/l$)	0.00	0.00–0.01	Degenerated leukocytes	0	Lipase (U/l)	110	/

1 = according to Weber et al. (2002); 2 = according to Car et al. (2006); 3 = according to Kampfmann et al. (2012); * = based on counting 2,000 cells / 1 = nach Weber et al. (2002); 2 = nach Car et al. (2006); 3 = nach Kampfmann et al. (2012); * = auf Basis der Zählung von 2.000 Zellen

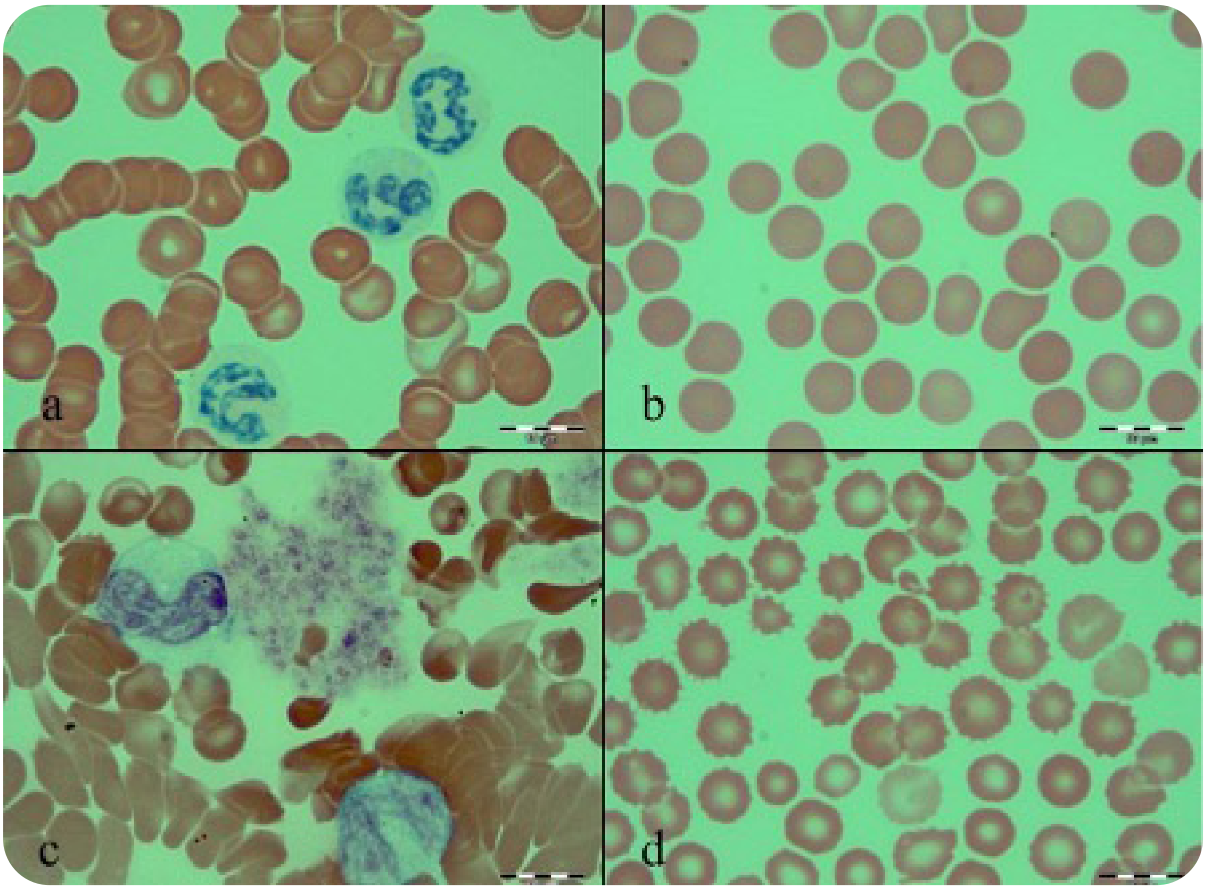

Fig. 2: Poikilocytic forms of erythrocytes and leukocytes; a) three neutrophils in the central part of the image; b) numerous spherocytes; c) two monocytes and a cluster of platelets; d) numerous echinocytes; magnification 1000x. / Poikilozytäre Formen von Erythrozyten und Leukozyten; a) drei Neutrophile im zentralen Teil des Bildes; b) zahlreiche Sphärozyten; c) zwei Monozyten und eine Ansammlung von Blutplättchen; d) zahlreiche Echinozyten; Vergrößerung 1000x.

