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EXPERIMENTAL

Would it be safe to have a dog in the MRI scanner before your own examination? A multicenter study to establish hygiene facts related to dogs and men

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Abstract

Objectives To determine whether it would be hygienic to evaluate dogs and humans in the same MRI scanner.

Methods We compared the bacterial load in colony-forming units (CFU) of human-pathogenic microorganisms in specimens taken from 18 men and 30 dogs. In addition, we compared the extent of bacterial contamination of an MRI scanner shared by dogs and humans with two other MRI scanners used exclusively by humans.

Results Our study shows a significantly higher bacterial load in specimens taken from men's beards compared with dogs' fur ($p = 0.036$). All of the men (18/18) showed high microbial counts, whereas only 23/30 dogs had high microbial counts and 7 dogs moderate microbial counts. Furthermore, human-pathogenic microorganisms were more frequently found in human beards (7/18) than in dog fur (4/30), although this difference did not reach statistical significance ($p = 0.074$). More microbes were found in human oral cavities than in dog oral cavities ($p < 0.001$). After MRI of dogs, routine scanner disinfection was undertaken and the CFU found in specimens isolated from the MRI scanning table and receiver coils showed significantly lower bacteria count compared with "human" MRI scanners ($p < 0.05$).

Conclusion Our study shows that bearded men harbour significantly higher burden of microbes and more human-pathogenic strains than dogs. As the MRI scanner used for both dogs and humans was routinely cleaned after animal scanning, there was substantially lower bacterial load compared with scanners used exclusively for humans.

Key points

- *Bearded men harbour significantly more microbes than dogs.*
- *Dogs are no risk to humans if they use the same MRI.*
- *Deficits in hospital hygiene are a relevant risk for patients.*

Keywords Hygiene · Cross infection · Disinfection · Animal experiments

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Introduction

Regardless of whether you like animals in general or dogs in particular, it is indisputable that dogs have been close companions of human beings since wolves were first domesticated about 40,000 years ago [1]. Dogs are integral members of many families and perform many services for human beings, for example as police dogs, military dogs or as a "life-long friend".

According to figures supplied by the European Union, around 500 million people live in Europe [2]. The number of pets, in particular dogs, is increasing in Europe and worldwide. According to the European Statistics Office, about 80 million dogs live in Europe [3]—a number equal to the total population of Germany [4]. Like humans, dogs have enjoyed longer life expectancies in recent decades. This can be explained by improved species-appropriate living conditions and better veterinary care [5]. Like humans, however, dogs are afflicted by age-related diseases similar to human diseases [6], for which imaging may be helpful for disease management planning.

To our knowledge, there are only a few veterinary clinics in Europe and worldwide equipped with dedicated animal scanners. One reason for the limited scanner availability is the cost of medical diagnostics for animals, costs which are almost always paid privately by the animals' owners. For this reason, financing of expensive large equipment for animals is more difficult. Although no exact figures are available, ultimately there are too few animal scanners for the large number of sick dogs worldwide. Frequently, pet owners are willing to pay considerable amounts of money for diagnostics and treatment. In the USA alone, pet owners spend US$11.1 billion annually on animal care [7]. There are ongoing discussions among veterinarians on how to increase imaging diagnostics at a time when there are simply not enough MRI scanners available for veterinary use.

It is obvious that the question will arise, in developed countries, as to whether a vacant or underutilized human MRI scanner may be made available for animal imaging. There are many reasons to be sceptical about examining animals in scanners intended for human use. One of the main reasons for this scepticism is the legitimate concern of hygiene. People are afraid that they will contract a zoonosis if they share scanners with their furry friends. However, it has previously been shown that domestic dogs and members of their households share bacterial populations [8]. However, less is known regarding the bacterial environment of dogs and the possible risk the associated bacteria pose to humans.

The main objective of this prospective multicenter study is to determine whether it would be hygienic to evaluate dogs and humans in the same MRI scanner by comparing the microbial flora of dogs and humans. With rising numbers of healthcare-associated infections (HAI), this is an important quality issue for patient care that should be addressed.

Material and methods

The bacteriological investigations of dogs, humans and MRI scanners were conducted between July and September 2017. General authorization was granted for the study by the local ethics commission.

We sequentially examined dogs that were scheduled for a routine investigation of neurological disorders affecting the brain or spinal cord at institute 1. Institute 1 is a European hospital radiology department performing about 8000 human MRI examinations and a variable, low number of canine MRI examinations per year.

