One Health 18 (2024) 100662

Contents lists available at ScienceDirect

One Health

journal homepage: www.elsevier.com/locate/onehlt

The role of veterinarians in zoonosis prevention: Advising families of immunocompromised children with pets

Paula Garcia-Sanchez [a,b,g,*], David Romero-Trancón [b], Talía Sainz [c,e,h,i], Cristina Calvo [c,e,h,i], Irene Iglesias [d], Belén Perez-Hernando [e,j], Jara Hurtado-Gallego [b,e], Rocío Sánchez [b,k], Sonia Alcolea [c,e,g], Laura Moya [f], Ana Mendez-Echevarria [c,e,h,i,l]

[a] Pediatric Emergency Department, La Paz University Hospital, Madrid, Spain
[b] La Paz Institute for Health Research (IdiPAZ), Madrid, Spain
[c] Pediatric Infectious and Tropical Diseases Department, La Paz University Hospital and La Paz Institute for Health Research (IdiPAZ), Madrid, Spain
[d] Center for Animal Health Research (CISA), INIA-CSIC, Madrid, Spain
[e] Center for Biomedical Research in the Infectious Diseases Network (CIBERINFEC), Madrid, Spain
[f] IDEXX Laboratorios, S.L. Laboratory Key Account Manager, Spain
[g] Doctoral Program in Medicine and Surgery, Autonomous University of Madrid (UAM), Madrid, Spain
[h] Pediatric Department, Autonomous University of Madrid (UAM), Madrid, Spain
[i] Translational Research Network in Pediatric Infectious Diseases (RITIP), Madrid, Spain
[j] Carlos III Health Institute, Spain
[k] Doctoral Program in Microbiology, Autonomous University of Madrid (UAM), Madrid, Spain
[l] ERN TransplantChild, Spain

ARTICLE INFO

Keywords:
Pets
Immunocompromised
Children
Survey
Zoonoses
Veterinarians

ABSTRACT

Background: Pet ownership is widespread, offering numerous benefits to individuals and families. However, the risk of zoonotic diseases must be carefully considered, especially for immunosuppressed patients. Knowledge gaps in preventive measures for zoonoses have been identified, underscoring the vital role of veterinarians in addressing this issue.

Objectives: This study aimed to assess the knowledge and recommendations of veterinarians regarding pet ownership by immunocompromised individuals. Additionally, we compared these insights with responses from European healthcare professionals specializing in pediatric transplant recipients.

Methods: We conducted an observational, cross-sectional study involving small animal veterinarians in Spain. An online survey was administered to gather information on veterinarians' knowledge of zoonoses and their recommendations for immunocompromised pet owners.

Results: A survey of 514 individuals was collected from experienced veterinarians mainly working in primary care clinics. Surprisingly, 63% of respondents did not routinely inquire about the presence of immunocompromised individuals among pet owners, although 54% offered specific recommendations for this group. Most respondents adhered to deworming guidelines for pets owned by immunocompromised individuals and demonstrated sound practices in *Leishmania* and *Leptospira* prevention, as well as the avoidance of raw food. However, gaps were noted concerning *Bordetella bronchiseptica* vaccination. Notably, veterinarians outperformed medical professionals in their knowledge of zoonotic cases and identification of zoonotic microorganisms. The presence of specific recommendations in veterinary clinics was viewed positively by nearly all respondents.

Conclusions: Our findings indicate that veterinarians possess a superior understanding of zoonotic pathogens and exhibit greater proficiency in diagnosing zoonoses compared with physicians. They stay well-informed about recommendations outlined in established guidelines and are more likely to provide written recommendations in their clinics than physicians. Nevertheless, knowledge gaps among veterinarians emphasize the need for enhanced communication between medical and veterinary professionals. Reinforcing the "One Health" concept is imperative, with veterinarians playing a pivotal role in this collaborative effort.

* Corresponding author at: Pediatric Emergency Department, La Paz University Hospital, Madrid, Spain.
E-mail address: paula.garsa@gmail.com (P. Garcia-Sanchez).

https://doi.org/10.1016/j.onehlt.2023.100662
Received 18 October 2023; Accepted 7 December 2023
Available online 12 December 2023

1. Introduction

Pet ownership is common worldwide. Approximately 90 million (46%) households in the European Union possess a companion animal [1], and 87 million (66%) households in the United States own a pet [2]. Companion animals are more commonly found in households with children [3], and interacting with animals has been shown to have positive effects on children's mental and physical health [4]. Previous experiences within the healthcare system have shown that patients visited by animals report lower anxiety and pain during medical procedures when animals are present [5].

However, contact with animals entails certain risks, especially for immunocompromised patients, who are at higher risk of developing serious infections. Taking the necessary precautions is important to prevent zoonotic infections, including routine veterinary care and avoiding risky behaviors, such as keeping stray or exotic companion animals, bed-sharing, kissing the animals, or feeding them raw food [6]. However, a lack of evidence often leads to gaps in the education of pet owners in preventive zoonotic measures. Clinicians in human healthcare have a worrisome lack of zoonosis knowledge and the specific risks associated with each type of pet [7]. As a result, patients do not receive proper and sufficient information about zoonoses from health professionals. These professionals sometimes base their recommendations on personal experience, with significant variability in their clinical practice, providing families with non-evidence-based information regarding the risks associated with pets. Low compliance with deworming protocols, and gaps in pets' immunization [8] have been reported in our and others' previous studies [7–10]. Considering these factors, it is essential to examine the knowledge and recommendations provided by veterinarians, who play a critical role in managing pets owned by immunocompromised individuals.

