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In vitro antibiotic resistance of Staphylococci isolated from different animal species

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Abstract: The purpose of this study is to investigate resistance to antibiotics of *Staphylococcus* species isolated from various samples belonging to different animal species. Among 48 *Staphylococcus* spp. strains, *Staphylococcus intermedius* was the most common species, followed by *S. aureus*, *S. epidermidis, S. hyicus*, *S. saprophyticus*. In a total of 48 *Staphylococcus* strains, the highest antibiotic resistance was observed to oxacillin (79.17%), tetracycline (39.58%), and ampicillin and cefoxitin (31.25%). Of 48 *Staphylococcus* strains, 42 showed resistance to at least one antimicrobial agent, while 23 of the strains had multidrug resistance. Antimicrobial resistance to tetracycline and ampicillin, erythromycin, streptomycin was detected frequently in *S. aureus*,*S. intermedius*, and *S. epidermidis*, respectively. Resistance rates for ampicillin, cefoxitin, and enrofloxacin were determined as 66.67% in *S. hyicus* strains. *S. saprophyticus* was determined to show resistance to 13 antibiotics other than meropenem. The highest antibiotic resistance was determined in *S. aureus, S. intermedius*, *S. epidermidis*, and in 48 *Staphylococcus* strains to oxacillin. Consequently, this study revealed resistance to various antibiotics in *Staphylococcus* species. Additionally, the presence of high oxacillin resistance and multidrug resistance in the *Staphylococcus* strains revealed the importance of determination of antimicrobial susceptibility before treatment and for rational use of antibiotics.

Key words: *Staphylococcus* spp., domestic animals, antimicrobial resistance, oxacillin

1. Introduction

Staphylococci are a part of the normal bacterial flora of the urogenital and digestive system mucous membranes and skin of several mammalian animals and poultry [1,2,3]. Most of the 44 *Staphylococcus* species defined so far are present in animals [2,4]. *Staphylococcus aureus (S. aureus)* is accepted as the most prevalent pathogen species in both humans and animals, while other significant pathogen species in veterinary medicine were reported as *S. hyicus* and *S. intermedius* (reclassified as *S. pseudointermedius*) [4,5,6]. As it is difficult to phenotypically distinguish *S. pseudointermedius,* which was recently defined from *S. delphini,* it is believed that it would be better to use the term "*S. intermedius* group" for the species *S. intermedius*, *S. delphini*, and *S. pseudointermedius* [4,5,6,7,8]. Based on the coagulase test, Staphylococci used to be defined as coagulase-positive *S. aureus* and negative staphylococci. However, while *S. intermedius*, *S. pseudintermedius*, and *S. delphini* are positive in terms of coagulase and *S. hyicus* shows a variety, coagulase-negative staphylococci are also associated with various infections in humans and animals [6]. *S. aureus* may lead to suppurative infections such as mastitis, dermatitis, and botryomycosis in cows, sheep, goats, horses, pigs, cats, and dogs. *S. intermedius* causes several different suppurative infections such as endometritis and pyoderma in cats and dogs [1,2,9]. *S. hyicus* causes exudative epidermitis in pigs and cutaneous infections in horses and cows [3]. Due to reports that *S. intermedius* can be transmitted from animals to humans (especially from pets to owners), like *S. aureus* (zoonotic significance), *S. intermedius* also poses a serious public health risk [10,11,12].

Several different antibiotic drugs are used in the treatment of *Staphylococcus* spp. infections. However, usage of these drugs for shorter or longer than normal duration, and usage without antimicrobial susceptibility tests or microbiological analyses, had led to the emergence of antibiotic-resistant staphylococcus strains. Increased resistance to antibiotics in recent years, including multidrug resistance (MDR), will lead to untreatable *Staphylococcus* infections [13]. Some studies reveal antibiotic resistance in *Staphylococcus* species isolated from various animal species and humans [10,14,15,16,17,18,19]. It is known that especially the increase in methicillin-resistant Staphylococci creates a risk for animal health and public health [20,21,22]. The mecgenes that are found on the

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Staphylococcal Cassette Chromosome mec (SCCmec) code the penicillin-binding protein 2a and lead to methicillin resistance by reducing the susceptibility of staphylococci to all β-lactam antibiotics [23,24,25]. In addition to the infections they cause in animals, methicillin-resistant staphylococci have become a significant risk due to their potential to be transmitted to people who are in close contact with animals, such as pet owners and veterinary clinic staff [20,26,27].

The purpose of this study is to determine resistance to antibiotics of *Staphylococcus* species isolated from samples belonging to different animal species brought to the Clinics of the Faculty of Veterinary Medicine at Ankara University with various complaints.