Tab. 2: Morphometric parameters of the internal organs / Morphometrische Parameter der inneren Organe der Ratte

Weight (g)		Length (cm)	
Body (total)	288.5	Duodenum	14.2
Heart	1.32	Jejunum	136
Lungs	6.5	Ileum	9.6
Liver	19.5	Cecum	2.75
Spleen	3.27	Colon	15.85
Stomach	7.4	Rectum	7.25
Kidneys	2.6		
Small intestine	17.6		
Large intestine	5.7		

Histopathological examinations of the alimentary tract

Tissues from segments of the small intestine (duodenum, jejunum) and liver were extracted and preserved in 10 % buffered formalin. They underwent dehydration through a standard alcohol series (70 %, 96 %, and 100 %) and were embedded in paraffin blocks, then transverse sections of 5 µm thickness were prepared and stained using the haematoxylin and eosin (HE) method for routine histological analysis.

Numerous eggs were found in one field of the liver (Fig. 3a), distributed in several clusters (*C. hepaticum*) surrounded by zones of marked fibrosis and intense inflammation. In the portal spaces around this field, there were dense infiltrates of lymphocytes, plasma cells and macrophages with cytoplasm stained with bile pigment. The liver lobules around the field had a disrupted architecture, with hepatocytes arranged in a micronodular pattern. Figure 3b, at higher magnification, clearly shows the eggs of *C. hepaticum*. The bioperculated ova with polar prominences at each end are characteristic of *C. hepaticum*. The presence of parasites was evident in the lumen of the jejunum (Fig. 4a). The lining of the jejunal mucosa was infiltrated with a moder-

