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Original Article

Occurrence of methicillin-resistant *Staphylococcus aureus* in pets and their owners in rural and urban communities in Trinidad

Naomi Scott[1], Christopher Seeraj[1], Brandon Satram[1], Natalie Michelle Sandy[1], Keenan Seuradge[1], Brittany Seerattan[1], Ishta Seeram[1], Alva Stewart-Johnson[2], Abiodun Adesiyun[2]

[1] *School of Medicine, Faculty of Medical Sciences, University of the West Indies, St. Augustine Campus, Trinidad and Tobago*
[2] *School of Veterinary Medicine, Faculty of Medical Sciences, University of the West Indies, St. Augustine Campus, Trinidad and Tobago*

Abstract
Introduction: The occurrence of methicillin-resistant *Staphylococcus aureus* (MRSA) in pets and their owners has increased due to the misuse and abuse of antibiotics. This study compared the prevalence of MRSA and *Staphylococcus aureus* strains in pets and their owners in urban and rural communities in Trinidad.
Methodology: Questionnaires were administered to gather demographic and risk factor data for MRSA for human participants, and their pets. Nasal swabs were obtained from 100 pets (dogs and cats) and their human owners. For the isolation of MRSA, nasal swabs obtained were enriched and then plated on selective media. *Staphylococcus aureus* was identified using standard biochemical procedures. The resistance of *S. aureus* initially assessed detection of MRSA isolates to cefoxitin and confirmed by the PBP2a latex agglutination test. Antibiotic resistance was determined using the disc diffusion method.
Results: The prevalence of MRSA was 6.0% (3/50) and 2.0% (1/50) in household pet animals and their owners, respectively in urban communities, while in rural communities, the prevalence was 6.0% (3/50) and 12.0% (6/50) respectively. The prevalence of *S. aureus* in pet owners was higher in the rural community (44.0%) compared to urban (30.0%). However, in pet animals, *S. aureus* was more frequently isolated from urban communities (78.0%) than rural ones (66.0%). Amongst the *S. aureus* isolates, 81.7% were resistant to one or more antimicrobial agents.
Conclusions: This study has demonstrated that living in a rural community increased the odds of MRSA colonization.

Key words: MRSA; owners; pets; rural; Trinidad; urban.

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Introduction
Staphylococcus aureus is a major pathogen in humans and animals capable of causing a wide variety of infectious diseases, ranging from mild skin infections to severe bacteremia [1]. Companion animals, particularly dogs, and cats can be colonized and infected by *S. aureus,* but it is not the most common coagulase-positive strain. In most studies, *S. intermedius* or *S. pseudintermedius* was more prevalent [2-4]. In Trinidad and Tobago, antimicrobial resistant *S. aureus* strains have been isolated from pets that are ill [5] however little is known about the prevalence of *S. aureus* in healthy pets.

In the past, most of *S. aureus* infections were susceptible to an antibiotic group called beta-lactams, which include amoxicillin, methicillin, oxacillin, and penicillin. However, the overuse and misuse of antibiotics have resulted in the development of a strain of *S. aureus* called methicillin resistant *S. aureus,* MRSA [6]. Initially, MRSA was considered a nosocomial infection, but it was discovered in the community and the term Community-Acquired MRSA (CA-MRSA) emerged. CA-MRSA can be spread from close skin-to-skin contact, skin cuts, contaminated objects, and poor hygienic practices [6]. CA-MRSA infections are normally resistant to only beta-lactams but are sensitive to other antimicrobial classes [7]. Initially in Trinidad and Tobago, CA-MRSA was rare, and most MRSA strains were healthcare-associated (HA-MRSA). However, over the years the prevalence of CA-MRSA has been increasing at an alarming rate [8].

In a study conducted on students in Iraq, residing in two types of communities (urban and rural) to detect

MRSA nasal carriage, it was reported that the *S. aureus* carriage rate was higher, but MRSA strains were lower in urban areas compared to rural areas which had lower *S. aureus* carriage but more MRSA strains [9]. MRSA strains are rarely reported in companion animals; however, some studies have indicated that they can act as potential reservoirs of MRSA [10,11].