The dogs were strictly separated from the human patients. After these canine radiologic examinations, standardized cleaning and disinfection of the exposed scanner was performed, after which regular MRI examinations of humans were resumed. The coils were used without protective films and had direct contact with the animals. After the cleaning and disinfection process, the bacteriological load of the MRI scanner at institute 1 was determined.

In addition, the bacteriological load of MRI scanners at two other European institutes (institutes 2 and 3), where only humans are examined (and never animals), were also measured.

Measurement of bacterial load of dogs

Dogs were anesthetized in an anteroom outside MRI by a specialist in veterinary medicine (FS). Intravenous access was achieved via leg cannulation and premedication comprising medetomidine (5–10 mg/kg of body weight) followed by individualized propofol injection was administered to maintain adequate levels of sedation.

While the dogs were under anesthesia, a targeted bacteriological assay was performed in the neck of each dog between the shoulder blades. We used a regular knock-out plate for this purpose (TSA TLHTh Contact plate, VWR Chemicals, Leuven, Belgium) in-between for 10 s. We examined the neck region, since according to information from the veterinarians, this is one of the few representative places on dogs that is particularly unhygienic and where most of the skin infections are encountered.

This was followed by an examination of the oral mucosa in the left half of the dog's oral cavity. For this, we used a standardized swab (eSwab, Copan, Italy) (Figs. 1, 2). MRI was always performed using standard surface receiver coil for the head (16-channel head coil) and the 32-channel body coil.

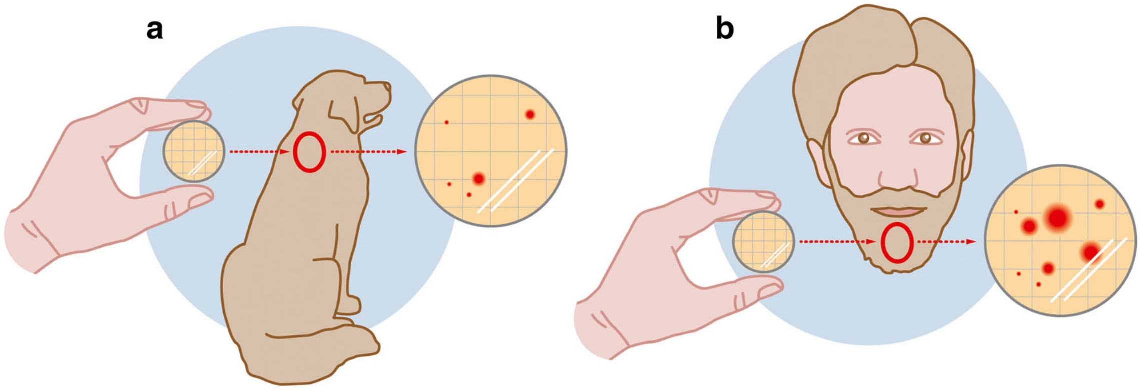


Fig. 1 While the dogs were under anesthesia a targeted bacteriological assay was performed in the neck of each dog between the shoulder blades (**a**). The surfaces of the human beard, like the sample dog hairs, were sampled by means of an agar plate (**b**)

The specimens were analysed at an internationally recognized laboratory to determine the number of colony-forming units (CFU) and the identification of microbes.

Measurement of bacterial loads of humans

We prospectively examined men with beards who were scheduled for a routine MRI examination in three different European radiological departments (institutes 1–3).

The beards were examined by means of an agar plate. The plates were pressed cautiously onto the beard (TSA TLHTh Contact plate) for 10 s. This was followed by an examination of the oral mucosa in the left halves of the men's mouths. For this purpose, we used swabs (eSwab, Copan, Italy) (Fig. 2). All patients were outpatients and had not been hospitalized during the last 12 months.

