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METHICILLIN –RESISTANT *STAPHYLOCOCCUS AUREUS* AS A ZOONOTIC PATHOGEN: HOW SAFE IS TO PAT KITTY?

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ABSTRACT

Humans and animals intimately sharing same environments will inevitably be exposed to each other's normal flora. Veterinarians have higher rates of methicillin-resistant *Staphylococcus aureus* (MRSA) nasal carriage compared to the general population and many human infections have been attributed to close animal contacts. Researchers in Europe favor the view that livestock particularly pigs and horses may represent an important reservoir for MRSA. In studies from three continents, MRSA has been isolated from retail meat products from milk and meat samples and from meat industry workers. Some studies have not found any colonization among surveyed pets, for example, among 200 healthy dogs in Europe. One outbreak of MRSA in a family was linked to pet cat. The clearance of ST 80 MRSA colonization in family member with furunculosis did not occur until systemic antimicrobial drug therapy was administered to the cat, which was colonized with same strain. More research is needed to assess the importance of pets as a reservoir of MRSA in the home and to what degree of *S.aureus* is a Zoonosis.

KEYWORDS: MRSA, Nasal Carriage, Household Pets, Veterinarian

INTRODUCTION

Staphylococcus aureus is responsible for a wide range of opportunistic infections in both humans and animals. In humans, infection with methicillin-resistant *S.aureus* (MRSA), which appeared in the late 1960s, has traditionally been nosocomial in origin [1]. Humans and animals intimately sharing same environment will inevitably be exposed to each other's micro biota. When one of those organisms is a drug- resistant pathogen then logistic of disease prevention are raised to a new level of complexity. For this reason the study of MRSA in man and animals is now a priority [2].

The strains colonizing and causing infection in dogs and cats such as colonal complex (CC) 22 most probably originated in humans but have not as yet become host-adapted in these companion animals[3,4]. By contrast, MRSA strains isolated from horses and livestock such as CC8 and ST398, which also originated in humans[5]. Internationally, veterinary personnel have higher rates of MRSA nasal carriage compared to the general population and several cases of MRSA infection in humans have been attributed to close animals contact [6]. MRSA infections have been reported in the companion animals in Australia. Researchers in Australia have confirmed that animal contact in clinical setting is an important risk factor for MRSA nasal carriage [2].

Livestock-associated methicillin resistant *Staphylococcus aureus* was first associated with human disease in 2003, when a MRSA clone associated with a reservoir in pigs and cattle was isolated from a human. This clone was not type able by pulsed-field gel electrophoresis(PFGE) with Sma 1 macro restriction digestion and belonged to multilocus sequence type ST 398.[7] Since then, rates of MRSA ST 398 carriage have been high (25% to 35%) for persons in Netherlands who have frequent contact with pigs and veal calves, but associated illness is rare.[8]. However, in Europe, Asia and the United

States, invasive infections and a hospital outbreak of MRSA ST398 have been reported.[9]. Livestock-associated MRSA ST398 was reported from 8 of 15 European countries. Except 4 countries and 1 region in Germany, the proportion of MRSA ST 398 among MRSA isolates from humans was <2%, suggesting that in 2007 this livestock-associated clone contributed to only a small fraction of all MRSA in humans. A recent study of laboratories in 26 European countries during September 2006-February 2007 found no MRSA ST398 among *S.aureus* isolates from persons with invasive infections. This article reviews MRSA as a Zoonotic pathogen and the role of pet or contact animals in the spread of MRSA infection [9].

ANIMALS AS RESERVIOR FOR HUMAN MRSA

Researchers in Europe favor the view that livestock particularly pigs, may represent an important reservoir for CA-MRSA strains that can colonize and infect humans in close contact with them[10,11]. ST398 is the most commonly reported MRSA sequence type among livestock in Europe. ST398 MRSA strains often carry genes coding for non-beta-lactam antimicrobial resistance, including a plasmid-borne trimethoprim resistance gene *dfr* K, identified in an isolate from a pig in Germany[12]. These ST398 isolates are often referred to as non-type able by PFGE because their genome is resistant to Sma1 digestion. The isolates carry SCC*mec* type IV or V and typically lack PVL genes; several common *spa* types have been associated with these isolates [13].