This statement is at variance with other studies that indicated humans as being the initial sources of MRSA colonization [12,13]. Regardless of the initial source of infection or colonization, MRSA can be transmitted in both directions [10]. It has been reported that MRSA isolated from pet animals and humans in the same household was indistinguishable by pulse field gel electrophoresis (PFGE) [14].

The prevalence of MRSA in companion animals appear to be low in other studies, 8.8% and 1.8% [15,16]. It has been documented that MRSA appears to be more associated with dogs than cats [13]. Risk factors for MRSA in pet animals include living in a household with humans or animals with MRSA, hospitalization, surgery, use of antimicrobial agents [13], intimate contact between pets and owners [12], having received surgical implants, the number of days admitted to the veterinary hospital, and the number of antimicrobial classes used [17].

In Trinidad and Tobago, MRSA has been isolated from pigs on farms [18], broilers [19], and abattoir workers [20]. However, Dziva *et al.* (2015) reported that none of the sick pet animals tested at a teaching hospital was positive for MRSA. To date, there is no published report on MRSA in healthy animals and whether the location of residence affects colonization in pet animals and humans. Therefore, the purpose of this study was to determine the prevalence of *Staphylococcus aureus* and MRSA in the anterior nares of cats and dogs and their owners from rural and urban communities in Trinidad, and their resistance to other antimicrobial agents and the risk factors involved.

Methodology

Study population

The participants in this study were from two different communities (rural and urban) in Trinidad. The subjects for this study were notified of the design and process of this study through community leaders, people at community centers, and through word-of-mouth communication among residents.

Estimated sample size

For pet animals, a sample size of 100 was calculated using the following formula: $n = [t^2 \times p\ (1-p)]/m^2$ [21] where n = required sample size, t = confidence level at 95% (standard value of 1.96), p = estimated prevalence of MRSA, and m = margin of error, a reported prevalence rate of 8.0% [22] and a margin of error of 4.0%. A minimum sample size estimated was therefore, $1.96^2\ (0.08 \times 0.92)/0.04^2 = 0.2843/0.0016 = 178$. However, for the study a sample size of 200 participants was used, comprising 100 samples each of animals (dogs or cats) and their owners. Overall, for the 200 participants, 50 samples each of pet animals and humans were sampled from each of the two communities.

Households without pets or with pets other than dogs or cats were excluded from the study. Also, animals and humans using antibiotics were omitted from the study. The households were chosen using a convenient sampling approach. There was no gender, racial or ethnic stratification in this study.

Sample collection

A pre-tested standardized questionnaire was administered to the person who had the most contact with the pet that was sampled. A consent form was also completed by all participants in the study. The questionnaire captured demographic data and risk factors for pet owners such as age, gender, area of residence, past or present employment in the healthcare system, history of hospitalization and antibiotic use, and use of over-the-counter antibiotics. Information on pet animals consisted of the age, history of hospitalization and antibiotic use, and degree of physical contact with the owner and neighboring pets were also obtained. Two anterior nares swabs were collected from each household, one from the pet owner and the other from the pet. The swabs were immediately placed in transport media and transported to the laboratory and processed between 18 hours and 24 hours of collection.