2. Materials and methods

2.1. Bacterial strains

Staphylococcus spp. strains were obtained from various samples of different animal species submitted to the Clinics of the Faculty of Veterinary Medicine at Ankara University. A total of 48 Staphylococcal strains, of which 15 strains were from dogs (31.25%), 12 from cats (25%), nine from cows (18.75%), four from horses (8.33%), three from chickens (6.25%), two from goats (4.17%), and one each from a calf, pigeon, and parrot (2.08%) were used in this study (Table 1).

2.2. Identification of *Staphylococcus* spp. strains

Staphylococcus spp. strains were identified based on colony characteristics, catalase production, Gram's stain, coagulase reaction, pigment production, and Deoxyribonuclease (DNase) reaction on DNase agar, etc. [2,9].

2.3. Antimicrobial susceptibility testing

Antibiotic resistance of staphylococci was tested with the Kirby-Bauer disc diffusion method according to the Clinical and Laboratory Standards Institute (CLSI) (2008) [28]. The following antibiotic discs (Oxoid, Basingstoke, UK) were used: ampicillin (10μg), enrofloxacin (5μg), ciprofloxacin (5μg), meropenem (10μg), chloramphenicol (30μg), streptomycin (10μg), mupirocin (200μg), erythromycin (15μg), rifampicin (5μg), tetracycline (30μg), gentamicin (10μg), tobramycin (10μg), and cefoxitin (30 μg). For oxacillin (1μg) resistance, Mueller Hinton agar (Oxoid, CM0337, UK) onto which 2% NaCl was added was used. A *Staphylococcus aureus* ATCC® 25923 strain was used as the positive control. The inhibition zone diameters were assessed based on CLSI [28]. Among the tested antibiotics, strains that showed resistance to ≥3 antimicrobial agent classes were defined as multidrug-resistant (MDR) strains [29,30].

3. Results

3.1. Bacteriological identification

Staphylococcus spp. strains were isolated from samples belonging to different animal species, distributed among *S. intermedius* 21(43.75%), *S. aureus* 15(31.25%), *S. epidermidis* 8 (16.67%), *S. hyicus* 3 (36.25%), and *S. saprophyticus* 1(12.08%) (Table 1).

3.2. Antimicrobial susceptibility testing

In a total of 48 *Staphylococcus* spp. strains, the highest antibiotic resistance was determined to oxacillin 38 (79.17%), tetracycline 19 (39.58%), and ampicillin and cefoxitin 15 (31.25%). Regarding the resistance rates (Table 2), 42 (87.5%) strains were resistant to at least one drug, and 47.92% of strains were multidrug-resistant. Resistance rates in *S. aureus, S. intermedius*, and *S. epidermidis* were variable, with 40% of *S. aureus* strains exhibiting resistance to cefoxitin and ampicillin, 20% of strains being resistant to erythromycin and enrofloxacin, and tetracycline and tobramycin; with 38.10% of *S. intermedius* strains being resistant to erythromycin, 19.05% of strains exhibiting resistance to ampicillin, tobramycin, gentamicin, and chloramphenicol; with 37.5% of *S. epidermidis* strains exhibiting resistance to streptomycin, 25% of strains being resistant to ampicillin and tetracycline, 12.5% being resistant to gentamicin, cefoxitin, chloramphenicol, erythromycin, mupirocin, and rifampicin. Resistance was not observed to rifampicin, ciprofloxacin, mupirocin, and meropenem in *S. aureus* strains, to mupirocin in *S. intermedius*, and to meropenem, tobramycin, ciprofloxacin, and enrofloxacin in *S. epidermidis*. Resistance rates of *S. hyicus* strains were determined to be 66.67% to ampicillin, cefoxitin, and enrofloxacin; 33.33% to tetracycline, erythromycin ciprofloxacin, and mupirocin. Resistance was not noted to meropenem, tobramycin, gentamicin, streptomycin, rifampicin, and chloramphenicol in *S. hyicus* strains. *S. saprophyticus* was determined to show resistance to 13 antibiotics other than meropenem. Also, antimicrobial resistance rates to oxacillin were noted in *S. aureus, S. intermedius, S. epidermidis*, *S. hyicus*, and *S. saprophyticus* (93.33%, 76.19%, 62.5%, 66.67%, and 100%, respectively).