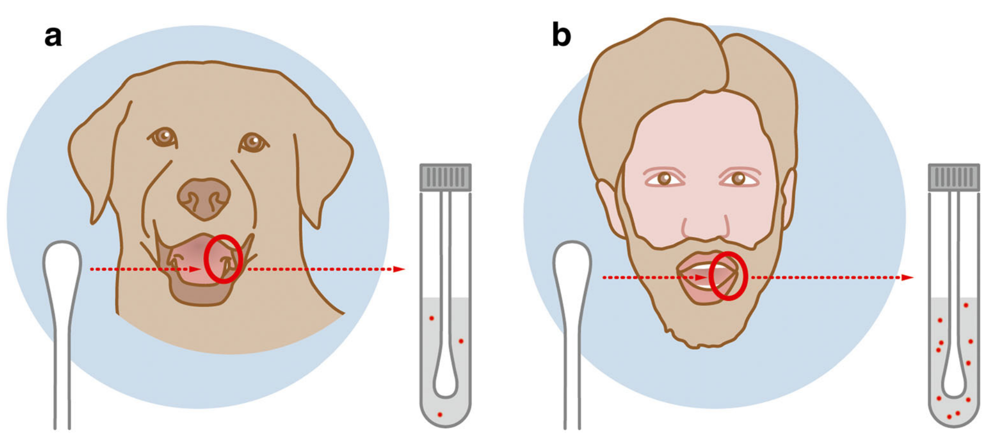
Following the bacteriological examination, we documented the respective beard lengths by gently pulling on the beard hair and measuring the length in centimetres with a ruler. The hair length was subdivided into three groups: group 1, 0–1 cm; group 2, 1.1–2 cm; group 3, more than 2.1 cm. The measurements were carried out by three trained examiners (AG, JG, JG).

Measurement of bacterial surface load of MRI scanners

Humans and dogs were always examined in the same scanner but separately at different time points at one institute (institute 1) using a 1.5-T MRI system (Avanto Fit, Siemens Healthcare). The same surface coils were used for all examinations in dogs and humans (16-channel head coil and 32-channel XL surface coil, Siemens Healthcare). On this scanner (institute 1), the bacteriological assay was performed either between clinical routine and/or after routine cleaning at the end of the time slots allotted to dogs. Three standardized samplings were performed each on three different days, taken from the surface of the patient table as well as at both entrances to the gantries (Fig. 3). In addition, a bacteriological sample was taken from the contact surface with the MR coil (Fig. 3).

A commercially available alcohol-free disinfection wipe (Septiwipe®, Medical Services Group, UK) was used to clean the MRI scanner and receiver coils after each canine examination. Cleaning and disinfection of the MRI scanner and coil took an average of 120 s. The MRI machine surfaces and the coil were wiped using regular hand movements in one direction. Cleaning of the MRI scanner was always begun with the surface of the patient table and then the surface and bore

Fig. 2 The oral mucosa in the left halves of dogs (**a**) and left buccal region of men (**b**) were examined using a swab



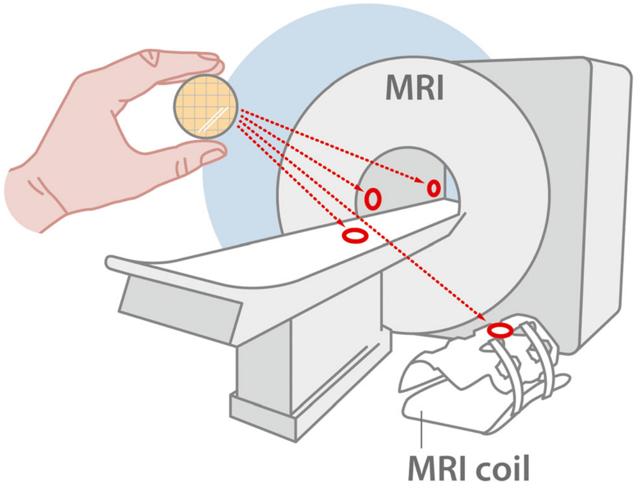


Fig. 3 For every MRI scanner, three samplings were performed on three different days on the same patient table as well as in both entrances to the gantry and on the surface of MR coil. In case of the dog imaging studies, the sampling was done immediately after the cleaning and disinfection process at the same locations described above

gantry of the machine. Regular hospital routine does not include MRI scanner or receiver coil disinfection as part of the clinical workflow processes.

At two other radiological institutes (institutes 2 and 3), participating in the study, only humans are evaluated with their MRI scanners and receiver coils. At institute 2, a 1.5-T MRI (Aera, Siemens Healthcare) was available. At institute 3, a 3-T MRI (Skyra, Siemens Healthcare) system was available. Both institutes employed a 16-channel head coil and a 32 XL surface receiver coil (Siemens Healthcare) in clinical routine. In each of these scanners, three bacteriological samplings similar to the one performed in institute 1 were also performed on three different days including the scanner table as well as at both entrances to the gantry. The measurement sites were similar to those described above for institute 1 (Fig. 3). Dedicated cleaning and disinfection are not part of the normal clinical routine on MRI scanners used exclusively for human patients.