Processing of samples

Each swab sample was placed into a labeled tube, corresponding to the sample I.D., containing Mueller Hinton broth (Oxoid Ltd., Basingstoke, Hampshire, England) with 6.5% sodium chloride (pre-enrichment). After overnight incubation at 37 °C, 10 µL of the pre-enrichment broth was inoculated onto Mannitol Salt agar (MSA) (Oxoid Ltd., Basingstoke, Hampshire, England) and incubated for 18-24 hours at 37 °C. Simultaneously, 1 mL of the pre-enrichment broth was placed into 9 mL of phenyl red mannitol broth (Becton Dickinson, Le Pont deClaix, France) with 75 mg/L aztreonam (Johnson Motthey Co. Devens, MA, USA) and 5 mg/L ceftizoxime (Tokyo Chemical Industry Co. Ltd. Kita-Ku, Tokyo, Japan) as selective enrichment and incubated at 37 °C for 18-24 hours. After incubation, the selective enrichment broth was inoculated onto CHROMagar MRSA (CHROMagar Limited. Paris, France) and was incubated for 18-24 hours at 37 °C. When characteristic colonies were not observed, they were incubated for a further 18-24 hours. Characteristic colonies from both MSA and CHROMagar were plated on 5% Blood agar (Oxoid Ltd., Basingstoke, Hampshire, England). All suspected colonies were identified as *S. aureus* using standard techniques which included tests for catalase, DNase, coagulase, and Gram staining. All Gram-positive cocci that were catalase, DNase, and coagulase-positive were identified as *S. aureus*. Pure *S. aureus* cultures were stored at -70 °C in Brain Heart Infusion broth (Oxoid Ltd., Basingstoke, Hampshire, England) with an equal volume of 50% glycerol.

Antimicrobial sensitivity testing

The susceptibility of the *S. aureus* isolates to the eight various antimicrobial agents (Oxoid Ltd., Basingstoke, Hampshire, England): Penicillin G (P, 10 iu), Enrofloxacin (ENR, 5 mcg), Amoxycillin (AML, 10 mcg), Cephalexin (CL, 30 mcg), Ciprofloxacin (CIP, 5 mcg), Cefoxitin (FOX, 30 mcg), Streptomycin (S, 10 mcg) and Sulphamethoxazole/Trimethoprim (SXT, 1.75/23.25 mcg) was read and compared to the chart for zones of resistance [23]. The selection of antimicrobial agents used in this study was based on their use by veterinarians and medical practitioners.

Determination of MRSA status of isolates

All isolates that were cefoxitin resistant were further tested using the Penicillin-Binding Protein (PBP2) Latex Agglutination test (Oxoid Ltd., Basingstoke, Hampshire, England) to positively confirm suspect strains as MRSA [19].

Data analyses

Data were analyzed with the Statistical Package for Social Sciences (SPSS), version 22.0 (IBM, Armonk, NY) or Stata. Logit model analysis was done to distinguish which of the independent variables (demographic data and risk factors) were predictive of the presence of *S. aureus* and MRSA. The frequency of detection of resistance to antimicrobial agents for the pathogens was also analyzed to detect any statistically significant association with the risk factors obtained from the questionnaires administered. The data were analyzed for any correlation between the prevalence and resistance of *S. aureus* in pet animals and their owners. The level of significance was tested at an alpha level of 0.05.

Results

Prevalence of MRSA and S. aureus

For this study, a total of 200 nasal swabs comprising 50 humans, 48 dogs, and 2 cats from the rural communities and 50 humans, 47 dogs, and 3 cats from the urban communities were sampled. Of the 100-household sampled, 50 each were from rural and 50 urban communities. All the rural samples were obtained from Caroni County. Of the 50-household sampled in the urban area, 22 (44.0%) were from Arouca, 19 (38.0%) from St. Joseph, and 9 (18.0%) from Champ Fleurs.

Of the 100 pet owners sampled from both the rural and urban communities, a prevalence of 37.0% and 7.0% were detected for *S. aureus* and MRSA respectively. For the 100 pets sampled from both communities, a prevalence of 72% and 6% was observed for *S. aureus* and MRSA respectively. For pet owners, there was a higher prevalence of *S. aureus* (44%) and MRSA (12%) in the rural area compared to the urban area where isolation rates of 30% and 2.0% were observed for *S. aureus* and MRSA respectively. The difference however was not statistically significant (Table 1). In household pets, however, the prevalence of *S. aureus* was higher in the urban area (78.0%) than in rural communities (66.0%) but the difference was not statistically significant ($p > 0.05$). The prevalence of MRSA in pets was the same in both rural and urban communities (6.0%) and MRSA was only isolated from dogs.