4. Discussion

This study investigated the antibiotic resistance of *Staphylococcus* species isolated from samples belonging to different animal species with various clinical symptoms and the presence of methicillin-resistant *Staphylococcus* species with zoonotic potential. A large proportion of cat and dog samples were obtained from the skin and ear, whereas all parrot and horse samples were taken from the skin. In our study, *S. intermedius* was identified as the most prevalent species from samples of the skin and ear. This could be related to the number of samples collected from the skin and ear. The most prevalent species were reported as *S. intermedius* and *S. aureus*in dogs with otitis externa and pyoderma [15,31,32]. *S. aureus* was isolated from cow milk samples in our study. Some researchers detected the most prevalent species as *S. aureus* and *S. epidermidis,*

Table 1. Distribution of the *Staphylococcus* spp. strains based on the animal species and samples they were isolated from [n (%)].

	Animal Species																				
	Dog					Cat					Cow			Horse	Chicken		Goat		Lamb	Pigeon	Parrot
	skin swab	ear swab	joint swab	nail wound swab	vaginal swab	skin swab	ear swab	nose swab	oral swab	urine	milk	nose swab	nail wound swab	skin swab	joint swab	sinus swab	nail wound swab	vaginal swab	lung	lung	skin swab
	15 (31.25)					12 (25)					9 (18.75)			4 (8.33)	3 (6.25)		2 (4.17)		1 (2.08)	1(2.08)	1 (2.08)
S. intermedius 21 (43.75)	5 (23.81)	3 (14.28)	1 (4.76)	1 (4.76)	1 (4.76)	4 (19.05)	1 (4.76)	-	-	-	-	-	-	4 (19.05)	-	-	-	-	-	1 (4.76)	-
S. aureus 15 (31.25)	1 (6.67)	-	-	-	-	1 (6.67)	-	1 (6.67)	1 (6.67)	-	5 (33.33)	2 (13.33)	1 (6.67)	-	1 (6.67)	1 (6.67)	-	-	1 (6.67)	-	-
S. epidermidis 8 (16.67)	-	3 (37.5)	-	-	-	3 (37.5)	-	-	-	-	-	-	-	-	-	-	1 (12.5)	1 (12.5)	-	-	-
S. hyicus 3 (6.25)	-	-	-	-	-	-	-	-	-	-	-	1 (33.33)	-	-	1 (33.33)	-	-	-	-	-	1 (33.33)
S. saprophyticus 1 (2.08)	-	-	-	-	-	-	-	-	-	1 (100)	-	-	-	-	-	-	-	-	-	-	-

Table 2. Antibiotic resistance in*Staphylococcus* species with different animal species origins [n (%)].

Antimicrobial agents	*S. aureus* (15)			*S. intermedius* (21)			*S. epidermidis* (8)			*S. hyicus* (3)			*S. saprophyticus* (1)			Total (48)		
	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R
	n (%)			n (%)			n (%)			n (%)			n (%)			n (%)		
OX	1 (6.67)	0	14 (93.33)	3 (14.28)	2 (9.52)	16 (76.19)	2 (25)	1 (12.5)	5 (62.5)	0	1 (33.33)	2 (66.67)	0	0	1 (100)	6 (12.5)	4 (8.33)	38 (79.17)
CFX	9 (60)	0	6 (40)	16 (76.19)	0	5 (23.81)	7 (87.5)	0	1 (12.5)	1 (33.33)	0	2 (66.67)	0	0	1 (100)	33 (68.75)	0	15 (31.25)
AMP	9 (60)	0	6 (40)	17 (80.95)	0	4 (19.05)	6 (75)	0	2 (25)	1 (33.33)	0	2 (66.67)	0	0	1 (100)	33 (68.75)	0	15 (31.25)
MER	15 (100)	0	0	19 (90.48)	0	2 (9.52)	8 (100)	0	0	3 (100)	0	0	1 (100)	0	0	46 (95.83)	0	2 (4.17)
TOB	11 (73.33)	2 (13.33)	2 (13.33)	17 (80.95)	0	4 (19.05)	7 (87.5)	1 (12.5)	0	3 (100)	0	0	0	0	1 (100)	38 (79.17)	3 (6.25)	7 (14.58)
CN	10 (66.67)	0	5 (33.33)	16 (76.19)	1 (4.76)	4 (19.05)	7 (87.5)	0	1 (12.5)	3 (100)	0	0	0	0	1 (100)	36 (75)	1 (2.08)	11 (22.92)
S	13 (86.67)	1 (6.67)	1 (6.67)	13 (61.90)	1 (4.76)	7 (33.34)	5 (62.5)	0	3 (37.5)	3 (100)	0	0	0	0	1 (100)	34 (70.83)	2 (4.17)	12 (25)
TET	7 (46.67)	0	8 (53.33)	14 (66.67)	0	7 (33.34)	6 (75)	0	2 (25)	2 (66.67)	0	1 (33.33)	0	0	1 (100)	29 (60.42)	0	19 (39.58)
E	11 (73.33)	1 (6.67)	3 (20)	13 (61.90)	0	8 (38.10)	6 (75)	1 (12.5)	1 (12.5)	1 (33.33)	1 (33.33)	1 (33.33)	0	0	1 (100)	31 (64.58)	3 (6.25)	14 (29.17)
CL	13 (86.67)	0	2 (13.33)	17 (80.95)	0	4 (19.05)	7 (87.5)	0	1 (12.5)	3 (100)	0	0	0	0	1 (100)	40 (83.33)	0	8 (16.67)
MUP	15 (100)	0	0	21 (100)	0	0	7 (87.5)	0	1 (12.5)	2 (66.67)	0	1 (33.33)	0	0	1 (100)	45 (93.75)	0	3 (6.25)
ENR	12 (80)	0	3 (20)	16 (76.19)	2 (9.52)	3 (14.29)	8 (100)	0	0	1 (33.33)	0	2 (66.67)	0	0	1 (100)	37 (77.08)	2 (4.17)	9 (18.75)
CIP	13 (86.67)	2 (13.33)	0	19 (90.48)	0	2 (9.52)	8 (100)	0	0	1 (33.33)	1 (33.33)	1 (33.33)	0	0	1 (100)	41 (85.42)	3 (6.25)	4 (8.33)
RIF	15 (100)	0	0	19 (90.48)	0	2 (9.52)	7 (87.5)	0	1 (12.5)	2 (66.67)	1 (33.33)	0	0	0	1 (100)	43 (89.58)	1 (2.08)	4 (8.33)