Classification of microbe counts into groups

The numbers of CFU were divided into three groups for the purpose of statistical comparison. The group with a "low" number of germs included CFU counts between 0 and 10 per plate. The group with a "moderate" bacterial load included CFU counts between 11 and 30 per plate. The group with a "high" number of germs exhibited 31 or more CFU on the agar plate and had been sampled from the buccal mucosa. The classification of CFU into these three categories is a standard approach for quantification in international hospital hygiene and standardized the description of the degree of contamination.

Statistics

The groups were compared using a Fisher's exact test for categorical variables or a Mann–Whitney *U* test for quantitative variables.

All analyses were performed using the R programming language (version 3.3.3) (R Core Team, 2017). The package "table one" (Yoshida and Bohn, 2015) was used to compute descriptive statistics and Fisher's exact tests or Mann–Whitney *U* tests. For all tests, a *p* value less than 0.05 was taken to statistically significant.

Results

A total of 18 bearded men were included in the study. The median age of the participants was 36 years (range 18–76 years). Five men had a beard length in group 1 (beard hair length 0–1 cm), four men were assigned to group 2 (beard hair length 1.1–2 cm) and nine men were in group 3 (beard hair length of more than 2.1 cm). There was no statistical difference in the distribution of men between the three different beard-length groups ($p > 0.05$).

A total of 30 dogs were included in the study. The median age of the dogs was 3.8 years (range 3 months–13 years). The breeds of the dogs are summarized in Table 1.

Comparison of bacterial load in men's beards and dogs' coats

There were significantly more CFU in men's beard compared with dogs' fur ($p = 0.036$).

A total of 18/18 men displayed high microbe counts, while 7 dogs exhibited moderate microbe counts and 23 dogs had high microbe counts.

More human-pathogenic bacteria were found in the men's beard than in the dogs' fur. In 7/18 humans and 4/30 dogs, we found human-pathogenic bacteria. However, this difference does not meet statistical significance ($p = 0.074$).

The seven human-pathogenic bacteria in men included five cases of *Enterococcus faecalis* and two cases of *Staphylococcus aureus*.

The four human-pathogenic bacteria found in the dogs coat included one case of *Staphylococcus aureus,* two cases of *Moraxella* spp. and one case of *Enterococcus* sp. (Table 2).

Comparison of bacterial load in buccal mucosa of men and dogs

There were significantly more microbes present in the oral cavities of the human subjects than in the oral cavities of the canine subjects ($p < 0.001$).

Table 1 Inclusion of different breeds with normal distribution

Breed	Number of dogs	Breed	Number of dogs
1 Border Collie	2	9 Cane Corso	1
2 Weimaraner	1	10 German Shepherd Dog	3
3 Dalmatian	1	11 Dachshund	2
4 Yorkshire Terrier	1	12 Airdale Terrier	1
5 Rhodesian Ridgeback	2	13 Golden Retriever	3
6 Pekinese	3	14 Labrador	3
7 Schnauzer	1	15 Sight Hound	1
8 French Bulldogs	4	16 Beagle	1

One man had a low number of microbes in his oral cavity, none displayed moderate microbe counts and 17 yielded high microbe counts in their oral cavities. A total of 9 dogs had a low number of microbes in their mouths, 9 dogs displayed moderate microbe counts and 12 dogs presented high microbe counts in their oral cavities.

However, we found human-pathogenic microbes (e.g. *Serratia marcescens*) in only 1/18 men. The rest of the microbial population comprised normal oral flora. However, in 19/30 canine subjects, we found microbes that are potentially pathogenic in humans: 3 cases of *Pasteurella sp.*, 14 cases of *Pasteurella canis*, 1 case of *Escherichia coli* and 1 case of *Enterococcus faecalis* ($p < 0.001$) (Table 3).

Comparison of bacterial load in scanners used exclusively for human patients and of scanners used by both humans and dogs

The number of bacterial CFU isolated from MRI scanners used by both humans and animals (institute 1) during the daily clinical routine showed no difference compared with MRI scanners used by patients (institutes 1, 2 and 3) ($p = 0.910$). At all three institutes, no human-pathogenic microbes were found in any of the scanners.