The number of immunocompromised patients has increased exponentially in recent decades [11]. In this context, recognizing the close interrelation between human and animal health (the "One Health" concept) and addressing health challenges *via* collaboration between human and veterinary medicine are crucial [12]. Although pet ownership is common, few studies have evaluated the role of veterinarians in managing pets of immunocompromised owners or the recommendations provided by these professionals, whose involvement is key to providing specific recommendations and proper care [6]. Veterinarians should be informed of the presence of an immunocompromised host in the household so as to adjust the preventive measures, establishing a specific healthcare plan for pets and individual veterinary procedures in accordance with the animal's lifestyle and the features of the household members [6].

The aim of our study was to evaluate the level of veterinarians' knowledge in Spain regarding zoonotic diseases and their risks in pets owned by immunocompromised individuals, as well as the recommendations provided. Our group recently performed a survey among European pediatricians caring for immunocompromised children [7], whose results we have analyzed here.

2. Methods

We conducted a national, observational, cross-sectional study among veterinarians specializing in small animal care, working in Spain. An anonymous questionnaire developed by the investigators was distributed by email to Spanish small animal veterinary clinics through the Spanish Official Colleges of Veterinarians as well as through private companies (*ELANCO* and *MSD animal health*). The survey was sent online using the "Google Forms questionnaire" platform from October 2022 to April 2023. In addition, *Animal's Health* and *Diario Veterinario*, two daily digital newspapers aimed at animal health professionals, published a link to the survey.

The study was approved by the Ethics Committee of La Paz University Hospital (PI-4770). The questionnaire included items about risk perception based on the type of pet and recommendations provided to immunocompromised owners, as well as veterinary recommendations regarding screening and prevention of zoonoses for pets owned by such individuals (vaccinations, external and internal deworming) (*Supplementary File 1*). Data regarding the length of professional practice or previous experience treating zoonoses were collected simultaneously. The knowledge regarding zoonoses and recommendations provided by Spanish veterinarians were compared with the results obtained from a recent survey among healthcare professionals who attend pediatric transplant recipients in large European centers [7].

The definition of "adequate compliance" was based on the published recommendations for zoonosis prevention [6,13–18] for general populations and for immunocompromised patients who own pets. According to these recommendations, these patients should avoid acquiring puppies and kittens younger than 6 months of age, nontraditional pets, wild-caught animals, or exotic pets, reptiles, turtles, or amphibians [6,14,18,19]. Dogs and cats sharing homes with children younger than 5 years and/or immunocompromised should be dewormed monthly or fecal analyses should be performed, depending on the risk assessment [13]. Related to core vaccines, strict adherence to the recommended vaccination schedule is important, avoiding the administration of live vaccines. *Bordetella bronchiseptica* immunization should be considered, selecting an inactivated vaccine over the conventional live vaccine [6].

Considering the total number of veterinarians working in small animal clinics in Spain (20,060 according to recent data [20]) and using the methods proposed by Taherdoost to determine the sample size [21], we estimated the inclusion of at least 377 respondents for a 95% confidence level and a marginal error of 5%.

The geographical distribution of the obtained responses was explored at the postal code level. Surveys were mapped and represented, employing a kernel density tool to facilitate the identification of areas with highest response rates (Spatial analyst, ArcGIS 10.9, ESRI, USA). To identify locations surrounded by a cluster of high (hot spot) or low survey response values, a Getis Ord analysis was applied (Spatial statistics, ArcGIS 10.9, ESRI, USA) [22].

Qualitative data were expressed as absolute frequencies and/or percentages; quantitative data were expressed as median and interquartile range (IQR), range, or as mean and standard deviation, depending on the data distribution. The chi-squared test and Fisher's exact test were used for the categorical variables, and Student's *t*-test or non-parametric tests, as appropriate, for the continuous variables. A two-sided value of $p \leq 0.05$ was considered statistically significant. The statistical analysis was performed with Stata v17.0 (StataCorp LP, College Station, TX, USA) and Prism v.7.0 (GraphPad, Inc., La Jolla, CA, USA).

3. Results

3.1. Survey respondents' characteristics

A total of 514 surveys were collected, representing 2.5% of the 20,060 Spanish veterinarians working in small animal veterinary clinics. Most (63%) of the surveyed professionals were experienced veterinarians older than 40 years, who worked mainly in primary care clinics; 75% of these professionals reported up to 10 years of professional experience, 72% of them attending >100 pets per month in their clinics. Table 1 summarizes the main characteristics of the study participants.

Compared with European physicians caring for transplant children, there were no differences in terms of sex and age, or the presence of children or pets in veterinarians' households, although veterinarians reported more years of professional experience (<0.01).

The highest number of responses were obtained in Madrid, Barcelona, Galicia, the Basque Country, and Valencia, most of which are Spanish coastal regions (Fig. 1A), corresponding to the areas with the highest population density in the country (Fig. 1B).

Table 1
Survey respondents' characteristics.

CHARACTERISTIC		TOTAL (N = 514)	%
Gender	Male	123	23.93
	Female	389	75.68
	Other	2	0.39
Age, years	<30	32	6.22
	30–40	156	30.35
	40–50	154	29.96
	50–60	155	30.15
	>60	17	3.3
Childcare	Yes	308	59.92
	No	206	40.07
Work environment	Rural	53	10.31
	Urban	298	57.97
	Both	163	31.71
Type of veterinary center	Primary care clinic	432	84.05
	Referral center	27	5.25
	Hospital	43	8.36
	University Hospital	10	1.95
	Emergency clinic	2	0.39
N° of pets attended per month	<50	29	5.64
	50–100	117	22.76
	101–200	166	32.29
	>200	202	39.3
Length of professional practice (years)	<5	41	7.98
	5–10	86	16.73
	10–15	72	14
	>15	315	61.28

3.2. Clinical practice and recommendations regarding pets

Up to 63% (325/514) of the surveyed veterinarians did not actively ask their clients about the presence of immunocompromised individuals in the household, although 54% (279/514) reported having specific written recommendations in their clinic for immunocompromised owners. Interestingly, when compared with our previously published data [7], Spanish veterinarians have more frequently written recommendations for immunocompromised patients with pets than units specifically caring for transplant children in large European hospitals (54%, 279/514 *vs.* 38%, 58/151) ($p < 0.01$). Veterinarians' recommendations for immunocompromised owners basically included intestinal deworming (97%, 270/279); external deworming (90%, 252/279); pet's hygiene and lifestyle (86%, 240/279); immunization (72%, 202/279); frequency of veterinary check-ups (67%, 186/279); specific screening for diseases/zoonosis (53%, 149/279); and feeding (31%, 87/279).

