Article

Coagulase positive staphylococcal colonization of humans and their household pets

Beth A. Hanselman, Steven A. Kruth, Joyce Rousseau, J. Scott Weese

Abstract — *Staphylococcus aureus* colonization was identified in 67/242 (28%) humans, 19/132 (14%) dogs, and 7/161 (4.3%) cats in households in Ontario, with methicillin-resistant *S. aureus* present in 8 (3.3%) humans, 2 (1.5%) dogs, and 0 cats. *Staphylococcus pseudintermedius* was isolated from 8 (4.1%) humans, 61 (46%) dogs, and 11 (6.8%) cats, with methicillin-resistant *S. pseudintermedius* detected in 1 (0.4%) human, 6 (4.5%) dogs, and 2 (1.2%) cats. *Staphylococcus schleiferi* subspecies *coagulans* was isolated from 1 (0.8%) dog. Regular hand washing was a protective factor for *S. pseudintermedius* colonization in humans. Indistinguishable *S. aureus* isolates were present in humans and their dogs in 4/8 households, where *S. aureus* was isolated concurrently from humans and dogs. Similarly, indistinguishable human and feline strains were isolated in 1 of 2 households with concurrent human/feline colonization. Indistinguishable canine and human *S. pseudintermedius* isolates were present in 4/9 of households with a human who was colonized.

Résumé — Colonisation par des staphylocoques positifs à l'épreuve de la coagulase chez des personnes et leurs animaux familiers. La colonisation par *Staphylococcus aureus* a été identifiée chez 67/242 (28 %) personnes, 19/132 (14 %) chiens et 7/161 (4,3 %) chats dans des ménages en Ontario, et *S. aureus* résistant à la méthicilline était présent chez 8 (3,3 %) personnes, 2 (1,5 %) chiens et 0 chat. *Staphylococcus pseudintermedius* a été isolé chez 8 (4,1 %) personnes, 61 (46 %) chiens et 11 (6,8 %) chats, et *S. pseudintermedius* résistant à la méthicilline a été détecté chez 1 (0,4 %) personne, 6 (4,5 %) chiens et 2 (1,2 %) chats. La sous-espèce coagulans de *Staphylococcus schleiferi* a été isolée chez 1 (0,8 %) chien. Le lavage régulier des mains était un facteur de protection contre la colonisation par *S. pseudintermedius* chez les humains. Des isolats de *S. aureus* non distinguables étaient présents chez les personnes et leurs chiens dans 4/8 des ménages où *S. aureus* avait été isolé simultanément chez les humains et les chiens. Parallèlement, des souches humaines et félines non distinguables ont été isolées dans 1 de 2 ménages avec une colonisation concomitante humaine et féline. Des isolats non distinguables canins et humains de *S. pseudintermedius* étaient présents dans 4/9 des ménages avec un humain colonisé.

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Introduction

Coagulase-positive staphylococci are common commensal microorganisms and opportunistic pathogens in humans and animals. In particular, methicillin-resistant *Staphylococcus aureus* (MRSA), an important cause of nosocomial and community-associated infections in humans, has become increasingly recognized as a pathogen in companion animals (1–3). There have been several recent reports describing carriage of indistinguishable MRSA strains in humans and animals, as well as suspected interspecies transmission of MRSA between humans and companion animals within households (3–8); however, the dynamics of interspecies staphylococcal transmission are poorly understood.

Other coagulase-positive staphylococci are primarily of relevance for dogs and cats, namely *S. intermedius, S. schleiferi* subsp. *coagulans,* and *S. pseudintermedius.* These species are commensal organisms, but are also a cause of disease (such as pyoderma and otitis externa) in both dogs and cats (9–11). *Staphylococcus*

Departments of Clinical Studies (Hanselman, Kruth) and Pathobiology (Rousseau, Weese), Ontario Veterinary College, University of Guelph, Guelph, Ontario N1G 2W1.

Dr. Hanselman's current address is Mississauga Oakville Veterinary Emergency Hospital, 2285 Bristol Circle, Oakville, Ontario L6H 6P8.