S: sensitive, I: intermediate, R: resistant; OX: oxacillin, CFX: cefoxitin, AMP: ampicillin, MER: meropenem, TOB: tobramycin, CN: gentamicin, S: streptomycin, TET: tetracycline, E: erythromycin, CL: chloramphenicol, MUP: mupirocin, ENR: enrofloxacin, CIP: ciprofloxacin, RIF: rifampicin.

S. aureus, S. agalactiae, and *S. hyicus* from cow milk with bovine mastitis in Turkey and Poland, respectively [33,34].*S. intermedius* (dog), *S. aureus* (cow), and *S. epidermidis* (goat) were isolated from the samples collected from wounds under the nails. Vanni et al. [15] also isolated *S. intermedius* (30%) from samples collected from under the nails of diseased and healthy dogs. *S. saprophyticus* was isolated from a cat urine sample, while it was determined to be susceptible to only meropenem among the antibiotics tested in our study. Some researchers have reported that *S. pseudointermedius* (20.1%), *S. saprophyticus* (2.9%), and *S. aureus* (2.5%) were isolated from urine samples of cats and dogs diagnosed with urinary system infection [22,35].

In the treatment of *Staphylococcus* spp. infections, long-term usage or repeated usage of both broad-spectrum and narrow-spectrum antibiotics may lead to the emergence of antimicrobial resistance, especially multidrug resistance. Considering the antibiotic resistance of all *Staphylococcus* spp. strains that we analyzed in our study, the resistance we determined to tobramycin (14.58%), streptomycin (25%), tetracycline (39.58%), and erythromycin (29.17%) were found to be higher than those reported by other researchers [14,33,36]. The resistance to ampicillin (31.25%), gentamicin (22.92%), rifampicin (8.33%), mupirocin (6.25%), chloramphenicol (16.67%), enrofloxacin (18.75%), and ciprofloxacin (8.33%) were lower [14,32,33,36]. It was determined that a large proportion of *Staphylococcus* spp. strains (87.5%) analyzed in the study showed resistance to at least one antimicrobial agent, while almost half of the strains (47.92%) had multidrug resistance. Some researchers have reported 36.4% and 35% multidrug resistance in Staphylococci isolated from different animal species [14,36]. Penna et al. [32,35] determined the ratio of strains resistant to at least one antimicrobial agent as 77.1% and 89% among the *Staphylococcus* strains they isolated from dogs with urinary system infection and otitis externa.

In the *S. intermedius* strains analyzed, we observed resistance to erythromycin (38.1%), streptomycin and tetracycline (33.34%), ampicillin (19.05%) and ciprofloxacin (9.52%) were similar to those in other studies [31,37,38,39,40]. However, the same strains' resistance to gentamicin and chloramphenicol (19.05%), enrofloxacin (14.29%), and rifampicin (9.52%) were determined to be lower than those reported by other researchers [15,32,35,38]. Additionally, all of the *S. intermedius* strains susceptible to mupirocin concurred with the results of Penna et al. [32].