Studies of asymptomatic MRSA colonization of a variety of farm animals have suggested that carriage rates vary widely. Among 300 healthy horses in Slovenia in 2005, no MRSA carriage was identified;[14]. A similar finding was obtained for 497 horses on 50 farms in 2006 in the Maritime Provinces of Canada [15] and for 87 military horses in Austria.[16]. In contrast, among 110 horses attending clinic in Belgium in 2007, 10.9% (12 horses) had nasal carriage with MRSA ST398 strains of two *spa* types[17]. ST398 was also isolated from poultry in Belgium in 2006.

In Netherlands in 2006, MRSA colonization of pigs was identified in 7/31 (23%) tested farms. The ST398 MRSA strains from this study also had a variety of *spa* types.[18]. Several studies have suggested high rates of asymptomatic colonization by ST398 MRSA backgrounds among swine and their handlers, suggesting that frequent transmission occurs, although secondary human-to-human spread to close contacts appears to be rare[19]. Moreover, clinical infection among exposed swine farm workers has been reported infrequently. In Iowa, 49% (147/299) of swine and 45% (9/20) of farm workers in 2007 to 2008 carried ST398 MRSA in nares; no other MRSA genetic backgrounds were identified. Younger swine were more likely to be carriers [20].

In Austria in March 2008, 13/162 (8%) pig farmers who attended a conference had MRSA nasal carriage, and all eight isolates examined had *spa* to34, a type associated with ST398 strains [10]. Among 127 farm workers and their contacts on 50 pig farms in Belgium in 2007, 37.8% (48/1270 had nasal or skin lesion colonization with MRSA. MRSA carriage was associated with close contact with pigs, dogs and horses and paradoxically, with the use of protecting clothing. The 48 isolates belonged to three *spa* types (t011, t034 and t567), but 94% (n=45) were t011isolates. Representative isolates of each *spa* type were found to share the ST398 genotypes [21].

In the Netherlands in 2004 > 20 % of pig farmers colonized with ST398 MRSA, as were 39 % of pigs destined for slaughterhouses, seven *spa* types were represented and four predominated[22]. In Austria, 21 of the 1,098 MRSA isolates from humans submitted to a reference laboratory in January 2006 to May 2008 were ST398 isolates. Among these isolates, 5 were obtained from clinical infections, 15 were obtained from cultures to assess colonization status, and the source of one was unknown. Of the 19 isolates from patients with information regarding animal exposure, 10 were from pig farmers or their relatives, 6 were from farmers with other animal exposures, and 3 were from people who had no known animal

contact. The percentage of ST398 isolates increased in each year the study and peaked at 2.5 % of submitted isolates in January to May 2008[23].

Invasive infection caused by ST398 occurs but rarely. In Italy, a pig farm worker developed, suggesting a porcine origin of strains pyomycositis caused by an MRSA ST398 strain. A subsequent investigation of the farm employing the patient revealed colonization by ST398 strains among 1 0f 11 swine workers and family members; ST398 strains were isolated from seven dust samples from furrowing areas on the farm, suggesting a porcine origin of strains. Researchers have confirmed the absence of PVL genes from ST398 strains; one report from Sweden described them for isolates from two ST398 SSTIs occurring in previously healthy patients in 2006 and 2007. The strains had the t034 *spa* type. Which has been widely reported among PVL-negative ST398 strains. Another PVL^+ ST398 MRSA isolate (*spa* type t034 and SCCmec type V) was submitted to the national reference collection of Netherlands in 2007 [24, 25]. ST398 MSSA strains were also identified by colonization studies of pig farmers in France but not in a sample of non-pig farmers, [26] suggesting that MSSA ST398 strains, like MRSA ST398 strains, are also most closely associated with pigs and pig farm workers.

Similarly, MSSA ST398 isolates colonized two pig farmers in Holland and were also isolated from the blood of three elderly hospitalized patients suggesting again that it may be a virulent clone in humans, at least occasionally [27].