Address all correspondence to Dr. J. Scott Weese; e-mail: jsweese@uoguelph.ca

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intermedius has been considered the predominant *Staphylococcus* sp. in dogs; however, recent evidence indicates that most or all isolates from dogs and cats previously identified as *S. intermedius* are actually the closely related *S. pseudintermedius* (9,12,13). Regardless of nomenclature, *S. intermedius* or *S. pseudintermedius* are rarely identified in humans, but a few reports have described some opportunistic infections (14–16), and higher rates of *S. intermedius* colonization have been reported in owners of dogs with *S. intermedius* pyoderma (17). Transmission of methicillin-resistant *S. intermedius* between a veterinarian and 5 dogs and 1 cat was suspected in a veterinary clinic (18). Despite these reports, there is limited information on the prevalence of coagulase-positive staphylococcal colonization in healthy dogs and cats, and minimal investigation into the possibility that these staphylococcal species may be transmitted between healthy humans and pets during normal household contact. It is important to examine these aspects of staphylococcal ecology in order to better understand the emergence of MRSA as a veterinary and zoonotic pathogen, to evaluate the risks of interspecies transmission of MRSA, and to determine appropriate household infection control practices.

The objectives of this study were to evaluate the prevalence of coagulase-positive staphylococcal colonization in humans and companion animals residing within a common residence; to determine the occurrence of concurrent colonization between humans and their dogs and cats; and to evaluate factors associated with concurrent coagulase-positive staphylococcal colonization in humans, dogs, and cats.

Materials and methods

Study population

A convenience sample of 122 households from southern Ontario was enrolled over a 2-month period from November to December, 2005. Inclusion criteria for households included individuals of any age, gender, or profession who resided with $\geq$ 1 dog and/or cat of any age, gender, or breed. Households were recruited on a voluntary basis from notices posted in 2 community centres, veterinary clinics in London, Strathroy, Guelph, Hamilton, Burlington, and Toronto, and in the Ontario Veterinary College. This study was approved by the University of Guelph Research Ethics Board and Animal Care Committee.

Sampling procedures

All consenting individuals within a household collected a single nasal swab themselves according to instructions that were provided. A cotton-tipped swab was inserted approximately 1 cm into each anterior nasal cavity. A single nasal and rectal swab was collected from each dog and/or cat within the household by the owner or a veterinary professional. Nasal swabs were collected by inserting the swab 0.5 to 1 cm into the nostrils, or by rubbing the swab over the external nares in the case of animals where the nares were too small for insertion of a swab. Rectal swabs were collected by inserting swabs 1 cm into the rectum. All swabs were placed in liquid Stuart's medium and maintained at 4°C until processing.

Owners completed a brief questionnaire at the time of sample collection investigating factors potentially associated with colonization such as age, gender, occupation (specifically noting healthcare workers and veterinary professionals), frequency of hand washing following contact with pets, previous (90 d) hospitalization, and previous (90 d) antimicrobial therapy of the individual or other members of the household. Questions on characteristics of each dog and cat in the household, including age, gender, breed, history of antimicrobial use, hospitalization or allergy therapy within the past 3 mo, and degree of owner contact with each pet, were included in the questionnaire.

Laboratory methods

Swabs were placed in 2 mL of enrichment broth consisting of 10 g/L Tryptone T, 75 g/L sodium chloride, 10 g/L mannitol, and 2.5 g/L yeast extract, for 24 h at 35°C. An aliquot of 100 μL broth was inoculated onto mannitol-salt agar and mannitol salt agar with 2 μg/mL oxacillin and incubated for 48 h at 35°C. Presumptive staphylococcal isolates were subcultured onto Columbia blood agar and incubated for 24 h at 35°C. Isolates were identified as coagulase-positive staphylococci based on colony morphology, gram-positive stain, positive catalase reaction and positive tube coagulase assay (BBL Coagulase Rabbit Plasma with EDTA; Fisher Scientific, Nepean, Ontario). *Staphylococcus aureus* was identified by biochemical tests, polymixin B resistance, and *S. aureus* latex agglutination test (Pastorex Staph Plus; Bio-Rad Laboratories, Mississauga, Ontario). *Staphylococcus pseudintermedius* and *S. schleiferi* were identified by polymixin B susceptibility and biochemical tests, and differentiated on the basis of positive or negative maltose and positive trehalose fermentation for *S. pseudintermedius* and negative maltose and trehalose fermentation for *S. schleiferi*. Methicillin-resistance was confirmed by demonstration of growth on Mueller Hinton agar with 6 μg/mL oxacillin for 24 h at 35°C and demonstration of penicillin binding protein (PBP) 2a antigen by latex agglutination test (Denka Seinken Company, Tokyo, Japan). Speciation of methicillin-resistant isolates was confirmed by sequencing of the *sodA* gene (13).