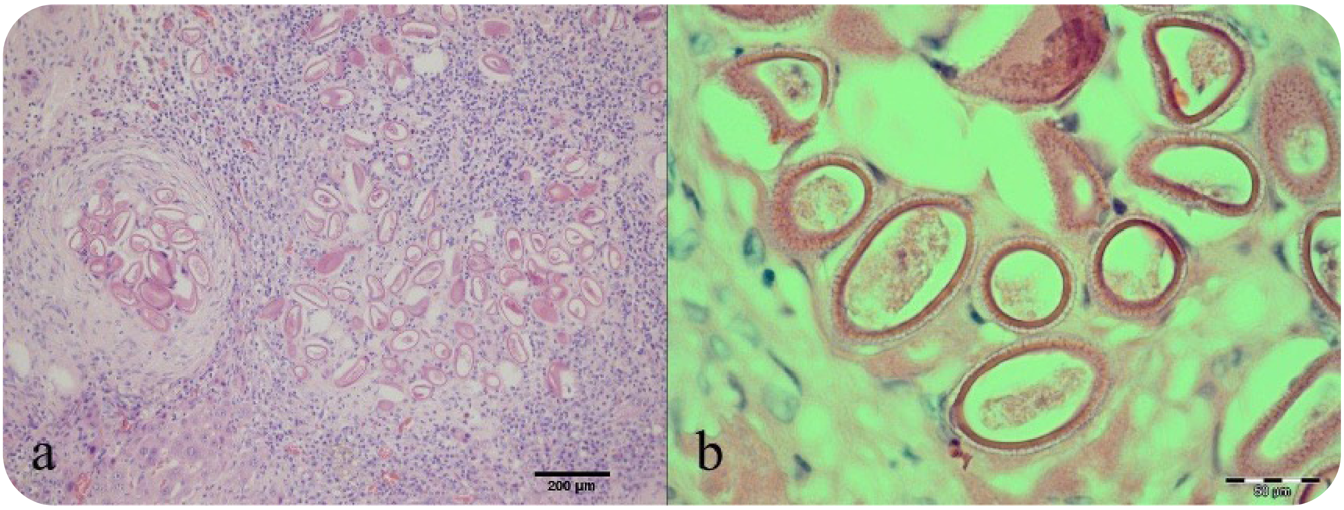

Fig. 3: Eggs of *C. hepaticum* in the liver tissue; 40x (a) and 200x (b) magnification; HE staining / Eier von *C. hepaticum* im Lebergewebe; 40fache (a) und 200fache (b) Vergrößerung; HE Färbung

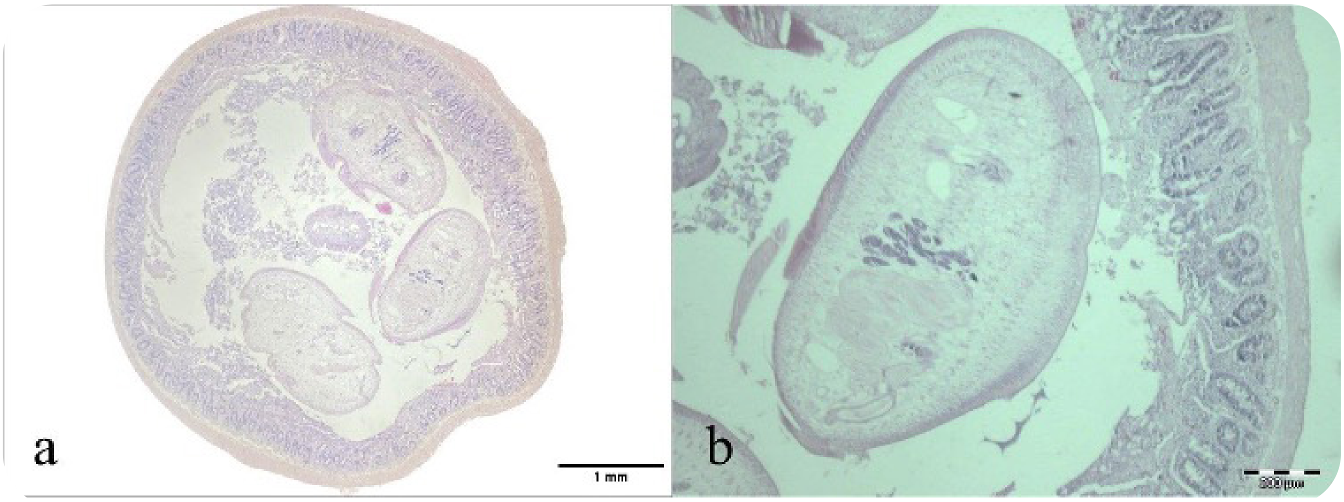

Fig. 4: Parasite stages in the lumen of the jejunum; 20x (a) and 40x (b) magnification; HE staining / Parasitenstadien im Lumen des Jejunum; 20fache (a) und 40fache (b) Vergrößerung; HE Färbung

ately dense infiltrate of lymphocytes and plasma cells that also contained numerous eosinophilic leukocytes. Up to 86 eosinophils were present in the mucosa in a single field of view at 400x magnification. No analysis of the intraepithelial lymphocytes or the ratio of villus height to crypt depth was possible due to autolysis of the superficial mucosal layer (Fig. 4b).

Parasitological examinations of faeces

Samples of rat faeces were collected from the lumen of the large intestine and subjected to coprological examination by the flotation method. The procedure is based on the flotation of developmental forms of parasites (helminth eggs, protozoan oocysts) to the surface of a flotation solution with a specific density greater than that of the eggs or oocysts. We used magnesium sulphate ($MgSO_4$) solution (Thienpont et al. 1979; Zajac et al. 2006) and identified *Rodentolepis* spp. and *H. diminuta* from the class Cestoda and *Trichuris muris, Strongyloides ratti* and *Nippostrongylus brasiliensis* from the class Nematoda (Fig. 5) (Zajac et al. 2006; Taylor et al. 2007).