Up to 73% (377/514) of the surveyed veterinarians followed the European Scientific Counsel for Companion Animal Parasites guidelines [13], recommending either monthly internal deworming or monthly fecal sample examination, depending on the risk assessment, in dogs of immunocompromised owners. This percentage was similar (69%, 653/514) regarding the recommendation for deworming cats of immunocompromised owners. Up to 97% (497/514) of the surveyed professionals advised against eating raw food or following a Biologically Appropriate Raw Food diet; 98% (501/514) recommend dog owners use repellent against *Leishmania* (collar, spot-on, sprays); and 98% (505/514) recommend vaccinating dogs against *Leptospira*.

Up to 52% (268/514) of the respondents would administer inactivated parenteral vaccine against *Bordetella bronchiseptica* to prevent an immunocompromised owner from acquiring a vaccine-related infection. However, a quarter (126/514) of the respondents would administer the oral vaccine, and up to 23% (120/514) would not recommend it despite the presence of an immunocompromised owner living in the household.

In the case of cats of immunocompromised owners, 32% (164/514) would recommend inactivated parenteral vaccine against *B. bronchiseptica*, 7.8% (40/514) would administer live oral vaccine, and up to 60% (310/514) would not recommend any immunization.

Nearly 80% of veterinarians advise against owning a puppy or kitten younger than 6 months of age if there is an immunocompromised owner in the family. However, approximately 35% of the surveyed veterinarians consider reptiles and turtles to be low-risk or no-risk animals (Table 2). Table 2 summarizes responses provided by Spanish veterinarians *versus* those obtained from healthcare professionals caring for European transplant children [7].

3.3. Knowledge of zoonoses

Regarding diseases transmitted to humans, 92% of the surveyed veterinarians (475/514) diagnosed a potentially transmissible zoonosis in a pet at least once a year. Of these, 35% (179/514) diagnosed them monthly and 25% (147/514) weekly. Most of the diseases reported were intestinal parasitosis and dermatophytosis (95%, 452/475) (*Supplementary file 2*).

At least 71% (367/514) of the veterinarians knew of a case of a zoonotic infection transmitted from a pet to its owner (Table 3), whereas only 29% (44/151) of the European medical professionals attending transplant children remembered having diagnosed a zoonosis in their patients ($p < 0.001$).

Veterinarians were more easily able to identify microorganisms that can be transmitted from animals to humans compared with medical professionals in the European pediatric transplant network ($p = 0.01$) (Fig. 2), with a median pathogen identification rate of 75% (IQR 64.2%–90.9%) *vs* 62.25% (IQR 42.3%–70.9%).

However, three pathogens were more frequently identified as zoonotic by medical doctors compared with veterinarians: *C. psittaci* (80.8%, 122/151 *vs.* 73%, 375/514); Hantavirus (51%, 77/151 *vs.* 34%, 175/514), and *F. tularensis* (70.9%, 107/151 *vs.* 63.4%, 326/514) ($p < 0.001$).

Lastly, 98.6% of the surveyed veterinarians believe that it would be beneficial to have specific veterinary care recommendations (in written form or available through an online link) in their clinics to provide to immunocompromised clients, in order to reduce health risks and facilitate a safer coexistence between pets and owners.

4. Discussion

Our results suggest that veterinarians in Spain have better knowledge regarding zoonotic pathogens and a greater ability and training to diagnose zoonotic diseases compared with other European physicians. They are properly updated on the recommendations included in published guidelines for pets living with immunocompromised owners [13–19], and they more frequently provide written clinical recommendations compared with European medical physicians who care for immunocompromised children. However, they often do not actively inquire of the pet owners whether there are immunocompromised household members, and we observed some gaps in veterinarians' knowledge, reflecting the need to increase awareness and communication among medical and veterinary professionals.

Our results highlight the importance of a One-Health approach in the attendance of immunocompromised patients who own pets. As we have previously reported, patients' decision about pet ownership is considerably influenced by their doctors' recommendations [9]. However, medical professionals often base their recommendations on personal opinions or experiences rather than on solid evidence [7]. Veterinarians have greater knowledge and ability to identify zoonoses. They frequently identify puppies or kittens as risky pets for immunocompromised individuals, are updated on guidelines, and more often provide the families with written recommendations for immunocompromised owners, including deworming protocols, immunization, pet hygiene, lifestyle, and frequency of veterinary check-ups. Unfortunately, many immunocompromised owners do not receive this type information from their healthcare providers [7,9]; thus, the role of veterinarians in