In situations where the same staphylococcal species was identified from both an animal and human in the same household, isolates were typed using *Sma*I pulsed-field gel electrophoresis, as has been described for MRSA (19). All methicillin-resistant isolates were tested for Panton-Valentine leukocidin (PVL) genes *luk*S and *luk*F using real-time PCR (20).

Statistical analysis

The prevalence of methicillin-sensitive and methicillin-resistant coagulase-positive staphylococcal colonization (*S. aureus, S. pseudintermedius, S. schleiferi* subsp. *coagulans*) in humans, dogs, and cats was calculated. Categorical comparisons were performed using chi-squared analysis, Fisher's exact and McNemars test using exact *P*-values. A *P*-value of < 0.05 was considered significant for all comparisons. Risk factors for colonization were evaluated via stepwise forward logistic regression using a statistical software package (SAS 9.1; SAS Institute, Cary, North Carolina, USA). GLIMMIX, a general linear model for binomial data, was used to account for the random effect of household. If household was not significant, exact conditional

Table 1. Prevalence of *Staphylococcus aureus, S. pseudintermedius, S. schleiferi* subsp. *coagulans,* methicillin-resistant *S. aureus* (MRSA), methicillin-resistant *S. pseudintermedius* (MRSP) and methicillin-resistant *S. schleiferi* subsp. *coagulans* (MRSS) in humans, dogs, and cats in households

	S. aureus *n* (%)	*S. pseudintermedius* *n* (%)	*S. schleiferi* *n* (%)	MRSA *n* (%)	MRSP *n* (%)	MRSS *n* (%)
Humans (*n* = 242)	67 (27.7%)[a]	10 (4.1%)[a]	0[a]	8 (3.3%)[a]	1 (0.4%)[a]	0
Dogs (*n* = 132)	19 (14.3%)[b] Nasal: 13 (68.4%) Rectal: 5 (26%) Both: 1 (5.3%)	61 (46.2%)[b] Nasal: 14 (23%) Rectal: 37 (60.7%) Both: 9 (15%)	1 (0.8%)[a] Rectal: 1 (100%)	2 (1.5%)[a] Nasal: 2 (100%)	6 (4.5%)[b] Nasal: 2 (33%) Rectal: 4 (67%)	0
Cats (*n* = 161)	7 (4.3%)[c] Nasal: 4 (57%) Rectal: 2 (29%) Both: 1 (14%)	11 (6.8%)[a] Nasal: 2 (18%) Rectal: 7 (64%) Both: 2 (18%)	0[a]	0[a]	2 (1.2%)[a,b] Rectal: 2 (100%)	0

[a,b,c] Different superscripts within columns indicate statistically significant difference ($P < 0.05$).

logistic regression was used. Variables achieving a liberal significance level of $P \leq 0.20$ in the univariate logistic analyses were considered for inclusion in the multivariable model. Variables achieving a $P < 0.05$ in the final model were considered significant and odds ratios were calculated.

Results

Over a 2-month period, 122 households consisting of 242 humans, 132 dogs, and 161 cats were enrolled. Humans in the veterinary profession were over-represented, accounting for 104/242 (42.5%) participants.

Staphylococcus aureus

The prevalence of *S. aureus* colonization in humans was 27.7% (67/242) (Table 1). Younger age approached significance on multivariable analysis, ($P = 0.052$), with a mean age of 30 y for colonized individuals versus 34 y for noncolonized individuals. In dogs, the prevalence of *S. aureus* colonization was 14.3% (19/132). No variables were significantly associated with colonization on univariate or multivariable analysis. The anterior nares were the most common site of *S. aureus* colonization in dogs (68.4%, 13/19) compared with rectal colonization (26.3%, 5/19); however, the difference was not statistically significant ($P = 0.096$). The prevalence of *S. aureus* colonization was lowest in cats at 4.3% (7/161). There was no significant difference in nasal versus rectal colonization rates ($P = 0.69$). No variables were significantly associated with colonization. The prevalence of *S. aureus* colonization in dogs was significantly higher than in cats ($P = 0.002$, OR 3.7; 95% CI: 1.5–9.7). Colonization with *S. aureus* in humans was significantly more common than in dogs ($P = 0.003$, OR 2.3; 95% CI: 1.3–4.0) or cats ($P < 0.001$, OR 8.4; 95% CI: 3.7–19.3).