Following cleaning and disinfection after the examinations with dogs, the number of bacterial CFU in the specimens from the MRI scanner at institute 1 showed significantly lower

Table 2 Comparing the bacteriological load and the proportion of human-pathogenic microbes between men's beard and dog's fur

Number of bacterial CFU			
	Beard of men (%)	Fur of dogs (%)	*p* value
Low	0 (0.0)	0 (0.0)	0.036
Moderate	0 (0.0)	7 (23.3)	
High	18 (100.0)	23 (76.7)	
Presence of human-pathogenic microbes			
	Beard of men (%)	Fur of dogs (%)	*p* value
No	11 (61.1)	26 (86.7)	0.074
Yes	7 (38.9)	4 (13.3)	

Table 3 Comparing the bacteriological load and the proportion of human-pathogenic microbes within the oral cavities of men and dogs

Number of bacterial CFU			
	Oral cavities of men (%)	Oral cavities of dogs (%)	*p* value
Low	1 (5.6)	9 (30.0)	< 0.001
Moderate	0 (0.0)	9 (30.0)	
High	17 (94.4)	12 (40.0)	
Presence of human-pathogenic microbes			
	Oral cavities of men (%)	Oral cavities of dogs (%)	*p* value
No	17 (94.4)	11 (36.7)	< 0.001
Yes	1 (5.6)	19 (63.3)	

numbers of bacteria compared with scanners used by humans during clinical routine (institutes 1, 2 and 3) (p = 0.004). Following disinfection of the animal scanner at institute 1, there was a mean of 0 microbes isolated compared with a mean value of 5 CFU from the MRI scanners of institutes 1, 2 and 3 during clinical routine (Table 4).

Comparison of bacterial load from coils used exclusively in patients and bacterial load from coils used by both humans and dogs

The number of bacterial CFU in specimens isolated from MRI coils used by both humans and dogs (institute 1) showed no statistical differences compared with the number of bacterial CFU in specimens from coils in all institutes during clinical routine (p = 0.926).

At institute 1, the bacterial CFU reached a mean value of 47 during clinical routine, whereas all institutes during clinical routine had a mean value of 10 CFU. There was no statistical difference for the presence of human-pathogenic bacteria (p = 0.509). In addition, we found no human-pathogenic microbes in the samples originating from the scanner at institute 1, while the specimens from institutes 2 and 3 (3 × *Staphylococcus aureus*) were positive.

The number of microbes found on the receiver coil from the MRI unit used for dogs (institute 1) after cleaning was significantly lower than the number of microbes in the coils used in all institutes during clinical routine (p = 0.012). At institute 1 the number of bacterial CFU in the specimens obtained was 0, whereas the specimens taken from all the coils during clinical routine had a mean bacterial CFU of 10 (Table 5).

Table 4 Comparing the bacteriological load of MRI scanners during clinical routine, after dog studies and following the standardized cleaning and disinfection process

	All scanners (institute 1 + 2 + 3) during normal clinical routine (N = 27)	Scanner institute 1 (N = 9)	p value
Mean (±sd) CFU/plate during normal clinical routine	5 (±10)	7 (±11) (Normal routine with humans)	0.910
Mean (±sd) CFU/plate during normal clinical routine (institute 1+2+3) versus scanner at institute 1 after dogs examination (±sd)	5 (±10)	0.1 (±0.3) After dogs and disinfection	0.004
Presence of human-pathogenic bacteria (% of coils)	0 (0.0)	0 (0.0) After dogs and disinfection	

Table 5 Comparing the bacteriological load and the proportion of human-pathogenic microbes on the MRI surface receiver coils

	All MRI coils (institutes 1 + 2 + 3) during normal routine (N = 9)	MRI coils institute 1 (N = 3)	p value
Mean (±sd) CFU normal routine with humans	10 (±9)	47 (±76) clinical routine	0.926
Mean (±sd) CFU during normal routine with humans (institute 1 + 2 + 3) versus scanner institute 1 after dogs (±sd)	10 (±9)	0.0 (±0.0)	0.012
Presence of human-pathogenic bacteria during routine (%)	3 (33.3) only from institutes 2 and 3	0 (0.0)	0.509

Discussion

In this study men have a significantly higher bacterial load in their beards than dogs have in their fur. More human-pathogenic bacteria were found in the men's beard than in the dogs' fur. Furthermore, dogs have a smaller total number of microbes in their oral cavities than humans. No microorganisms causing zoonotic diseases could be detected in the environmental probes sampled in the MRI scanners after the canine exams. On the basis of these findings, dogs can be considered as "clean" compared with bearded men. We also showed that MRI scanners and receiver coils used for clinical studies bear considerable bacterial contamination risk with human-pathogenic microbes. After dog examinations and standardized scanner disinfection, the scanners are clean and have almost no detectable remaining bacteria.