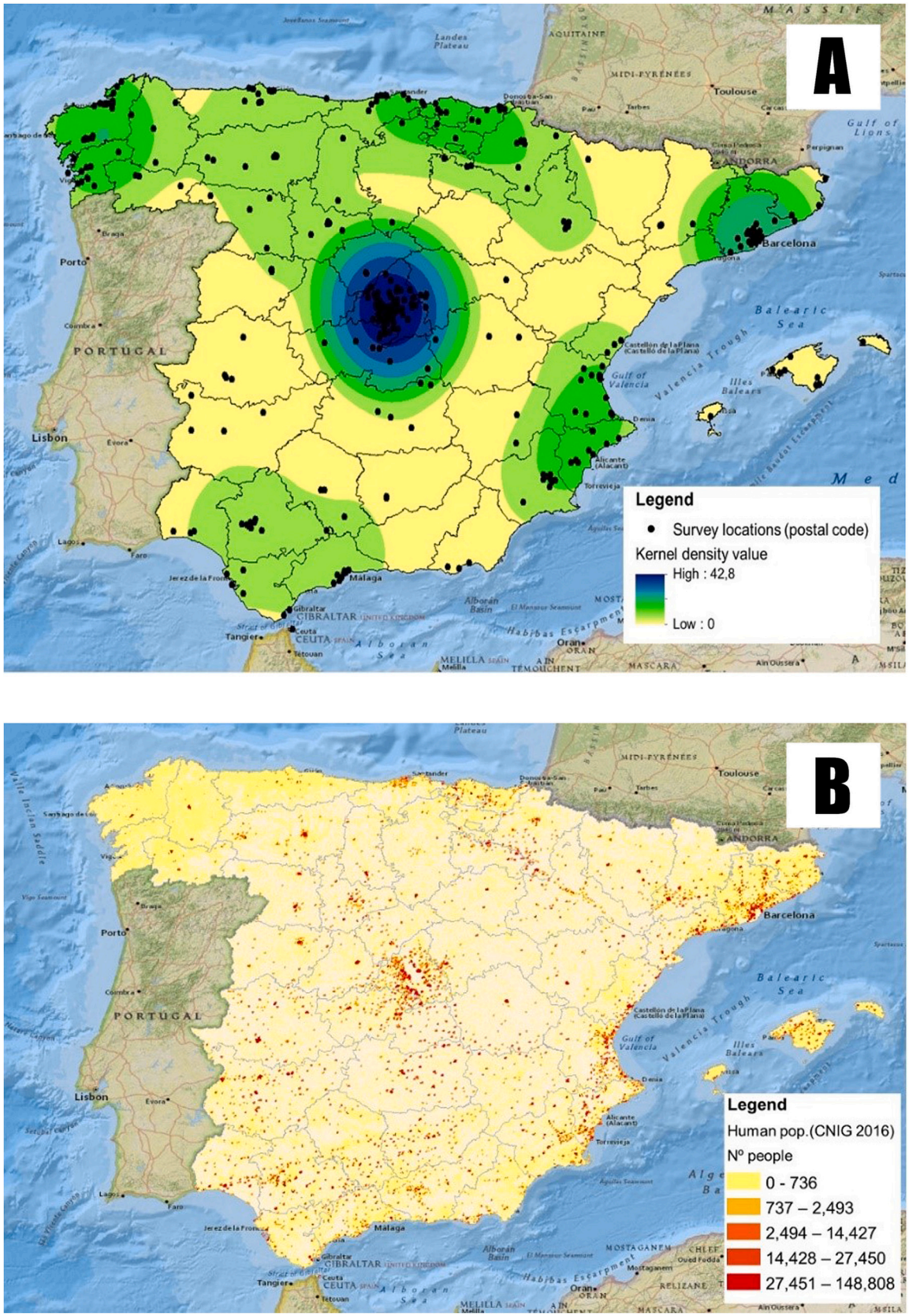

Fig. 1. (A) Geographical distribution of the surveys answered by veterinarians in Spain using kernel density tool. Shades of blue indicate higher values and yellow lower values. Black points show survey postal code locations. (B) Human populations in Spain. Colors from yellow to red express increasing density of human population per municipality (Data source CNIG [23]). A similar geographical distribution is observed, indicating that the results appear to be evenly distributed throughout the national territory based on population distribution. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 2
The risk assessment of various pets by surveyed Spanish veterinarians and surveyed professionals dedicated to pediatric transplantation in large European Centers[7].

Animal	High risk, %		Low risk/no risk		Doesn't know		p
	VMD (n = 514)	MD (*n* = 151)	VMD (n = 514)	MD (n = 151)	VMD (n = 514)	MD (n = 151)	
Puppies < 6 months	79%	NA*	18.7%	NA*	2.3%	NA*	–
Kittens < 6 months	79.2%		18.7%	NA*	2.1%		
Dogs	**36.2%**	18.5%	56.2%	74.8%	2.3%	6.6%	**<0.01**
Cats	35.4%	39.7%	**62.6%**	52.9%	**1.9%**	7.3%	**<0.01**
Rabbits and rodents	33%	36.4%	44.7%	49%	22.2%	14.6%	0.1
Birds	46.3%	**58.9%**	36.6%	32.4	**17.1%**	**8.6%**	**<0.01**
Fish	11%	12.6%	62.6%	72.8%	26.3%	14.6%	**0.011**
Turtles	43%	46.4%	**36.2%**	**33.1%**	**20.8%**	20.5%	0.7
Other reptiles: snakes, iguanas	36.8%	49.7%	**35.2%**	26.5%	**28%**	23.8%	**0.015**

* VMD: veterinary medicine doctor; MD: medical doctor; NA: Not available.

Table 3
Zoonoses transmitted from pets to owners as reported by the surveyed veterinarians.

ZOONOSES (*n* = 367)	N	%
Dermatophytosis	277	75.5%
Sarna and other ectoparasites	74	20.2%
Internal parasites	35	9.5%
Toxocariasis	1	0.3%
Cat-scratch disease	1	0.3%
Echinococcosis (hydatid cyst)	1	0.3%
Psittacosis	1	0.3%
Bacterial conjunctivitis	1	0.3%
Ocular herpes	1	0.3%

preventing human zoonoses is relevant, according to our results.