Resistance of *S. aureus* strains to ampicillin (40%), enrofloxacin (20%), chloramphenicol (13.33%), and streptomycin (6.67%) were lower than those reported by other researchers, however; higher resistance to tetracycline (53.33%), gentamicin (33.33%), erythromycin (20%). and tobramycin (13.33%) were observed [14,16,32,34,35,36,40,41]. All of the *S. aureus* strains susceptible to ciprofloxacin, rifampicin, mupirocin, and meropenem concurred with the results of some researchers [14,33,36,40].

In *S. epidermidis* strains, resistance to ampicillin (25%), erythromycin, mupirocin, chloramphenicol, and gentamycin (12.5%) were determined to be lower than those reported by some researchers [25,32,34,35,39]. In terms of resistance to streptomycin (37.5%), tetracycline (25%) and rifampicin (12.5%), our results were determined to be higher [14,16,25]. Similar to the results presented in this study, Kirkan et al. [33], no ciprofloxacin-resistant strain was determined among *S. epidermidis* strains. On the other hand, the finding that all analyzed *S. epidermidis* strains were susceptible to enrofloxacin and tobramycin was different from the results of some researchers [25,32,35].

No study was found of resistance to meropenem in *S. intermedius, S. aureus, S. epidermidis*, and all *Staphylococcus* spp. strains, and resistance to tobramycin *S. intermedius* strains. Therefore, the comparison of resistance to meropenem and tobramycin *Staphylococcus* spp. strains with other studies could not be made. However, analyzing resistance to meropenem and tobramycin in *Staphylococcus* strains is believed to provide a significant contribution to literature. Also, owing to a few strains of *S. hyicus* and *S. saprophyticus*, the antimicrobial resistance results of the strains have not been compared with other studies.

Several methods are being used in revealing methicillin resistance in staphylococci [17,42,43,44,45]. However, there is confusion in the determination of methicillin resistance in staphylococci due to heterogeneous resistance in coagulase-negative staphylococci and studying different *Staphylococcus* species in different geographical regions [17,45,46,47]. In the CLSI report in 2008, it was stated that using cefoxitin is more suitable in determining methicillin resistance [28]. Considering the comparison of resistance to the two antimicrobials, the resistance determined to oxacillin and cefoxitin was observed to agree in the *S. hyicus* (66.67%) and *S. saprophyticus* (100%) strains, whereas it showed differences in the *S. aureus* (93.33% / 40%), *S. intermedius* (76.19% / 23.81%), *S. epidermidis* (62.5% / 12.5%), and all *Staphylococcus* strains (79.17% / 31.25%). High oxacillin resistance in the *S. intermedius, S. aureus, S. epidermidis,* and all *Staphylococcus* strains was in agreement with the results of other researchers [25,33,38,48]. However, some researchers reported oxacillin resistance to be low in *S. aureus* strains [14,32,35,36,49]. Low cefoxitin resistance in the analyzed *S. intermedius, S. epidermidis,* and all *Staphylococcus* spp. strains was similar to the results in some studies [16,36,39]. Cefoxitin resistance observed

in approximately half (40%) of the *S. aureus* strains was in agreement with the findings of Couto et al. [36], whereas Kot et al. [16] reported encountering no cefoxitin-resistant *S. aureus* strains. A literature review did not reveal any study of cefoxitin resistance in *S. saprophyticus* strains, and this study can be considered as the first to determine cefoxitin resistance in a *S. saprophyticus* strain.

Consequently, this study indicated that *Staphylococcus* strains and *Staphylococcus* species originating from different animal species have high oxacillin resistance, but all *Staphylococcus* strains have high levels of meropenemas a common feature. It has also shown that almost half of the *Staphylococcus* strains have MDR. It was demonstrated that determining antimicrobial susceptibility and effective treatment based on this, especially in infections caused by *Staphylococcus* species with MDR, carries great significance in terms of both animal health and reduction of the risk of resistance to antibiotics. Additionally, this study also revealed the necessity of taking the necessary health precautions by keeping in mind the probability of transmission of MRSs with zoonotic potential to pet owners and healthcare employees in close contact with animals and the formation of control programs regarding the carriage of the factor.

Conflict of interest

The authors declare no conflict of interest.