Methicillin-resistant *S. aureus* (MRSA)

The prevalence of MRSA nasal colonization in humans was 3.3% (8/242). There was no history of healthcare-associated risk factors in humans colonized with MRSA. Six of 8 colonized individuals were employed in the veterinary profession, consisting of 3 veterinarians, 1 veterinary technician, and 2 veterinary clinic staff. Being a veterinary professional approached significance of being associated with MRSA colonization in humans on univariate analysis ($P = 0.078$), but not multivariable analysis ($P = 0.270$). Similarly, lack of hand washing following contact with household pets also approached significance on univariate analysis ($P = 0.064$), but did not achieve significance in the multivariable model ($P = 0.135$).

Methicillin-resistant *S. aureus* colonization was identified in 2 dogs (1.5%); both from the anterior nares. Neither of the colonized dogs had a history of hospitalization or antimicrobial use. In 1 of the colonized dogs, however, the owners reported that a family member had been previously hospitalized and treated with antimicrobials within the past 3 mo. No cats were colonized with MRSA. Risk factor analyses for MRSA colonization in dogs and cats were not performed due to the low prevalence. All isolates were negative for the Panton-Valentine leukocidin.

Staphylococcus pseudintermedius

The prevalence of *S. pseudintermedius* nasal colonization was 4.1% (10/242) in humans, which was significantly lower than the prevalence of *S. aureus* colonization ($P < 0.001$, OR 6.7; 95% CI: 3.42–14.61). Lack of routine hand washing after handling household pets ($P = 0.045$, OR 1.97; 95% CI: 1.05–3.69) was significantly associated with *S. pseudintermedius* colonization in humans.

The prevalence of *S. pseudintermedius* colonization was significantly higher in dogs at 46.2% (61/132), than in humans ($P < 0.001$, OR 20; 95% CI: 9.6–44) or cats ($P < 0.001$, OR 11.6; 95% CI: 5.8–23.6). No risk factors for colonization were identified on univariate or multivariable analysis. In dogs, *S. pseudintermedius* colonization was significantly greater than *S. aureus* ($P < 0.001$, OR 1.2; 95% CI: 0.44–3.1), and rectal colonization (60.7%, 37/61) was significantly more common than nasal colonization (23.0%, 14/61) ($P = 0.001$, OR 1.4; 95% CI: 0.56–3.6).

The prevalence of *S. pseudintermedius* colonization in cats was significantly lower than in dogs at 6.8% (11/161) ($P < 0.001$, OR 0.09; 95% CI: 0.04–0.17) and no risk factors for colonization were identified. There was no significant difference between the prevalence of *S. pseudintermedius* colonization in cats versus humans ($P = 0.588$), nor was there a difference in rectal versus nasal colonization in cats ($P = 0.180$).

Methicillin-resistant *S. pseudintermedius* (MRSP)

Methicillin-resistant *S. pseudintermedius* colonization was identified in 1 (0.4%) human, 6 (4.5%) dogs, and 2 (1.2%) cats ($P = 0.01$). Risk factors were not evaluated because of the low prevalence. All isolates were negative for the Panton-Valentine leukocidin.

Staphylococcus schleiferi subsp. *coagulans*

The prevalence of *S. schleiferi* colonization was 0.8% (1/132) in dogs and 0% in humans and cats. The colonized dog also harboured *S. pseudintermedius.* No methicillin-resistant *S. schleiferi* (MRSS) were isolated from any source.

Comparison of staphylococcal isolates in households

Concurrent human and animal colonization with *S. aureus* was demonstrated in 10 (8.2%) households. *Staphylococcus aureus* isolates were indistinguishable between humans and their dogs in 4/8 households where *S. aureus* was isolated from both humans and dogs. Similarly, indistinguishable human and feline strains were isolated in 1 of 2 households where *S. aureus* was isolated from both humans and cats. Concurrent human and animal colonization by MRSA was not identified.

Indistinguishable canine and human *S. pseudintermedius* isolates were present in 4/9 of households with a colonized human. Concurrent human and feline colonization was not identified.