The majority of surveyed veterinarians are accustomed to diagnosing infections in pets that are potentially transmissible to humans, mainly intestinal parasitosis and dermatophytosis. Interestingly, veterinarians more easily identified zoonotic pathogens compared with medical professionals, indicating their expertise in this field. However, some specific pathogens, such as *C. psittaci*, Hantavirus, and *F. tularensis*, were better identified by medical professionals despite the presence of these zoonotic pathogens in the area of the survey study [24–26]. This could be explained because veterinarians who work primarily with dogs and cats may not be aware of these diseases, as dogs and cats are not main reservoirs of these diseases. *C. psittaci* is present in birds, Hantavirus in rodents, and *F. tularensis* in rodents and lagomorphs. Not all veterinarians who work with dogs and cats have expertise in other pets, including exotic ones. Thus, veterinarians working on exotic animals and public health play a crucial role in preventing these zoonoses. The majority of the respondents would vaccinate against leptospirosis in the case of dogs living with immunocompromised owners, as some authors have recommended [6].

Regarding the risk perception for different types of pets, veterinarians consider cats to be less risky animals as frequently as medical professionals do. Toxoplasmosis is a severe disease in immunocompromised hosts; thus, many doctors recommend patients avoid owning cats. However, the presence of *Toxoplasma* oocytes in domestic cats' fecal samples in developed countries is exceptional, whereas the presence of these oocysts in soil is much more frequent [27]. While the global prevalence of oocysts in soil samples is higher than 25%, this prevalence in fecal specimens from domestic cats is estimated in 2.6%, and even lower in the case of developed countries (0.9% in North-America, and lower than 2% in many European countries) [27]. Studies performed in European cities such as Madrid, Lyon or Milan have shown a total absence of oocysts in fecal samples obtained from domestic cats [27]. Many data suggest that kittens may pose a higher risk of *Toxoplasma* infection than contact with older cats. A Polish study reported that the prevalence of anti-*Toxoplasma* antibodies was significantly greater in older cats (>1 year) than in younger cats, demonstrating that primary infection, and thus the higher risk of oocyst shedding, often occurs in kittens [28]. Deksne et al. demonstrated, through the use of multiple

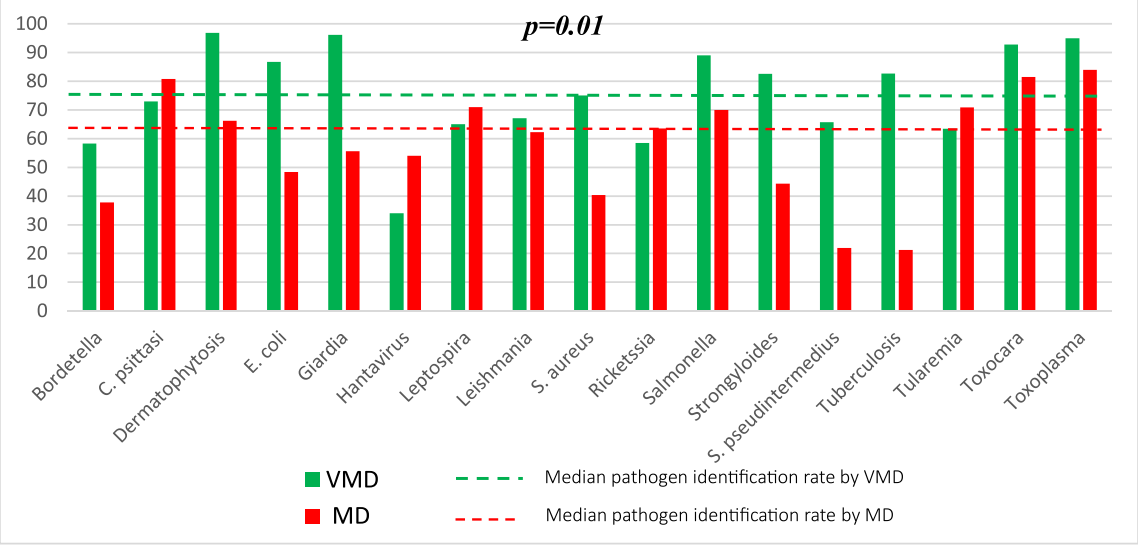

Fig. 2. Percentage of pathogens correctly identified as having potential zoonotic transmission by professionals attending transplanted children in Europe and by veterinarians working in Spain.

logistic regression analyses, that age and outdoor access were found to be the most significant factors associated with *T. gondi* infection in Latvia [29]. In addition, infected felids only shed *T. gondii* oocysts for a few days after primary infection [27]. This short period of shedding and the low prevalence rate of felids that actively excrete oocysts have led some authors to discuss whether felids should be considered a risk factor for human infection [27]. Previous European studies had observed that pregnant women acquired toxoplasmosis after the consumption of undercooked meat products or soil contact, whereas contact with cats was not identified as a risk factor [30].

Regarding dogs (excluding puppies), a higher number of veterinarians compared with physicians consider that they could pose a risk for immunocompromised patients. Although the main guidelines for immunocompromised patients used by physicians [14,18,19] do not consider these pets especially risky, there is growing literature on the high prevalence of intestinal infections among domestic dogs in developed countries [31,32]: up to 22% of dogs tested positive for an intestinal parasite in a European multicenter study [31]. This high prevalence can result in ongoing zoonotic transmission among owners.

The survey also revealed that many of the respondents were unaware of whether the pet lived with an immunocompromised individual, which could result in these recommendations not being effectively communicated to the families. According to previous studies, up to 50% of Spanish families of immunocompromised children who own dogs and/or cats do not comply with at least one of the recommendations concerning vaccination, deworming, feeding, and/or veterinary controls [9].

Regarding the *Bordetella bronchiseptica* vaccine, although it is a non-core vaccine, it should be considered for pets of immunocompromised owners [6], given that *B. bronchiseptica* could cause severe infections in immunocompromised patients exposed to ill and/or unvaccinated animals [33]. Inactivated vaccine should be selected over the conventional live oral vaccine, because severe infections have been reported in patients after the exposure to recently vaccinated dogs [34,35]. However, a quarter of our respondents would administer live vaccine to dogs living with these patients instead of an inactivated one, and up to 23% would not recommend the pet's vaccination despite living with an immunocompromised host.