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References

1. Rich M. Staphylococci in animals: prevalence, identification and antimicrobial susceptibility, with an emphasis on methicillin-resistant *Staphylococcus aureus*. British Journal of Biomedical Science 2005; 62 (2): 98-105.
2. Markey B, Leonard F, Archambault M, Cullinane A, Maguire D. *Staphylococcus* species. In: Edwards R, Hewat C (editor). Clinical Veterinary Microbiology. 2th. ed. Missouri, USA: Mosby Elsevier; 2013. pp. 105-119.
3. Smeltzer MS, Beenken KE. *Staphylococcus.* In: McVey DS, Kennedy M, Chengappa MM (editor). Veterinary Microbiology. 3th. ed. Iowa, USA: Wiley-Blackwell; 2013. pp. 184-193.
4. Bond R, Loeffler A. What's happened to *Staphylococcus intermedius*? Taxonomic revision and emergence of multi-drug resistance. Journal of Small Animal Practice 2012; 53 (3): 147-154. doi: 10.1111/j.1748-5827.2011.01165.x
5. Ross Fitzgerald J. The *Staphylococcus intermedius* group of bacterial pathogens: species re-classification, pathogenesis and the emergence of methicillin resistance. Veterinary Dermatology 2009; 20 (5-6): 490-495. doi: 10.1111/j.1365-3164.2009.00828.x
6. Hermans K, Devriese LA, Haesebrouck F. *Staphylococcus*. In: Gyles CL, Presscott JF, Songer G, Thoen CO (editor). Pathogenesis of Bacterial Infections in Animals. 4th. ed. Iowa, USA: Wiley-Blackwell; 2010. pp.75-89.
7. Devriese LA, Vancanneyt M, Baele M, Vaneechoutte M, De Graef E, et al. *Staphylococcus pseudintermedius* sp. nov., a coagulase-positive species from animals. International Journal of Systematic and Evolutionary Microbiology 2005; 55 (4): 1569-1573. doi: 10.1099/ijs.0.63413-0
8. Van Duijkeren E, Catry B, Greko C, Moreno MA, Pomba MC, et al. Review on methicillin-resistant *Staphylococcus pseudintermedius*. Journal of Antimicrobial Chemotherapy 2011; 66 (12): 2705-2714. doi: 10.1093/jac/dkr367
9. Akan M. *Staphylococcus*İnfeksiyonları. In: Aydın N, Paracıkoğlu J (editor). VeterinerMikrobiyoloji (BakteriyelHastalıklar). 1th. ed. Ankara, TÜRKİYE: İlke-EmekYayınları; 2006. pp. 5-13.
10. Simoons-Smit A, Savelkoul P, Stoof J, Starink T, Vandenbroucke-Grauls C. Transmission of *Staphylococcus aureus* between humans and domestic animals in a household. The European Journal of Clinical Microbiology & Infectious Diseases 2000; 19 (2): 150-152. doi: 10.1007/s100960050450
11. Tanner MA, Everett CL, Youvan DC. Molecular phylogenetic evidence for noninvasive zoonotic transmission of *Staphylococcus intermedius* from a canine pet to a human. The Journal of Clinical Microbiology 2000; 38 (4): 1628-1631.
12. Boost MV, O'donoghue M, James A. Prevalence of *Staphylococcus aureus* carriage among dogs and their owners. Epidemiology and Infection 2008; 136 (7): 953-964. doi: 10.1017/S0950268807009326
13. Davis J, Jackson C, Fedorka-Cray P, Barrett J, Brousse J, et al. Carriage of methicillin-resistant staphylococci by healthy companion animals in the US. Letters in Applied Microbiology 2014; 59 (1): 1-8. doi: 10.1111/lam.12254
14. Lilenbaum W, Veras M, Blum E, Souza G. Antimicrobial susceptibility of staphylococci isolated from otitis externa in dogs. Letters in Applied Microbiology 2000; 31 (1): 42-45. doi: 10.1046/j.1472-765x.2000.00759.x
15. Vanni M, Tognetti R, Pretti C, Crema F, Soldani G, et al. Antimicrobial susceptibility of *Staphylococcus intermedius* and *Staphylococcus schleiferi* isolated from dogs. Research in Veterinary Science 2009; 87 (2): 192-195. doi: 10.1016/j.rvsc.2009.01.011

16. Kot B, Piechota M, Wolska K, Frankowska A, Zdunek E, et al. Phenotypic and genotypic antimicrobial resistance of staphylococci from bovine milk. Polish Journal of Veterinary Sciences 2012; 15 (4): 677-683. doi: 10.2478/v10181-012-0105-4

17. Hancı H, Ayyıldız A, Baltacı MÖ, İgan H, Uyanık MH, et al. *Staphylococcus aureus*SuşlarındaMetisilinDirencininKlasikveMolekülerYöntemlerleAraştırılması. Klimik Dergisi 2018; 31 (1): 30-33. doi: 10.5152/kd.2018.09

18. Worthing KA, Abraham S, Pang S, Coombs GW, Saputra S, et al. Molecular characterization of methicillin-resistant *Staphylococcus aureus* isolated from Australian animals and veterinarians. Microbial Drug Resistance. 2018; 24 (2): 203-212. doi: 10.1089/mdr.2017.0032

19. Sığırcı Diren B. Methicillin-resistant Staphylococci from dogs and cats with dermatologic problems. International Journal of Agriculture, Environment and Biotechnology 2019; 4 (2): 24-30.