Discussion

Method of catching the rat

The ineffectiveness of rodenticides and the presence of resistance in the population of commensal rats in urban areas is evident (Esther et al. 2022) and is consistent with our experience with the use of rodenticides to suppress the population of brown rats. Due to the reasons given above, we opted for an opportunistic approach to research. In our case, the rat ignored the rodenticide that was offered but instead approached the mechanical trap. In addition, our long-term experience

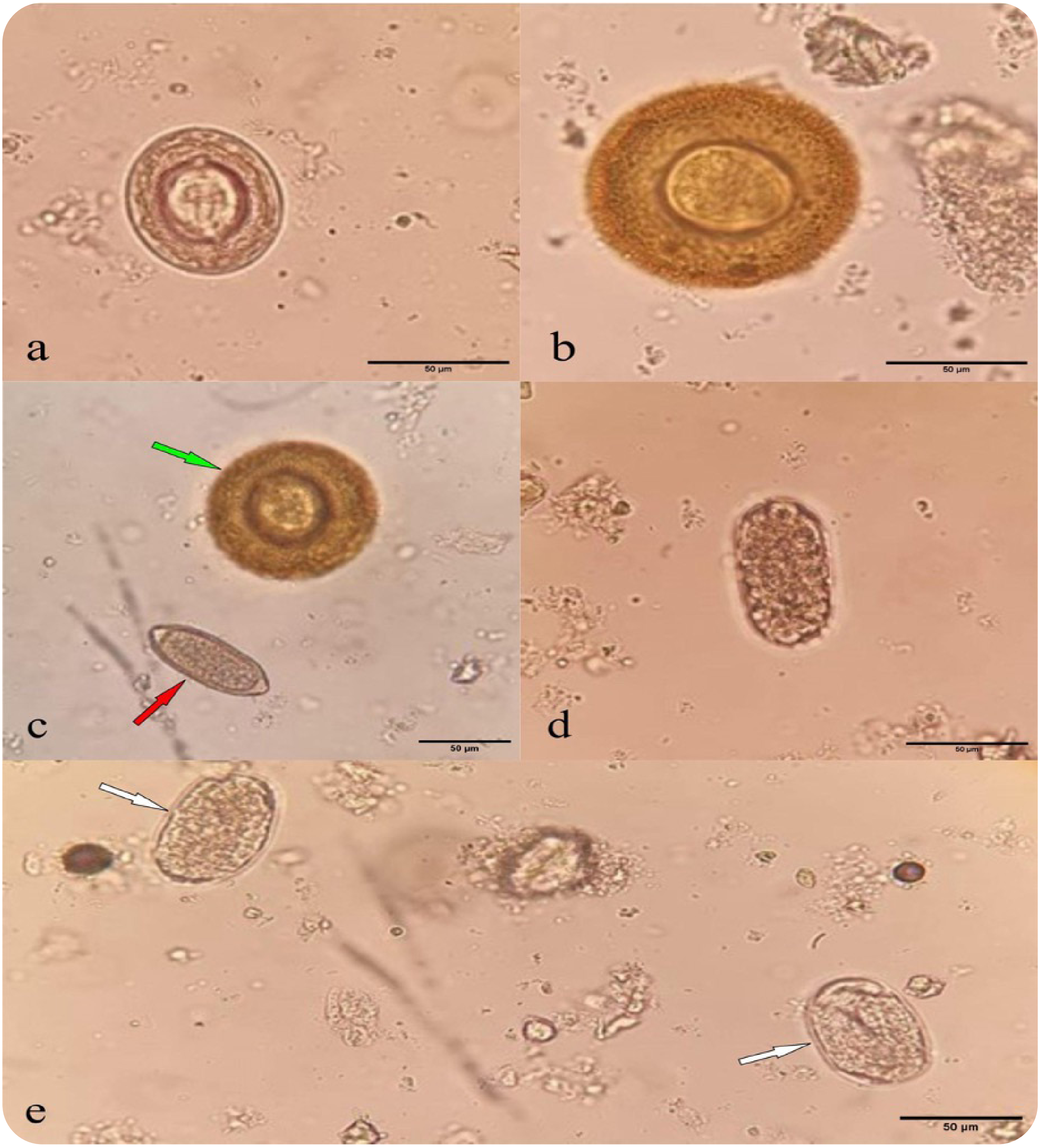

Fig. 5: a) *Rodentolepis* sp. eggs; b) *H. diminuta* eggs; c) *H. diminuta* eggs (green arrow), *T. muris* eggs (red arrow); d) *N. brasiliensis* eggs; e) *Strongyloides ratti* eggs (white arrows); magnification 10x / a) Eier von *Rodentolepis* sp.; b) Eier von *H. diminuta*; c) Eier von *H. diminuta* (grüner Pfeil), Eier von *T. muris* (roter Pfeil); d) *N. brasiliensis* Eier; e) *S. ratti* Eier (weiße Pfeile); zehnfache Vergrößerung

with rat-control measures suggests that brown rats very often avoid consuming rodenticides. We did not test the rat for genetic resistance to anticoagulant rodenticides. The use of snap traps for catching wild rats is allowed in circumstances where the use of rodenticides is not appropriate (NEA 2024) or may pose a risk of secondary poisoning of non-target species (Esther et al. 2022). In general, snap traps are not the method of choice for rat control as they cannot ensure the immediate death of a caught rat, as we saw in our case.

Pathological conditions in the liver

A total of 164 species reportedly parasitize *Rattus norvegicus* globally (Wells et al. 2015). The number of helminths in *R. norvegicus* and *R. rattus* may vary, with a lower prevalence reported in temperate areas. A slightly lower number of 156 parasites has been reported for *Rattus rattus* and 65 helminths are common to *R. rattus* and *R. norvegicus*. Through the analysis of histopathological and coprological results from the liver and small intestine of the examined rat, we identified various developmental stages of parasites, including five in the faeces and one in the liver. Within the hepatic parenchyma, numerous eggs of the nematode *C. hepaticum* were distributed in several clusters (Figures 3a and 3b). The presence of these eggs adversely affects the functional state of the liver, which can be correlated with the extremely elevated values of the liver enzyme ALT (Table 1). Our findings are in accordance with previous research, as the brown rat is the principal host of the parasite *C. hepaticum*, with reported prevalences of over 50 % on several continents (Fuehrer 2014). *C. hepaticum* is a parasitic nematode common to rodents and is frequently found in *R. norvegicus*. Infection by this parasite has been documented in more than 140 species of mammals (including humans, dogs, cats, and horses) worldwide (Berentsen et al. 2015) and there are rare cases of liver infection in humans (Manor et al. 2021).

Alterations in the blood profile

The snap trap did not ensure the immediate death of the rat, which was found in a state of total immobilization with clear signs of agitation, stress and pain. These circumstances allowed us to extract peripheral blood from the live animal and to perform standard haematological tests. The haematological results reflect the blood profile under stressful situations and showed reduced values of platelets, haematocrit, haemoglobin content and mean corpuscular haemoglobin (MCH). The findings are consistent with research suggesting that complete immobilization in rats decreases values blood parameters such as haemoglobin, haematocrit, MCV, MCH and MCHC (Caporossi et al. 2010; Ramadan & Alshamrani 2015).

Histopathological alterations in the intestinal tract and coproscopic examination