In terms of the type of pet, a significant proportion of veterinarians considered reptiles and turtles as low-risk animals. However, these pets are frequent *Salmonella* carriers, and zoonotic transmission of these bacteria has been extensively reported among owners [36], with children and immunocompromised hosts at special risk for this infection. In addition, reptiles could be *Cryptosporidium* carriers [6], and this pathogen is relevant for immunocompromised hosts [37]. Many veterinarians are not aware of the zoonotic risk of keeping birds in the household of immunocompromised patients. *Cryptococcus* is mainly an environmental yeast that colonizes bird feces, leading to its airborne dissemination, given that C*ryptococcus* can be aerosolized [38]. However, some authors have recently reported colonization of *Cryptococcus* in swabs from oropharynx, crop and cloaca obtained directly from birds. Thus, birds could also be colonized by this yeast [39]. Cryptococcosis preferentially affects immunocompromised patients, and it has dramatically increased in recent decades as new populations of immunocompromised hosts have emerged [40]. Furthermore, pet birds can give rise to other common zoonotic events, such as salmonellosis, campylobacteriosis, giardiasis, and cryptosporidiosis [41], which are relevant in immunocompromised patients. Doctors are more aware of the risks associated with the presence of birds in the patient household than veterinarians are. In addition, we observed that *C. psittaci* was less frequently identified as a zoonotic pathogen by veterinarians compared with doctors, which indicates that veterinarians are unaware of the risk of immunocompromised patients owning birds.

All these discrepancies emphasize the importance of aligning veterinary recommendations with medical guidelines to ensure the safety of immunocompromised owners.

Our study has some limitations. First, it involved the use of an online questionnaire, with the subsequent inherent risk of selection bias. The study was conducted in a single country, thus results might not be generalizable to other populations or regions. However, it is one of the first studies evaluating the role of veterinarians in managing pets of immunocompromised owners and analyzing the recommendations provided by these professionals. The responses were distributed throughout Spain, obtaining more responses in areas with a higher population density. These responses were collected among veterinarians with over 15 years of professional experience who attend >100 pets per month in their clinics.

5. Conclusions

In summary, veterinarians play a pivotal role in the prevention of zoonoses, providing proper care for pets of immunocompromised owners, for which specific recommendations and considerations should be offered. They should be involved in a specific healthcare plan for pets, and they should actively ask about immunocompromised owners or the presence of immunosuppressed patients in the household. It is essential to train both professionals and patients in order to promote health and reduce zoonosis risk. Almost all the surveyed veterinarians considered it beneficial to have specific veterinary care recommendations for immunocompromised clients available in their clinics. Digital applications and tools designed for patients could offer an accessible and understandable way for pet owners to obtain relevant information and support regarding their animals' health and well-being.

By promoting collaboration among professionals from a variety of disciplines, including human and veterinary medicine, we can collectively address health challenges more effectively and work toward improving the well-being of both humans and animals, reinforcing the concept of "One Health," which focuses in the interrelationship between human, animal, and environmental health [12].

Funding

This study was supported by the Spanish Pediatrics Association (AEP) 2021 Research Grant, by the Spanish Ministry of Science and Innovation – Instituto de Salud Carlos III, and Fondos FEDER of the UE, Grant N° PI23/00917 [Fondo de Investigaciones Sanitarias-Spanish Health Research Fund (ISCIII)] and, by the MAPFRE Foundation ("Research grants by Ignacio H. de Larramendi 2021"). Talía Sainz has been funded by Carlos III Health Institute-Fondos Feder (BAE21/00022). Belén Perez-Hernando has been funded by CIBERINFEC. Rocío Sánchez has been funded by *Programa Investigo* 2022 (reference A113), Comunidad de Madrid Government (Spain). The funding bodies did not have a role in the design or conduct of the study, the analysis and interpretation of the results, the writing of the report, or the decision to publish.

CRediT authorship contribution statement

Paula Garcia-Sanchez: Conceptualization, Data curation, Methodology, Investigation, Formal analysis, Writing – original draft, Writing – review & editing. **David Romero-Trancón:** Investigation, Data curation, Writing – review & editing. **Talía Sainz:** Conceptualization, Supervision, Writing – review & editing. **Cristina Calvo:** Conceptualization, Supervision, Writing – review & editing. **Irene**

Iglesias: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Belén Perez-Hernando:** Conceptualization, Data curation, Investigation. **Jara Hurtado-Gallego:** Conceptualization, Data curation, Investigation. **Rocío Sánchez:** Conceptualization, Data curation, Investigation. **Sonia Alcolea:** Conceptualization, Data curation, Investigation. **Laura Moya:** Conceptualization, Data curation, Investigation. **Ana Mendez-Echevarria:** Conceptualization, Formal analysis, Methodology, Project administration, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Data availability

Data will be made available on request.

Acknowledgments

To Alejandra González from ELANCO S.L., to Federica Burgi, Barbara Astilleros and Miruna Andrea Martin from M.S.D.- Animal Health Spain Spain; to Animal's Health, to Diario Veterinario and to the Spanish Official Colleges of Veterinarians for their involvement in facilitating the survey dissemination.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.onehlt.2023.100662.