MRSA genetic back grounds other than ST398 have likely also been transmitted between farm animal handlers and livestock. For example, at meat markets and livestock farms in Taiwan in 2004 to 2005, 3 MRSA isolates were isolated from fomites and 27 were isolated from the nares of workers; the most common strain was ST59, ST338 and a single-locus variant of ST398 [28]. Transmission among swine and swine farm workers of ST398 strains among MRSA disease isolates from other patients have been studied more carefully in the Netherlands.

At a hospital in a region of the country with 7000 pig farms screening of health care workers and high-risk individuals who were hospitalized was routinely performed in 2002 to 2006. Seventy three colonized individuals were identified, 31.5% of whom (23 individuals) carried “non- type able” MRSA presumed to be ST398 all of the non-type able strains were identified in 2004 to 2006 [29,30]. In July to December 2006, a period when a history of direct exposure to pigs or veal calves triggered a screening nasal culture, 19 patients with PGFE-non- type able MRSA carriage were identified, 87% of them whom had previous exposure to pigs or calves. Among MRSA carriers with PGFE-non type able strains, clinical infection was less common (13%) than among carriers of PGFE-type able strains (42%), again suggesting that ST398 may not be a virulent as other genetic backgrounds [31].

In Netherlands among 1,721 health care workers MRSA colonization was 10-fold higher (1.7%) among those reporting contact with pigs and veal calves than those without such contact (0.15%), although this difference was not significant [32]. At a Dutch hospital in 2002 to 2006, 26 % of 95 patients and health care workers from whom MRSA was isolated likely acquired their isolates from animals. Individuals with animal contact were responsible for the over 3 fold annual increase in the rate of MRSA isolation during this period [33].

In the 6 months after the introduction of more intensive surveillance programs in July 2006 over 21% of all MRSA strains obtained by the national reference center for MRSA in the Netherlands were non-type able and presumably ST398 strains [34]. In 2007, the percentage of MRSA that were non-type able increased to 30.3% (793/2619), with 80% of these isolates having *spa* type T108.[29]In addition to the risk posed to farmers and others working with animals, the general population may be at risk for exposure to MRSA carried by livestock from poor hygienic practices at petting Zoo animals [36].

VETERINARY ASPECTS OF MRSA TRANSMISSION

Researchers have confirmed asymptomatic colonization of animals at veterinary clinics worldwide. In Canada 3,372 horses admitted to veterinary teaching hospital in Ontario, in 2002 to 2005, 69 (2%) were colonized with MRSA; risk factors included antimicrobial use in the previous 30 days, previous MRSA colonization or infection, known MRSA colonization or infection in the past on the farm of origin, admission to hospital's surgery service, or being in a neonatal intensive care unit [37]. Among dogs admitted to a Canadian veterinary teaching hospital in 2004, 1/93 (0.5%) carried MRSA recovered from the nares, axilla and rectum [38]. Several studies suggested that MRSA strains may be transmitted between humans and animals in the veterinary setting [39,40]... The human and animal strains share common genetic backgrounds and were closely related; few differences were identified when comparing the DNA sequences of selected genes of MRSA isolates sharing genetic backgrounds from human and horses [41].

Veterinarian, particularly those caring for large animals, has been identified as high- risk group for asymptomatic MRSA carriage, likely because of their close animal contact. Among 152 Dutch veterinary doctors and veterinary students with history of contact with livestock, a high prevalence (4.6%) of MRSA colonization was documented [42]. At a veterinary conference in 2005 in Baltimore, MD, 6.5% (27/417) of tested attendees carried MRSA in the nares, including 15.6% (15/96) of personnel caring for large animals [43]. At an international equine veterinary conference in San Antonio, TX, 101% (26/257) of attendees tested carried one of three pulso types of MRSA (USA300, USA 100, or USA500). Risk factors for MRSA carriage included a history of caring for a horse with MRSA infection in the previous year, attendee having had an MRSA infection in the past year and self-reported failure to wash hands between farms or between or between handling of infected animals [44].