Antimicrobial Resistance

In pet owners in rural communities, a high frequency of resistance was observed by MRSA

Table 1. Carriage of *S. aureus* and MRSA in pets and owners in urban and rural zones of Trinidad.

Parameter	Community	No. of samples tested	*S. aureus*, Number (%)		MRSA, Number (%)	
			positive	*p*-value	positive	*p*-value
Pet owners	Rural	50	22 (44.0)	0.147	6 (12.0)	0.112
	Urban	50	15 (30.0)		1 (2.0)	
Household pets	Rural	50	33 (66.0)	0.181	3 (6.0)	NA
	Urban	50	39 (78.0)		3 (6.0)	

NA: Not Applicable.

isolates to cefoxitin and amoxicillin (100.0%), followed by cephalexin and penicillin (83.3%). A moderate frequency of resistance was observed to sulfamethoxazole/trimethoprim and ciprofloxacin (50.0%) and a low frequency of resistance to enrofloxacin (33.3%). All MRSA isolates from pet owners in rural communities were susceptible to streptomycin. Multi-drug resistance (resistance to three or more antimicrobial classes) was exhibited by 33.3% of the isolates. The lone MRSA isolate from an urban pet owner was resistant to cephalexin, cefoxitin, streptomycin, penicillin, and amoxicillin. The isolate did not exhibit multi-drug resistance.

The MRSA isolates from rural pet animals were only resistant to all beta-lactam antimicrobial agents (penicillin, amoxicillin, cephalexin, and cefoxitin). The three MRSA isolates from the rural pets exhibited the same resistance patterns (CL-FOX-P-AML). The MRSA resistance patterns from pet animals in urban communities were variable. All the MRSA isolates from the urban pets were resistant to penicillin, amoxicillin, cephalexin, cefoxitin, streptomycin, and sulfamethoxazole/trimethoprim. A moderate frequency of resistance was exhibited to ciprofloxacin and enrofloxacin (66.6%). All the urban pet MRSA isolates were multi-drug resistant. MRSA was isolated from one owner and her dog in the rural district and the antibiotic resistance pattern (CL-FOX-P-AML) was identical for both isolates.

Amongst the 159 *S. aureus* isolates, 130 (81.7%) were resistant to one or more antimicrobial agents whereas 29 (18.2%) were susceptible to all agents. A slightly higher frequency (82.9%) of *S. aureus* isolates from the rural communities exhibited resistance to one or more antimicrobial agents compared to the urban communities (80.7%). The highest prevalence of resistance was exhibited to penicillin (67.1%) and to streptomycin (55.4%) in rural and urban communities respectively. Most of the isolates (68.4%) were resistant to the beta-lactams in rural communities, however, the isolates from the urban communities exhibited higher resistance to the aminoglycosides (55.4%). A moderate frequency of resistance was observed to fluoroquinolones in both communities (32.7%) (Figure 1).

Figure 1. Frequency of resistance of *S. aureus* isolates from rural and urban communities in Trinidad.

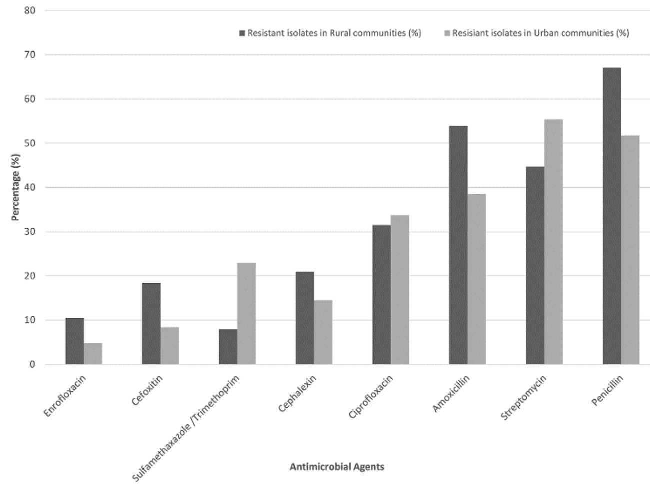

Table 2. Risk factors for carriage of *S. aureus* and MRSA in pet owners in urban and rural zones of Trinidad.