The decision to permit the examination of dogs in MRI units used for clinical human studies varies across institutions, with a proportion viewing this as posing significant risk without good evidence. From a hygiene point of view, considering our results, it can even be advantageous as disinfection of the scanner following a dog examination renders the scanner almost sterile, which may not be the case following a clinical examination without any cleaning and/or disinfection process.

The hygiene standards across hospital practices remain heterogeneous, with each adopting different practices to minimize healthcare associated infections (HAIs) infection. Despite great efforts to lower the rate of HAIs, deficits in hospital hygiene have been repeatedly reported. For example, it was recently found that ultrasound probes in European hospitals contain more pathogenic microbes than toilet seats and poles on public buses [9, 10]. Hence, evidence-based practices in this area can help to balance the optimal use of our imaging facilities with the need to ensure patient safety.

According to recent scientific data, there are far too many human-pathogenic microbes in hospital areas, resulting in a constant risk for patients in contracting HAIs [11]. The estimated number of HAIs in US hospitals was calculated to be approximately 1.7 million patients per year. The death rate in the USA attributable to HAIs was around 100,000 patients per year [12]. The direct cost of HAIs ranges from US$28 billion to US$45 billion per year, which has a tremendous impact on health economics worldwide [13]. Over the last few years, an increasing number of nosocomial infections have been observed in hospitals, and an increasing number of resistant bacterial strains have been described. The reason for this is the indiscriminate administration of antibiotics but also the poor hygiene conditions in hospitals and other healthcare settings dealing with patients [14]. In the USA, one out of 25 patients contracts at least one infection during his or her hospital stay every day. In Switzerland, the estimated rate of HAIs has been reported to be 5.9% [15]. It must be pointed out that nearly all HAIs are preventable [16].

In our efforts to reduce HAI, the central question should perhaps not be whether we should allow dogs to undergo imaging in our hospitals, but rather we should focus on the knowledge and perception of hygiene and understand what poses real danger and risk to our patients. The question of how informed hospital staff are concerning hygiene and effectiveness in reducing the specific risk is also critical. In a well-managed and hygiene-aware department, the question of whether a dog has undergone an MRI examination prior to clinical human scanning should therefore become irrelevant. To our knowledge there are no international standards for MRI hygiene, which seems to be organized individually in each hospital. There are few publications of hygiene and animals without clear recommendations for radiology departments [17–19].

As a result of limited diagnostic possibilities, however, there is a lack of dedicated examination sites for canines despite a rapidly rising need. Opening the imaging facilities to dogs under these circumstances is essential. This study shows that dogs do not pose a hygiene risk if they are examined in scanners originally dedicated to humans. On the contrary, since MRI devices are rarely cleaned during routine use in hospitals, the diagnostic equipment cleaned meticulously after the dog examination almost reaches bacteriologically sterile conditions.

In addition to the social tasks of dogs, there is often uncertainty in animal experiments. From a hygiene point of view, it is important to clarify if it is possible to examine animals in the MRI of a human hospital. The data in this presented study should further objectify the discussion.

Limitations of this study

First, we only investigated the hygiene conditions of the MRI scanners at three European hospitals. Hence, we cannot be certain to what extent our findings can be generalized. However, it is likely that the hospitals included in our study and their hygiene practices are representative of hospitals elsewhere in Europe. Second, we only examined 30 dogs and 18 bearded men. There is a gender bias in our study population as no women were included in our study. There is no reason to believe that women may harbour less bacteriological load than bearded men. However, this would need to be investigated in a separate study if there is scientific interest in this issue.

Finally, we did not explicitly look for other microorganisms such as worms. But we can confirm that no macroscopic visible contamination of the surfaces (i.e. with fleas or worms) was observed and we did not find fungal growth either.