20. Pantosti A. Methicillin-resistant *Staphylococcus aureus* associated with animals and its relevance to human health. Frontiers in Microbiology 2012; (3):1-12. doi: 10.3389/fmicb.2012.00127

21. Bierowiec K, Płoneczka-Janeczko K, Rypuła K. Cats and dogs as a reservoir for *Staphylococcus aureus*. Postępy Higienyi Medycyny Doświadczalnej (Advances in Hygiene and Experimental Medicine) (Online) 2014; (68): 992-997. doi: 10.5604/17322693.1117546

22. Göçmen H, Şükür H, Tamakan H, Esendal ÖM. Kuzey Kıbrıs Türk Cumhuriyeti'nde Hayvanlardan İzole Edilen Stafilokok Türlerinin Metisilin Dirençliliği Üzerine Retrospektif Bir Çalışma. Etlik Veteriner Mikrobiyoloji Dergisi 29 (2): 87-93.

23. Weese JS, Van Duijkeren E. Methicillin-resistant *Staphylococcus aureus* and *Staphylococcus pseudintermedius* in veterinary medicine. Veterinary Microbiology 2010; 140 (3-4): 418-429. doi: 10.1016/j.vetmic.2009.01.039

24. Weese JS. Methicillin-resistant *Staphylococcus aureus* in animals. Institute for Laboratory Animal Research 2010; 51 (3): 233-244.

25. McManus BA, Coleman DC, Deasy EC, Brennan GI, O'Connell B, et al. Comparative genotypes, staphylococcal cassette chromosome mec (SCCmec) genes and antimicrobial resistance amongst *Staphylococcus epidermidis* and *Staphylococcus haemolyticus* isolates from infections in humans and companion animals. PLoSOne 2015; 10 (9): 1-18. doi: 10.1371/journal.pone.0138079

26. Van Duijkeren E, Houwers D, Schoormans A, Broekhuizen-Stins M, Ikawaty R, et al. Transmission of methicillin-resistant *Staphylococcus intermedius* between humans and animals. Veterinary Microbiology 2008; 128 (1): 213-215. doi: 10.1016/j.vetmic.2007

27. Van Duijkeren E, Kamphuis M, Van der Mije I, Laarhoven L, Duim B, et al. Transmission of methicillin-resistant *Staphylococcus pseudintermedius* between infected dogs and cats and contact pets, humans and the environment in households and veterinary clinics. Veterinary Microbiology 2011; 150 (3-4): 338-243. doi: 10.1016/j.vetmic.2011.02.012

28. Wayne PA. Clinical and Laboratory Standards Institute. Performance standards for antimicrobial susceptibility testing. 18th informational supplement. CLSI document 2008; M100-S18: 100-121.

29. Tenover FC. Mechanisms of antimicrobial resistance in bacteria. The American Journal of Medicine 2006; 119 (6): S3-10. doi: 10.1016/j.ajic.2006.05.219

30. Schwarz S, Silley P, SimjeeS, Woodford N, van Duijkeren E, et al. Assessing the antimicrobial susceptibility of bacteria obtained from animals. Journal of Antimicrobial Chemotherapy 2010; 65 (4): 601-604. doi: 10.1016/j.vetmic.2009.12.013

31. Oliveira LC, Leite CA, Brilhante RS, Carvalho CB. Comparative study of the microbial profile from bilateral canine otitis externa. The Canadian Veterinary Journal2008; 49 (8): 785-788.

32. Penna B, Varges R, Medeiros L, Martins GM, Martins RR, et al. Species distribution and antimicrobial susceptibility of staphylococci isolated from canine otitis externa. Veterinary Dermatology 2010; 21 (3): 292-296.

33. Kırkan Ş, Göksoy EÖ, Kaya O. Identification and antimicrobial susceptibility of *Staphylococcus aureus* and coagulase negative staphylococci from bovine mastitis in the Aydın region of Turkey. Turkish Journal of Veterinary and Animal Sciences 2005; 29 (3): 791-796.

34. Klimienė I, Ružauskas M, Špakauskas V, Matusevičius A, Mockeliūnas R, et al. Antimicrobial resistance patterns to beta-lactams of gram-positive cocci isolated from bovine mastitis in Lithuania. Polish Journal of Veterinary Sciences 2011; 14 (3): 467-472. doi:10.2478/v10181-011-0069-9

35. Penna B, Varges R, Martins R, Martins G, Lilenbaum W. In vitro antimicrobial resistance of staphylococci isolated from canine urinary tract infection. Veterinary Dermatology. 2010; 51 (7): 738-742.