Risk factor	Rural communities						Urban communities					
	S. aureus			MRSA			*S. aureus*			MRSA		
	No. of owners	Positive, Number (%)	*p*-value	No. of owners	Positive, Number (%)	*p*-value	No. of owners	Positive, Number (%)	*p*-value	No. of owners	Positive, Number (%)	*p*-value
Age (years)			0.943			0.606			0.324			0.606
< 21	2	1 (50.0)		2	1 (50.0)		10	1 (10.0)		10	0 (0.0)	
21 - 30	13	7 (53.8)		13	2 (15.4)		6	4 (66.7)		6	0 (0.0)	
31 - 40	9	4 (44.4)		9	1 (11.1)		6	2 (33.3)		6	0 (0.0)	
41 - 50	12	5 (41.7)		12	1 (8.3)		7	2 (28.6)		7	0 (0.0)	
51 - 60	10	4 (40.0)		10	1 (10.0)		10	3 (30.0)		10	0 (0.0)	
> 60	4	1 (25.0)		4	0 (0.0)		11	3 (27.3)		11	1 (9.1)	
Total	50	22 (44.0)		50	6 (12.0)		50	15 (30.0)		50	1 (2.0)	
Gender			0.009			0.917			0.902			0.881
Male	26	16 (61.5)		26	3 (11.5)		26	8 (30.8)		26	1 (3.8)	
Female	24	6 (25.0)		24	3 (12.5)		24	7 (29.2)		24	0 (0.0)	
Occupation			0.776			0.8282			0.709			0.696
Healthcare	10	4 (40.0)		10	1 (10.0)		6	2 (33.3)		6	0 (0.0)	
Non-health care	40	18 (45.0)		40	5 (12.5)		44	13 (29.5)		44	1 (2.3)	
Hospitalization			0.707			0.519			0.268			0.820
Yes	31	13 (41.9)		31	3 (9.7)		36	11 (30.6)		36	1 (2.8)	
No	19	9 (47.4)		19	3 (15.8)		13	4 (30.8)		13	0 (0.0)	
Contact with pets			0.879			0.387			0.561			0.840
Yes	28	11 (3.2)		28	4 (14.3)		22	5 (22.3)		22	1 (4.5)	
No	22	11 (50.0)		22	2 (9.1)		28	10 (35.7)		28	0 (0.0)	
Prescribed antibiotics			0.701			0.241			0.820			0.766
Yes	47	21 (44.7)		47	5 (10.6)		46	14 (30.4)		46	1 (2.3)	
No	3	1 (33.3)		3	1 (33.3)		4	1 (25.0)		4	0 (0.0)	
Took full course of antibiotics			0.330			0.415			0.968			0.866
Yes	35	14 (40.0)		35	4 (11.4)		41	13 (31.7)		41	1 (2.4)	
No	11	8 (72.7)		11	2 (18.2)		6	2 (33.3)		6	0 (0.0)	
Use over-the counter antibiotics			0.300			0.337			0.710			0.435
Yes	19	12 (63.2)		19	2 (10.5)		19	8 (42.1)		19	1 (5.3)	
No	31	10 (32.3)		31	4 (12.9)		27	7 (25.9)		27	0 (0.0)	