In an international conference of veterinarians in Denmark in 2006, 12.5% (34/272) carried MRSA in the nares or the throat; 31 of 34 recovered MRSA isolates were likely ST398 isolates. MRSA carriers came from nine countries [45]. This trend was not observed for Czech Republic, where, at a veterinary conference in 2008, only 0.7% (2/280) of screened attendees carried MRSA [46]. Similarly, at a university small-animal veterinary clinic in Scotland, 2/64 (3.1%) personnel had nasal carriage of MRSA; both isolates were EMRSA-15 by PFGE analysis, a common strain among human nosocomial infections [47].

MRSA IN RAW MEAT AND IN MILK

In studies from three continents, MRSA has been isolated from retail meat products, from milk and meat samples [48-50] and from meat industry workers. In Netherlands, MRSA was isolated 2 of 79 raw beef and pork samples from retail meat stores in 2006. One isolate was a USA300 strain and other was untypeable by PFGE using Sma1 digestion. This isolate may have been an ST398 strain, although sequence typing was not performed [51]. In 2007 to 2008, 264/2, 217 (11.9%) raw retail meat sample in the Netherlands had recoverable MRSA. Analysis of spa types suggested that 85% of recovered isolates were ST398[16]. The testing of 120 retail meat samples from grocery stores in Baton Rouge, LA, in 2008 revealed *S. aureus* on 45.6% of pork and 20% of beef samples. MRSA was isolated from 5% (6/120) of meat samples. The MRSA strain belonged to the USA300 or USA 100 pulsotype. At present no studies has been conducted whether the consumers face risk of MRSA colonization or infection [52].

HOUSEHOLD PETS AS RESERVIOR OF MRSA INFECTION

Many researchers favor the view that household pets may be a predisposing factor in MRSA infection in the community. The transmission of HA-MRSA strains among pets and owners did occur in the pre CA-MRSA era [53] and

after 2000 CA-MRSA strain transmission, [54, 55] including USA300 and ST398 strains has been reported [56, 57]. Among 70 *S. aureus* isolates from 46 cats treated at a clinic in Philadelphia in 2002 to 2005, all 15 MRSA strains tested carried SCCmec type 11, a molecular characteristic of HA-MRSA strains from people[58]. This finding suggests that cats may serve as a reservoir of MRSA in humans.

In Hong Kong, only 17 of 736 tested dogs owners both were colonized with *S.aureus* and owned a colonized dog. MRSA strains were isolated from 8.2% of the dogs and from 2.3% of the dog owners, but only one dog owner pair was concordant in MRSA colonization status. Furthermore, only 6/17 of the dog-owner *S.aureus* isolate pairs shared PFGE types, [59] implying that the transmission of *S.aureus* between dogs and their owners was relatively infrequent despite the high MRSA carriage rate. Some studies have not found any colonization among surveyed pets, for example, among 200 healthy dogs in Europe [60]. Despite this, pets have been anecdotally implicated as a source of human infection cause by MRSA. One outbreak of MRSA in a family was linked to a pet cat.

The clearance of ST80 MRSA colonization in family member with furunculosis did not occur until systemic antimicrobial drug therapy was administered to the cat, which was colonized with same strain [61]. More research is needed to assess the importance of pets as a reservoir of MRSA in the home and to what degree of *S.aureus* is a zoonosis. Few data on the use of antimicrobial drugs among pets in the United States has been collected; the over use of these drugs may increase the risk of MRSA carriage in pets [16, 62].

CONCLUSIONS

Household pets and livestock have been identified as carriers of MRSA in many countries. Many researchers favor the view that domestic pets may be predisposing factors in MRSA infection in community. Several studies suggested that MRSA strains may be transmitted between humans and animals in the veterinary setting. Humans and animals strains share common genetic backgrounds and closely related.

REFERENCES

1. **Bassetti M., *et al.*** Why is community –associated MRSA spreading across the world and how it will change clinical practice?. *Int J Antimicrob Agents*.2009**;34:**S15-S19.doi:10.1016/S0924-8579 (0) 70544-8.