36. Couto N, Monchique C, Belas A, Marques C, Gama LT, et al. Trends and molecular mechanisms of antimicrobial resistance in clinical staphylococci isolated from companion animals over a 16 year period. Journal of Antimicrobial Chemotherapy 2016;71(6):1479-1487. doi: 10.1093/jac/dkw029

37. Pedersen K, Pedersen K, Jensen H, Finster K, Jensen VF, et al. Occurrence of antimicrobial resistance in bacteria from diagnostic samples from dogs. Journal of Antimicrobial Chemotherapy 2007; 60 (4): 775-781.

38. Blunt CA, Van Vuuren M, Picard J. Antimicrobial susceptibility profiles of *Staphylococcus intermedius* isolates from clinical cases of canine pyoderma in South Africa 2013;16 (84): E1-6. doi: 10.4102/jsava.v84i1.276

39. Moser A, Stephan R, Ziegler D, Johler S. Species distribution and resistance profiles of coagulase-negative staphylococci isolated from bovine mastitis in Switzerland. Schweizer ArchivfürTierheilkunde 2013; 155 (6): 333-338. doi: 10.1024/0036-7281/a000468

40. Youn J-H, Park YH, Hang'ombe B, Sugimoto C. Prevalence and characterization of *Staphylococcus aureus* and *Staphylococcus pseudintermedius* isolated from companion animals and environment in the veterinary teaching hospital in Zambia, Africa. Comparative Immunology, Microbiology & Infectious Diseases 2014; 37 (2): 123-130. doi: 10.1016/j.cimid.2014.01.003

41. Park J, Friendship RM, Poljak Z, Weese JS, Dewey CE. An investigation of exudative epidermitis (greasy pig disease) and antimicrobial resistance patterns of *Staphylococcus hyicus* and *Staphylococcus aureus* isolated from clinical cases. The Canadian Veterinary Journal 2013; 54 (2): 139-144.

42. Tiwari DH, Sapkota D, Das AK, Sen MR. Assessment of different tests to detect methicillin resistant *Staphylococcus aureus*. The Southeast Asian Journal of Tropical Medicine and Public Health 2009; 40 (4): 801-806.

43. Vural A, Afşar İ, Kurultay N, Demirci M. *Staphylococcus aureus*' da metisilin direncinin saptanmasında disk difüzyon, oksasilin agar tarama, mikrodilüsyon ve PBP2A lateks aglütinasyon testlerinin karşılaştırılması. Ankem Dergisi 2011; 25 (3): 145-149. doi:10.5222/ankem.2011.145

44. Pourmand MR, Hassanzadeh S, Mashhadi R, Askari E. Comparison of four diagnostic methods for detection of methicillin resistant *Staphylococcus aureus*. The Iranian Journal of Microbiology 2014; 6 (5): 341-344.

45. Shah DA, Wasim S, Abdullah FE. Comparison of oxacillin and cefoxitin for the detection of mecA gene to determine methicillin resistance in coagulase negative Staphylococci (CoNs). Journal of College of Physicians and Surgeons Pakistan 2017; 27 (8): 520-522. doi: 10/2685

46. Antunes ALS, Secchi C, Reiter KC, Perez LRR, Freitas ALPD, et al. Evaluation of oxacillin and cefoxitin disks for detection of resistance in coagulase negative staphylococci. The Memórias do Instituto Oswaldo Cruz 2007;102(6):719-723. doi: 10.1590/S0074-02762007005000078

47. Anand K, Agrawal P, Kumar S, Kapila K. Comparison of cefoxitin disc diffusion test, oxacillin screen agar, and PCR for mecA gene for detection of MRSA. Indian Journal of Medical Microbiology 2009; 27 (1): 27-29.

48. Moon BY, Youn J-H, Shin S, Hwang SY, Park YH. Genetic and phenotypic characterization of methicillin-resistant staphylococci isolated from veterinary hospitals in South Korea. The Journal of Veterinary Diagnostic Investigation 2012; 24 (3): 489-498. doi: 10.1177/1040638712440985

49. Öztürk D, Türütoğlu H, Pehlivanoğlu F, Yapıcıer ÖŞ. Identification of bacteria isolated from dairy goats with subclinical mastitis and investigation of methicillin and vancomycin resistant *Staphylococcus aureus* strains. Ankara Üniversitesi Veteriner Fakültesi Dergisi 2019; 66 (2): 191-196. doi: 10.33988/auvfd.431465