Risk factors

In both communities, the only risk factor that was significantly associated with the carriage of *S. aureus* in pet owners was the gender of the pet owner in the rural community ($p = 0.0009$) (Table 2). There were no risk factors associated with *S. aureus* or MRSA carriage in the urban community. For pet animals in rural communities, of the seven risk factors investigated, contact with other animals was the only risk factor that was statistically significantly ($p = 0.004$) associated with the isolation of *S. aureus* while none was significantly associated with the isolation of MRSA (Table 3). For all the isolates from pet animals sampled in urban communities, none (0.0%) of the seven risk factors was statistically significantly ($p > 0.05$) associated with the isolation of *S. aureus*. However, five (71.4%) of the risk factors were significantly associated with the isolation of MRSA, namely, location of pets in/around the house ($p = 0.006$), contact with other animals ($p = 0.048$), pets hospitalized within the previous six months ($p = 0.034$), a pet given antibiotics within the previous six months ($p = 0.029$) and completed the full course of antibiotics treatment ($p = 0.039$).

Antibiotic Usage

The antibiotics most frequently used by rural pet owners were augmentin (38.0%) followed by amoxicillin (34.0%). Of the 50 pet owners, 13 (26.0%) did not remember the antibiotics used. In the urban communities, of the 38 (76%) participants that remembered the antibiotic used, 26 (68.4%) of the pet owners remembered using augmentin, and 12 (31.6%) had used amoxicillin. Most of the pets were not administered antibiotics in both rural (60.0%) and urban (64.0%) communities. In the urban communities, the most frequent antibiotics administered to pet animals was augmentin, whereas, in rural communities, it was amoxicillin (10.0%).

Discussion

In humans, a relatively high prevalence of *S. aureus* (37.0%) was observed in the Trinidad community (both rural and urban combined). This was higher than the 17.7% reported in Iraq [9], comparable to the 33.3% observed in Nigeria [24] but lower than the 52.3% observed in India [25]. In the current study, a prevalence of 7.0% for MRSA in pet owners in the Trinidadian community was observed. This prevalence was higher than the 0.4% reported in Iraq [9], comparable to the 8.3% observed in Nigeria [24] but lower than the 24.0% observed in Pakistan [26].

The present study observed an extremely high prevalence of *S. aureus* (72.0%) in household pets. This prevalence is much higher than the 33.3% observed in Trinidad dogs at the Veterinary Teaching Hospital [5] and the less than 10% observed by others [3,27,28]. This can be explained in part that some of the *S. aureus* isolates may not have been *S. aureus* since it has been documented that coagulase-positive *S. intermedius* or *S. pseudintermedius* is more common in companion animals (dogs and cats) [2]. In pets, a prevalence of 6.0% was observed for MRSA in the Trinidad community. The prevalence was the same for both

Table 3. Risk factors for carriage of *S. aure*us and MRSA in pet animals in urban and rural zones of Trinidad.