References

[1] FEDIAF, Annual Report 2022. https://europeanpetfood.org/wp-content/uploads/2023/02/Annual-Report-2022-2.pdf, 2022 (accessed 10 July 2023).
[2] American Pet Products Association (APPA), Pet Industry Market Size, Trends & Ownership Statistics. https://www.americanpetproducts.org/, 2023 (accessed 1 July 2023).
[3] C. Westgarth, J. Heron, A.R. Ness, P. Bundred, R.M. Gaskell, K.P. Coyne, et al., Family pet ownership during childhood: findings from a UK birth cohort and implications for public health research, Int. J. Environ. Res. Public Health 7 (2010) 3704–3729, https://doi.org/10.3390/ijerph7103704.
[4] R. Purewal, R. Christley, K. Kordas, C. Joinson, K. Meints, N. Gee, et al., Companion animals and child/adolescent development: a systematic review of the evidence, Int. J. Environ. Res. Public Health 14 (2017) 234, https://doi.org/10.3390/ijerph14030234.
[5] L. Vagnoli, S. Caprilli, C. Vernucci, S. Zagni, F. Mugnai, A. Messeri, Can presence of a dog reduce pain and distress in children during venipuncture? Pain Manag. Nurs. 16 (2015) 89–95, https://doi.org/10.1016/j.pmn.2014.04.004.
[6] P. García Sánchez, I. Iglesias, I. Falces-Romero, M. Serrano-Villar, C. Calvo, S. Alcolea, et al., Balancing the risks and benefits of pet ownership in pediatric transplant recipients, Transplantation. 107 (2023) 855–866, https://doi.org/10.1097/TP.0000000000004419.
[7] L. Platero, P. Garcia-Sanchez, T. Sainz, C. Calvo, I. Iglesias, F. Esperon, et al., Pets for pediatric transplant recipients: to have or not to have, Front. Vet. Sci. 2022 (9) (2022), 974665, https://doi.org/10.3389/fvets.2022.974665.
[8] M. Evason, M. McGrath, J. Stull, Companion animal preventive care at a veterinary teaching hospital - knowledge, attitudes, and practices of clients, Can. Vet. J. 62 (2021) (2021) 484–490.
[9] P. Garcia-Sanchez, E. Aguilar-Valero, T. Sainz, C. Calvo, I. Iglesias, D. Bueno, et al., Immunocompromised children and young patients living with pets: gaps in knowledge to avoid zoonosis, Transbound. Emerg. Dis. (2023), e2151761, https://doi.org/10.1155/2023/2151761.
[10] C. Roussel, J. Drake, J.M. Ariza, French national survey of dog and cat owners on the deworming behaviour and lifestyle of pets associated with the risk of endoparasites, Parasit. Vectors 12 (2019) 480, https://doi.org/10.1186/s13071-019-3712-4.
[11] B.I. Wallace, B. Kenney, P.N. Malani, D.J. Clauw, B.K. Nallamothu, A.K. Waljee, Prevalence of immunosuppressive drug use among commercially insured US adults, 2018-2019, JAMA Netw. Open 4 (2021), e214920, https://doi.org/10.1001/jamanetworkopen.2021.4920.
[12] M. De Giusti, D. Barbato, L. Lia, V. Colamesta, A.M. Lombardi, D. Cacchio, et al., Collaboration between human and veterinary medicine as a tool to solve public health problems, Lancet Planet Health 3 (2019) e64–e65, https://doi.org/10.1016/S2542-5196(18)30250-X.
[13] ESCCAP, ESCCAP Guideline 01 Sixth edition- May 2021. Warm control in dogs and cats, 2021. https://www.esccap.org/uploads/docs/oc1bt50t_0778_ESCCAP_GL1_v15_1p.pdf (accessed 15 July 2023).
[14] R.K. Avery, M.G. Michaels, AST infectious diseases Community of Practice. Strategies for safe living following solid organ transplantation-guidelines from the American Society of Transplantation infectious diseases Community of Practice, Clin. Transpl. 33 (2019), e13519, https://doi.org/10.1111/ctr.13519.
[15] K.E. Creevy, J. Grady, S.E. Little, G.E. Moore, B.G. Strickler, S. Thompson, et al., AAHA Canine Life Stage Guidelines, J. Am. Anim. Hosp. Assoc. 55 (2019) (2019) 267–290, https://doi.org/10.5326/JAAHA-MS-6999.
[16] M.J. Day, M.C. Horzinek, R.D. Schultz, R.A. Squires, Vaccination guidelines group (VGG) of the world small animal veterinary association (WSAVA). WSAVA guidelines for the vaccination of dogs and cats, J. Small Anim. Pract. 57 (2016) E1–45, https://doi.org/10.1111/jsap.2_12431.
[17] J. Quimby, S. Gowland, H.C. Carney, T. DePorter, P. Plummer, J. Westropp, AAHA/AAFP Feline Life Stage Guidelines, J. Feline Med. Surg. 23 (2021) (2021) 211–233, https://doi.org/10.1177/1098612X21993657.
[18] M. Tomblyn, T. Chiller, H. Einsele, R. Gress, K. Sepkowitz, J. Storek, et al., Guidelines for preventing infectious complications among hematopoietic cell transplantation recipients: a global perspective, Biol. Blood Marrow Transplant. 15 (2009) 1143–1238, https://doi.org/10.1016/j.bbmt.2009.06.019.
[19] B.M. Blair, Safe living following solid organ transplantation, Surg. Clin. North Am. 99 (2019) 153–161, https://doi.org/10.1016/j.suc.2018.09.011.
[20] Animal's Health, Las cifras del sector de la salud de los animales de compañía de España en 2022. https://www.animalshealth.es/empresas/cifras-sector-salud-de-animales-compania-espana-2022, 2022 (accessed 4 July 2023).
[21] H. Taherdoost, Determining sample size; how to calculate survey sample size, Int. J. Econ. Manage. Syst. 2 (2017) 237–239. https://ssrn.com/abstract=3224205 (accessed 23 June 2023).