The histopathological findings in the jejunum lumen indicate areas of superficial mucosal autolysis where the relationship between villus height and crypts cannot be clearly determined (Fig. 4a and 4b). An evident deficiency of absorptive cells, such as enterocytes, resulted in the disturbance of the absorption of food components in the digestive tract (Faixova et al. 2012), as indicated by reduced haematological values of HCT, MCH and haemoglobin (Tab. 1). The decreased values of these haematological parameters, along with the moderate presence of spherocytes (4.95 %) (Fig. 2b), suggest anaemia (Božić & Ivanović 2012), which may be related to the autolysis of the superficial jejunum mucosa. In contrast to the reduced values of certain erythrocytic indices, we found slightly elevated values of some leukocytic cells. Evident neutrophilia (5.81 x 10^9/l) and monocytosis (1.63 x 10^9/l) (Tab. 1) may be attributable to inflammatory foci (Božić & Ivanović 2012) or to stress due to the capture method and/or that inflammatory foci. The histopathological examination of the jejunum lumen revealed the highest density of eosinophilic leukocytes within the mucosal *lamina propria*. The decreased values of eosinophils, below the lower physiological limit, in peripheral blood (0.04 x 10^9/l) (Tab. 1) and the highest density within the jejunum mucosal *lamina propria* indicate the migration of eosinophils from the cardiovascular system to areas of parasitic invasion. Figure 4 shows transverse sections of certain parasitic species within the jejunum lumen. Coprological examination showed the presence of *Rodentolepis* spp. and *H. diminuta* from the class Cestoda and *T. muris*, *S. ratti* and *N. brasiliensis* from the class Nematoda (Fig. 2).

Hymenolepiasis, as a zoonotic disease, is caused by three species of tapeworms, *Rodentolepis nana*, *Rodentolepis fraternal* and *H. diminuta* (rat tapeworm). Our results are consistent with previous findings (Coomansingh-Springer et al. 2019; Tijjani et al. 2020). *H. diminuta* is a common cestode among rodents but is rarely seen in humans (Řežábková et al. 2019), although it can be transmitted from person to person (Craig & Ito 2007; Strand & Lundkvist 2019). Infections with these tapeworms are usually asymptomatic, although severe infections with *H. nana* can lead to symptoms such as weakness, headaches, anorexia, abdominal pain and diarrhoea (David 1978). In the United Kingdom, *R. nana* has zoonotic potential (McGarry et al. 2015; Strand & Lundkvist 2019). *R. nana* and *H. diminuta* are thought to have infected over 175 million people worldwide (Crompton 1999; Kim et al. 2014; Yang et al. 2017).

We also found the nematodes *T. muris* and *N. brasiliensis* (Fig. 5c, d, e). Over 500 million cases of trichuriasis in humans worldwide can be attributed to infection with *Trichuris trichiura* (Tijjani et al. 2020), although the work (and previous studies; Koyama (2013)) did not identify *Trichuris* to the species level and there is a possibility, based on reports from Iran (Cheng 1986), that the figure may include infections with *T. muris*, which is known to infect mice. *N. brasiliensis* is another member of the class Nematoda: it is a gastrointestinal roundworm that infects rodents, primarily rats (Swain et al. 2016). We found eggs in the faeces of the rat (Fig. 5d and 5e). The confirmation of *S. ratti* (Fig. 3e) indicates the need for further studies on a larger number of rats to determine the prevalence of strongyloidiasis in these animals.

Alterations in morphometric characteristics of the intestinal tract

Morphometric investigations of the alimentary tract of the *R. norvegicus* showed that the weight of the gastrointestinal tract was 30.7 grams, which constituted 10.64 % of the rat's total body weight of 288.5 grams (Tab. 2). Other parameters from Table 1 are slightly higher than previous reports (Silva-Santana et al. 2019), which gave the weight of the kidneys, the heart, the liver, the stomach and the small intestine as 1.27 g, 0.72 g, 11.4 g, 1.58 g and 8.33 g, respectively. The weight of the large intestine, 4.81 g, corresponded to previous findings. Most of these figures, especially for hollow organs, should be taken with caution as the organs were weighed together with the intestinal content.

The total length of the rat small intestine ranges from 120 to 170 cm (Hebel and Stromberg 1976), although a significantly shorter length of 50.6 cm has been reported (Silva-Santana et al. 2019). We found a similar length of the small intestine as for Wistar rats, 159.8 cm. The length of the large intestine is approximately 26 cm (Hebel & Stromberg 1976), which was almost exactly what we found, 25.85 cm.