Conclusion

In this prospective multicenter study, we showed that dogs do not pose a significant hygiene risk to humans even if they utilize the same MRI scan facility. The beards of men harbour significantly more microbes than the neck fur of dogs and these microbes were significantly more pathogenic to humans. As the MRI scanner used for imaging of the dogs was cleaned and disinfected more regularly, it is contaminated with substantially fewer human-pathogenic microbes than the scanners used exclusively by humans.

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Compliance with ethical standards

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Informed consent Written informed consent was waived by the institutional review board

Ethical approval Institutional review board approval was obtained.
Approval from the institutional animal care committee was obtained.

Methodology
• prospective
• experimental
• multicenter study

References

1. Udell M, Wynne CA (2008) Review of domestic dogs' (*Canis familiaris*) human-like behaviors: or why behavior analysts should stop worrying and love their dogs. J Exp Anal Behav 89:247–261
2. Eurostat (2018) Population and population change statistics. http://ec.europa.eu/eurostat/statistics-explained/index.php/Population_and_population_change_statistics. Accessed 28 Mar 2018
3. Statista (2018) Number of dogs in the European Union in 2017, by country (in 1000s). https://www.statista.com/statistics/414956/dog-population-european-union-eu-by-country/. Accessed 28 Mar 2018
4. Destatis (2017) Bevölkerung, Familien, Lebensformen. https://www.destatis.de/DE/Publikationen/StatistischesJahrbuch/Bevoelkerung.pdf?__blob=publicationFile. Accessed 28 Mar 2018
5. Klopfenstein M, Howard J, Rossetti M, Geissbühler U (2016) Life expectancy and causes of death in Bernese mountain dogs in Switzerland. BMC Vet Re 12:153
6. Cozzi B, Ballarin C, Mantovani R, Rota A (2017) Aging and veterinary care of cats, dogs, and horses through the records of three university veterinary hospitals. Front Vet Sci 4:14
7. AnimalScan (2013) Understanding MR imaging for your pet. http://animalscan.com/understanding-mr-imaging-for-your-pet/. Accessed 28 Mar 2018
8. Torres S, Clayton JB, Danzeisen JL et al (2017) Diverse bacterial communities exist on canine skin and are impacted by cohabitation and time. Peer J 5:e3075
9. Sartoretti T, Sartoretti E, Bucher C et al (2017) Bacterial contamination of ultrasound probes in different radiological institutions before and after specific hygiene training: do we have a general hygienical problem? Eur Radiol 27:4181–4187
10. Nyhsen CM, Humphreys H, Koerner RJ et al (2017) Infection prevention and control in ultrasound - best practice recommendations from the European Society of Radiology Ultrasound Working Group. Insights Imaging 8:523–535
11. Murphy RA, Chua AC (2016) Prevention of common healthcare-associated infections in humanitarian hospitals. Curr Opin Infect Dis 29:381–387
12. Klevens M, Edwards JR, Richards CL Jr et al (2007) Estimating health care-associated infections and deaths in U.S. hospitals, 2002. Public Health Rep 122:160–166
13. Stone PW (2009) Economic burden of healthcare-associated infections: an American perspective. Expert Rev Pharmacoecon Outcomes Res 9:417–422
14. Gerlich MG, Piegsa J, Schäfer C et al (2015) Improving hospital hygiene to reduce the impact of multidrug-resistant organisms in health care–a prospective controlled multicenter study. BMC Infect Dis 15:441
15. Hôpitaux Universitaires de Genève (2017) Point prevalence survey 2017 of healthcare-associated infections and antimicrobial use in Swiss acute care hospitals. https://www.swissnoso.ch/fileadmin/swissnoso/Dokumente/5_Forschung_und_Entwicklung/2_Punktpraevalenzstudie/Report_Point_Prevalence_Survey_2017_of_HAI_and_antimicrobial_use_in_Swiss_acute_care_hospitals.pdf. Accessed 16 Feb 2018
16. [No authors listed] (2015) Health care-associated infections in the USA. Lancet 385:304. https://doi.org/10.1016/S0140-6736(15)60101-5
17. Shen DT, Crawford TB, Gorham JR, McGuire TC (1977) Inactivation of equine infectious anemia virus by chemical disinfectants. Am J Vet Res 38:1217–1219
18. Scott FW (1980) Virucidal disinfectants and feline viruses. Am J Vet Res 41:410–414
19. Brown TT Jr (1981) Laboratory evaluation of selected disinfectants as virucidal agents against porcine parvovirus, pseudorabies virus, and transmissible gastroenteritis virus. Am J Vet Res 42:1033–1036