[22] A. Getis, J.K. Ord, The analysis of spatial association by use of distance statistics, in: L. Anselin, S. Rey (Eds.), Perspectives on Spatial Data Analysis, Advances in Spatial Science (The Regional Science Series), Springer, Berlin, 2010.
[23] CNIG, Human population per municipality 2016, National Centre for Geographical Information, 2016. http://www.ign.es (accessed 21 August 2023).
[24] P. Fernández, M.A. Iborra, M. Simón, M. Segovia, Outbreak of chlamydia psittaci pneumonia in the region of Murcia, Enferm. Infecc. Microbiol. Clin. 38 (2020) 300–301, https://doi.org/10.1016/j.eimc.2020.01.006.
[25] S. Herrero-Cófreces, F. Mougeot, T. Sironen, H. Meyer, R. Rodríguez-Pastor, J. J. Luque-Larena, Viral Zoonoses in small wild mammals and detection of hantavirus, Spain, Emerg. Infect. Dis. 28 (2022) 1294–1296, https://doi.org/10.3201/eid2806.212508.
[26] ISCII, Informe epidemiológico sobre la situación de la Tularemia en España, in: Resultados de la notificación a la Red Nacional de Vigilancia Epidemiológica de los años 2019, 2020 y 2021, 2022. https://www.isciii.es/QueHacemos/Servicios/VigilanciaSaludPublicaRENAVE/EnfermedadesTransmisibles/Documents/archivos%20A-Z/Tularemia/Tularemia_RENAVE_2019-2021%20Final.pdf (accessed 4 September 2023).
[27] K. Hatam-Nahavandi, R. Calero-Bernal, M.T. Rahimi, A.S. Pagheh, M. Zarean, A. Dezhkam, et al., Toxoplasma gondii infection in domestic and wild felids as public health concerns: a systematic review and meta-analysis, Sci. Rep. 11 (2021) 9509, https://doi.org/10.1038/s41598-021-89031-8.
[28] J. Sroka, J. Karamon, J. Dutkiewicz, A. Wójcik Fatla, V. Zając, T. Cencek, Prevalence of toxoplasma gondii infection in cats in southwestern Poland, Ann. Agric. Environ. Med. 25 (2018) 576–580, https://doi.org/10.26444/aaem/94675.
[29] G. Deksne, A. Petrusēviča, M. Kirjušina, Seroprevalence and factors associated with toxoplasma gondii infection in domestic cats from urban areas in Latvia, J. Parasitol. 99 (2013) 48–50, https://doi.org/10.1645/GE-3254.1.
[30] A.J. Cook, R.E. Gilbert, W. Buffolano, J. Zufferey, E. Petersen, P.A. Jenum, et al., Sources of toxoplasma infection in pregnant women: European multicentre case-control study. European Research Network on Congenital Toxoplasmosis, BMJ. 321 (2000) 142–147, https://doi.org/10.1136/bmj.321.7254.142.
[31] J. Drake, S. Sweet, K. Baxendale, E. Hegarty, S. Horr, H. Friis, et al., Detection of Giardia and helminths in Western Europe at local K9 (canine) sites (DOGWALKS study), Parasit. Vectors 15 (2022) 311, https://doi.org/10.1186/s13071-022-05440-2.
[32] S. Sweet, E. Hegarty, D.J. McCrann, M. Coyne, D. Kincaid, D. Szlosek, A 3-year retrospective analysis of canine intestinal parasites: fecal testing positivity by age, U.S. geographical region and reason for veterinary visit, Parasit. Vectors 14 (2021) 173, https://doi.org/10.1186/s13071-021-04678-6.
[33] Z. Ner, L.A. Ross, M.V. Horn, T.G. Keens, E.F. MacLaughlin, V.A. Starnes, et al., Bordetella bronchiseptica infection in pediatric lung transplant recipients, Pediatr. Transplant. 7 (2003) 413–417, https://doi.org/10.1034/j.1399-3046.2003.00074.x.
[34] J.J. Gisel, L.M. Brumble, M.M. Johnson, Bordetella bronchiseptica pneumonia in a kidney-pancreas transplant patient after exposure to recently vaccinated dogs, Transpl. Infect. Dis. 12 (2010) 73–76, https://doi.org/10.1111/j.1399-3062.2009.00451.x.
[35] J.E. Moore, J.C. Rendall, B.C. Millar, A doggy tale: risk of zoonotic infection with Bordetella bronchiseptica for cystic fibrosis (CF) patients from live licenced bacterial veterinary vaccines for cats and dogs, J. Clin. Pharm. Ther. 47 (2022) 139–145, https://doi.org/10.1111/jcpt.13492.
[36] M. Dróżdż, M. Małaszczuk, E. Paluch, A. Pawlak, Zoonotic potential and prevalence of Salmonella serovars isolated from pets, Infect. Ecol. Epidemiol. 11 (2021) 1975530, https://doi.org/10.1080/20008686.2021.1975530.
[37] J.R. Mead, Early immune and host cell responses to Cryptosporidium infection, Front. Parasitol. 2 (2023) 1113950, https://doi.org/10.3389/fpara.2023.1113950.

[38] J.D. Nosanchuk, S. Shoham, B.C. Fries, D.S. Shapiro, S.M. Levitz, A. Casadevall, Evidence of zoonotic transmission of Cryptococcus neoformans from a pet cockatoo to an immunocompromised patient, Ann. Intern. Med. 132 (2000) 205–208, https://doi.org/10.7326/0003-4819-132-3-200002010-00006.

[39] M. Florek, U. Nawrot, A. Korzeniowska-Kowal, K. Włodarczyk, A. Wzorek, A. Woźniak-Biel, et al., An analysis of the population of Cryptococcus neoformans strains isolated from animals in Poland, in the years 2015-2019, Sci. Rep. 11 (2021) 6639, https://doi.org/10.1038/s41598-021-86169-3.

[40] A.C. Gushiken, K.K. Saharia, J.W. Baddley, Cryptococcosis, Infect. Dis. Clin. N. Am. 35 (2021) 493–514, https://doi.org/10.1016/j.idc.2021.03.012.

[41] G. Boseret, B. Losson, J.G. Mainil, E. Thiry, C. Saegerman, Zoonoses in pet birds: review and perspectives, Vet. Res. 44 (2013) 36, https://doi.org/10.1186/1297-9716-44-36.