Discussion

The prevalence of nasal *S. aureus* colonization in humans (27.7%) was consistent with previous reports from the general population (21,22); however, the prevalence of *S. aureus* colonization in dogs (14.3%) was somewhat higher than expected, as it is not regarded as a commensal organism of dogs (23). When one considers that *S. aureus* is not typically considered to be a canine or feline commensal and that indistinguishable strains were found in humans and animals in 50% of households where both dogs or cats and a person were colonized, it is reasonable to suspect that interspecies transmission had occurred. Similarly, the finding of indistinguishable strains of *S. pseudintermedius,* which is not considered a commensal in humans, in 44% of households where both a dog and human were colonized, supports canine to human transmission. Cross-sectional studies such as this cannot definitively determine whether transmission occurred or the direction of transmission and common source infection cannot be ruled out. These data, however, suggest that interspecies transmission of commensal staphylococci may not be an uncommon event in households. This is not surprising when one considers the close nature of contact between humans and their pets, and reports indicating intra-household transmission of MRSA.

Based on published community studies, the prevalence of MRSA colonization in humans (3.3%) was somewhat higher than anticipated (22,24). High MRSA colonization rates have been reported in veterinary personnel (25–27) and the bias towards humans in the veterinary profession could have impacted the MRSA colonization rate; however, a significant association between employment in the veterinary profession and MRSA colonization was not identified.

The low prevalence of MRSA colonization in dogs (1.5%) was consistent with low rates reported in community-based studies in Ontario and elsewhere (23,28–30). Considering the rapid emergence of MRSA in humans in the community and the potential for interspecies transmission, continued surveillance is indicated to monitor colonization rates.

The prevalence of *S. pseudintermedius* colonization in humans (4.1%) was higher than expected, as this species has rarely been reported as a commensal organism in the nasal passages of healthy humans (15). A previous study demonstrated higher *S. intermedius* carriage in owners of dogs with deep pyoderma than in the general population (17) and it is possible that pet ownership or contact with dogs in the veterinary profession may have contributed to the relatively high prevalence of *S. pseudintermedius* colonization in this study. Because this study did not evaluate a non-pet-owning group, the influence of pets could not be determined. It was interesting to note that rare or infrequent hand washing after handling household pets was significantly associated with *S. pseudintermedius* colonization in humans. This is the first study suggesting that routine, household-based hand hygiene may be effective at reducing transmission of microorganisms between humans and pets in the household. The high prevalence of *S. pseudintermedius* colonization in dogs (46.2%) was not surprising.

The relatively high (4.5%) prevalence of MRSP colonization and high prevalence of methicillin resistance (9.8%) among *S. pseudintermedius* isolates from healthy dogs is concerning, particularly in light of recent reports of increasing rates of MRSI/MRSP in chronic pyoderma or otitis externa (10,31,32). The reason that MRSP was significantly more common in dogs compared with humans or cats likely relates to an overall increase in *S. pseudintermedius* colonization and the dog as a natural reservoir for this species; however, other factors such as antimicrobial use practices cannot be dismissed. The emergence of methicillin-resistance in *S. pseudintermedius* may be due to selection pressure from antimicrobial use or horizontal spread of resistance factors from MRSA within the community. Currently, MRSP appears to be a relatively uncommon cause of clinical infection in dogs in Ontario (unpublished observation); however, rates may be increasing and MRSP is a significant concern in some regions.

There were several limitations to this study. All data were collected at a single point in time; therefore, the length of colonization and direction of transmission could not be assessed. Furthermore, the absolute numbers of individuals colonized with staphylococcal species, with the exception of MSSA in humans and methicillin-sensitive *S. pseudintermedius* in dogs, were low, which limited the ability to evaluate risk factors. The data were collected as a convenience sample and participants were volunteers, which lead to a biased population with a high proportion of veterinary professionals. This may have resulted in a higher prevalence of MRSA and *S. pseudintermedius* colonization in these individuals, as contact with animals has been previously identified as a potential risk factors for both. Thus, the prevalence data reported here should not necessarily be

considered to reflect the population prevalence. While the study population should not be regarded as definitively representative of the pet-owning population in Ontario, the results provide a good preliminary indication of the potential for staphylococcal transmission between owners and pets.

The relatively high prevalence of *S. aureus* colonization in dogs and *S. pseudintermedius* in pet owners as well as the identification of concurrent colonization of humans and their pets in some households suggests transmission of coagulase-positive staphylococci may occur between humans and companion animals residing within the same household. Based on the identification of lack of hand washing as a risk factor for *S. pseudintermedius* colonization, it is possible that interspecies transmission of coagulase positive staphylococci may be reduced through routine hand hygiene following animal contact. This may be particularly important for high-risk (immunocompromised) pet owners. Further investigation of staphylococcal ecology within species in a household will help determine additional risk factors for colonization that may allow implementation of control measures to reduce rates of infection and dissemination of methicillin-resistant strains, particularly MRSA.

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