Risk factor	Rural communities						Urban communities					
	S. aureus			MRSA			*S. aureus*			MRSA		
	No. of pets	Positive, Number (%)	*p*-value	No. of pets	Positive, Number (%)	*p*-value	No. of pets	Positive, Number (%)	*p*-value	No. of pets	Positive, Number (%)	*p*-value
Age (years)			0.304			0.307			0.856			0.474
< 0.5	11	10 (90.9)		11	2 (18.2)		2	2 (100.0)		2	0 (0.0)	
0.5 – 1	2	2 (100.0)		2	0 (0.0)		5	4 (80.0)		5	0 (0.0)	
> 1-3	17	9 (52.9)		17	0 (0.0)		15	11 (73.3)		15	0 (0.0)	
> 3	20	12 (60.0)		20	1 (5.0)		28	22 (78.6)		28	3 (10.7)	
Breed			0.450			0.696			0.668			0.754
Pure	12	9 (75.0)		12	1 (8.3)		21	17 (81.0)		21	1 (4.8)	
Mixed	38	24 (63.2)		38	2 (5.2)		29	22 (75.9)		29	2 (6.9)	
Location			0.161			0.345			0.619			0.006
Indoor	4	4 (100.0)		4	0 (0.0)		2	1 (50.6)		2	1 (50.0)	
Outdoor	31	21(67.8)		31	3 (9.7)		33	26 (78.8)		33	0 (0.0)	
Mixed	15	8 (53.3)		15	0 (0.0)		15	12 (80.0)		15	2 (13.3)	
Contact with other animals			0.948			0.242			0.148			0.048
Yes	14	10 (71.4)		14	0 (0.0)		13	12 (92.3)		13	2 (15.4)	
No	36	23 (63.9)		36	3 (8.3)		37	27 (73.0)		37	1 (2.7)	
Contact with humans *			0.879			0.387			0.561			0.840
Yes	28	28 (100.0)		28	3 (10.7)		22	17 (77.3)		22	3 (13.6)	
No	22	5 (22.3)		22	0 (0.0)		28	22 (78.6)		28	0 (0.0)	
Hospitalized **			0.180			0.696			0.507			0.034
Yes	12	6 (50.0)		12	1 (8.3)		16	11 (68.8)		16	3 (18.8)	
No	38	27 (71.1)		38	2 (5.3)		34	28 (82.4)		34	0 (0.0)	
Antibiotic administered ***			0.773			0.113			0.265			0.029
Yes	23	15 (65.2)		23	0 (0.0)		20	14 (70.0)		20	3 (15.0)	
No	27	18 (66.7)		27	3 (11.1)		30	25 (83.3)		30	0 (0.0)	
Full course of antibiotics taken			0.345			0.113			0.300			0.039
Yes	19	12 (63.2)		19	0 (0.0)		18	12 (66.7)		18	3 (16.7)	
No	4	4 (100.0)		4	3 (21.4)		2	2 (100.0)		2	0 (0.0)	

* Very close direct contact with humans most of the times; ** Pet has been hospitalized within the last 6 months; *** Antibiotics prescribed were administered to treat pet.

urban and rural communities. This prevalence is higher than that observed by others in the USA [27,28] but lower than that observed by Faires and others in Canada and USA in 2009 [15]. In the present study, all the *S. aureus* and MRSA isolates were from dogs. This finding was similar to that of Morgan [13] who detected a higher frequency of MRSA in dogs when compared to cats in the UK in 2008.

In humans, a higher frequency for *S. aureus* carriage was observed in the rural community. This is contrary to the report by Hussein *et al.* [9] who found a higher carriage rate for *S. aureus* in humans (20.5%) in urban communities than in rural communities (15.2%). A number of factors may be responsible for the differences in both studies which include the activities or occupation of humans in the areas studied, hygienic practices, compromised immune systems, and a high prevalence of extended families with small household settings.

MRSA strains were also isolated at a higher frequency from human owners of pets in rural communities (12%) compared with only 2% detected in humans sampled from urban communities in the current study. Similar findings have been reported by others [9,29]. This can be a result of pets in the rural community having more contact with their environment as well as other animals in the area.

In the current study, a relatively high percentage of *S. aureus* isolates were resistant to penicillin. Furthermore, a high frequency of resistance by *S aureus* isolates was displayed in all beta-lactams tested. This finding is in agreement with an earlier report which states that β-lactams are ineffective against most *S. aureus* strains through the production of beta-lactamase (penicillinase) [6]. It was of interest that the frequency of resistance to penicillin was higher for isolates from the rural community (67.1%) than the urban communities (55.2%). This may reflect a more prevalent abuse or misuse of penicillin in rural communities compared to urban communities. In addition, amoxicillin (beta-lactam) use was considerably higher in the rural district as 24 (48%) of the owners admitted to purchasing this antibiotic without prescription in their local pharmacies for reasons such as the common cold and fever, whereas in the urban communities only 16 (32%) reported such a practice. Also, 28 (56%) of the owners in the rural district admitted to not taking the full course while in the urban communities the corresponding frequency was 26 (52%). These prevalent practices in rural communities may have contributed to increasing the likelihood of bacteria developing resistance mechanisms. A moderate frequency of resistance was observed to streptomycin by *S. aureus* in the rural (44.7%) and urban (55.4%) communities. A moderate frequency of resistance (49.2%) to streptomycin was also reported by *S. aureus* isolates from ill dogs in a Veterinary Teaching Hospital in Trinidad [5].