Significance of rats as carriers of zoonotic agents

Brown rats are reservoirs for various pathogens that can seriously threaten public health due to the close interactions with humans, as they are the second most abundant mammal in urban areas (after humans) (Shah et al. 2023). The high risk to public health from diseases transmitted by rodents is evident in urban areas where sanitary, technical and hygienic conditions are poor (De Santos et al. 2017). *Rattus norvegicus* prefers environments with available water, and its presence is especially pronounced in areas with open sewage infrastructure (Langton et al. 2001). Suitable places for rats to hide and nest are key risk factors for the transmission of parasitic and other zoonoses. These include buildings built on slopes, such as hillside urban areas (De Santos et al. 2017), as well as fences and walls of buildings in poor condition (De Masi et al. 2009). Additionally, neglected, devastated and abandoned houses, along with garbage and/or other waste dumps, serve as hiding spots and provide an additional source of food for rodents (Esther et al. 2022). A high proportion (>44 %) of urban poor households in Brazil are infected with zoonotic agents from *Rattus norvegicus* (De Santos et al. 2017).

Settlements with well established formal urban infrastructure and good sanitary, technical and hygienic conditions have a significantly lower risk of transmission of parasitic zoonoses to humans. Denying rats access to food, water and nesting places is the most effective measure of rat control (NEA 2024). It can be achieved by the implementation of permanent sanitary, technical and hygienic measures, which is typically the case in urban settlements of developed countries. When extermination and sanitary services do not function normally, there is a real danger of an increase in the rat population and a risk to public health. Developed countries (in North America, Europe, Australia, New Zealand and Japan) have a population of urban rats with an evident fauna of helminths (Gliga et al. 2020).

The present case report is limited by the number of animals analysed and the lack of information on the genotypes of the parasites or their developmental forms. However, despite these limitations, the results should stimulate comprehensive investigations of the commensal rat population in Sarajevo and other cities in Bosnia and Herzegovina.

Practical significance of the study

This study highlights the danger posed by commensal rats if systematic eradication is not fully implemented. The results should guide comprehensive investigations into helminth fauna in rats within urban areas of Bosnia and Herzegovina, where failures of the control and surveillance of rats have been recorded. We intend to suggest to local communities the improvement of technical and hygienic conditions and to suggest using only the latest generation of rodenticides. A systematic monitoring of the population of commensal rats is necessary to provide an objective picture of the risk to public health.

The opportunistic approach of catching rats with a snap trap has proven to be effective when the usual rat-control procedures do not achieve satisfactory results, so it should not be ignored in practice. For scientific studies, there are ethical concerns because snap traps do not ensure the immediate death of the animal.

Conflict of interest

The authors declare no conflict of interest.

Fazit für die Praxis:
Diese Studie verdeutlicht die Gefahr, die von kommensalen Ratten ausgeht. Die Ergebnisse dieses Fallberichts sollten letztlich als Leitfaden für künftige detaillierte Untersuchungen der Helminthenfauna bei Ratten in städtischen Siedlungen in Bosnien und Herzegowina dienen, wo Versäumnisse bei den Maßnahmen zur Rattenbekämpfung und -überwachung zu verzeichnen sind. Unsere Absicht ist es, den lokalen Gemeinden vorzuschlagen, die technischen und hygienischen Bedingungen zu verbessern und nur Rodentizide der neuesten Generation zu verwenden. Es ist notwendig, die Population von Wanderratten systematisch zu überwachen, um ein objektives Bild des Risikos für die öffentliche Gesundheit zu erhalten.
Der opportunistische Ansatz, Ratten mit einer Schlagfalle zu fangen, hat sich als wirksam erwiesen, wenn die üblichen Verfahren zur Rattenbekämpfung keine zufriedenstellenden Ergebnisse lieferten, und sollte daher in der Praxis nicht ignoriert werden. Für wissenschaftliche Studien stehen der Anwendung von Schlagfallen aber ethische Vorbehalte gegenüber, da Schlagfallen nicht mit Sicherheit den sofortigen Tod des Tieres herbeiführen.

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