All 13 MRSA-positive isolates were resistant to more than one antimicrobial agent. The high frequency of resistance by MRSA isolates to beta-lactams in this study was not a surprise since that is a characteristic of MRSA because of the acquisition of the low-affinity penicillin-binding protein 2a (PBP2a) [30]. It must be noted that MRSA was not isolated from sick dogs at the Veterinary Teaching Hospital in Trinidad [5]. Interestingly, in pets, multidrug resistance was only observed in the urban community (100.0%). All rural MRSA isolates from pets were resistant to beta-lactams only. This is an indication that pets in the rural community were colonized by CA-MRSA because it has been stated that CA-MRSA tends to be resistant to only beta-lactam antibiotics but are susceptible to other classes [8]. This result also implies that all urban MRSA-positive pets were colonized by HA-MRSA strains.

In this study in the rural district, there was one case where MRSA was isolated from both the owner and the pet. It is pertinent to note that the same antimicrobial resistance pattern was observed in the dog and its owner thus suggesting possible transmission between the two. This observation is in agreement with another study where MRSA isolated from humans and pets in the same household were indistinguishable by PFGE [14,15].

Risk factors

Pet Owners

The only risk factor that was significantly associated with *S. aureus* carriage in pet owners was the gender of the pet owner ($p = 0.0009$). In rural areas, the prevalence of *S. aureus* was higher in males (32%) than in females (12%). This observation agrees with another study where a higher rate of *S. aureus* carriage was found in men compared to women [31].

Pets

In the urban district, pet location ($p = 0.006$), contact with animals, being hospitalized ($p = 0.034$), antibiotics taken by pets ($p = 0.029$), and whether the full course was taken ($p = 0.039$) were significantly associated with MRSA colonization in pets. Contact with animals was statistically significantly associated with MRSA colonization ($p = 0.008$). Many pet owners from urban and rural areas commented that their pets (both dogs and especially cats) were stray and adopted off the streets and therefore already had a habit of roaming the streets. This practice allowed free contact with other animals and unclean surfaces and may have provided the bacterium with optimum transmission opportunities to pet animals.

Pet location was statistically significantly associated with MRSA colonization (p = 0.006), Pets having both indoor and outdoor access had a higher prevalence of MRSA than those who could access only indoors or outdoors. This is expected since pets with access to both indoors and outdoors had a greater chance of being in contact with an MRSA-positive human, pet, or surface. There was a statistically significant association between pet hospitalization and isolation of MRSA in urban areas (p = 0.034). This observation has also been reported by others [12,13]. There was a statistically significant risk association between previous antibiotic usage in pets and the carriage of MRSA in urban areas (p = 0.039). Tacconelli *et al.* [32] stated that previous antibiotic use was expected to increase MRSA risk as natural body microbiota is depleted, making bacterial colonization easier.

Conclusions

In conclusion, the carriage rate of *S. aureus* in humans was higher in rural districts compared to urban communities. In the rural district, the *S. aureus* strains isolated from the household pets and their owners were found to be more resistant to penicillin whereas, in the urban district, resistance was most prevalent to streptomycin. Multi-drug resistance in *S. aureus* and MRSA was detected in both rural and urban communities and may pose challenges to the successful therapy of infections by *S. aureus*. The only risk factors significantly associated with the carriage of *S. aureus* in both rural and urban communities were the contact of pet animals with other animals and the gender of pet owners.

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Corresponding author
Professor Abiodun Adesiyun DVM, MPH, PhD
School of Veterinary Medicine, Faculty of Medical Sciences
University of the West Indies, St. Augustine, Trinidad and Tobago
Telephone: 1-868-777-7480
Fax: 1-868-645-7428
E-mail: abiodun.adesiyun@sta.uwi.edu

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