2. **Darren Trott, David Jordan, Mary Barton, Sam Abraham, Mitchel Groves.** Vets versus pets: methicillin –resistant Staphylococcus aureus in Australian Animals and their doctors. *Aust Microbiol*. 2013**; 34:** 25-27.

3. **Morgan M**. Molecular typing of Staphylococci isolates from cats and dogs. *JAntimicrob Chemothe*r. 2006**; 58**:428-431.doi:10.1093/jac/dkl253.

4. **Wees JS, vanDujikeren E**. Methicillin –resistant *Staphylococcus aureus* and *Staphylococcus pseudiintermedus* in veterinary medicine. *Vet Microbiol*.2010;**140**:418-429.doi:10.1016/jvetmic.2009.01.039.

5. **VanDujikeren E., *et al***. Transmission of methicillin-resistant *Staphylococcus aureus intermedus* between humans and animals. *Vet mIcrobiol*.2008;**128**:213-215.doi:10.1016/j, vetmic.2007.11.016.

6. **Jordan D., *et al*.** Carriage of methicillin –resistant *Staphylococcus aureus* by veterinarians in Australia. *Aust Vet J*.2011;**152**:-159.doi:10.1111/j.1751.0813.2011.00710.x.

7. **Huijsdens XW, van Dijke BJ, Spalburg E, van Santen- Verheuvel MG, Heck ME, Pluister GN.** Community-acquired MRSA and pif-farming. *Ann. Clin. Microbiol. Antimicrob.*2006;**5:** 26.

8. **Broek van den IVF, Cleef van BAGL, Haenen A, Broens EM, Wolf van der PJ, Broek van den MJM,** *et al.* Methicillin-resistant *Staphylococcus aureus*in people living and working in pig farms. *Epidemiol. Infect.* 2008; **137:** 700-8.

9. **Wulf MW, Markestein A, van der Linden FT, Voss A, Klaassen C, Verduin CM.** First outbreak of methicillin-resistant *Staphylococcus aureus* ST398 in a Dutch hospital, June 2007. *Euro Surveill.*2008; **13:** 8051.

10. **Declerq, P., D. Petre, B. Gordts, and A. Voss**. Complictaed community-acquired soft tissue infection by MRSA from porcine origin. *Infection*.2008; **36**:590-592.

11. **Leonard, F. C., and B. K. Markey**. Methicillin-resistant *Staphylococcus aureus* in animals: a review. *Vet. J*. 2008; **175**:27-36.

12. **Kadlec, K., and S. Schwarz**. Identification of a novel trimethoprim resistance gene, *dfrK,* in a methicillin-resistant *Staphylococcus aureus* ST398 and its physical linkage to the tetracycline resistance gene *tet*(L). *Antimicrob. Agents Chemother*.2009; **53**:776-778.

13. **Bens, C. C. P. M., A. Voss, and C. H. W. Klassen**. Presence of a novel DNA methylation enzyme in methicillin-resistance *Staphylococcus aureus* isolates associated with pig farming leads to uninterpretable results in standards pulse-field gel electrophoresis analysis. *J. Clin. Microbiol*.2006; **44**:1857-1876.

14. **Vengust, M., M. E. Anderson, J. Rousseau, and J. S. Weese**. Methicillin-resistant staphylococcal colonization in clinically normal dogs and horses in the community. *Lett. Appl. Microbiol*. 2006; **43**:602-606.

15. **Burton, S., R. Reid-Smith, J. T. McClure, and J. S. Weese**. *Staphylococcus aureus* in healthy horses in Atlantic Canada. *Can. Vet. J.* 2008; **49**:797-799.

16. **Springer, B., U. Orendi, P. Much, G. Hoger, W. Ruppitsch, K. Krziwanek, S. Metz-Gercek, and H. Mittermayer.** Methicillin-resistant *Staphylococcus aureus*; a new zoonotic agent? *Wien. Klin. Wochenschr*. 2009; **121**: 86-90. (In German).

17. **Van den Eede, A., A. Martens, U. Lipinska, M. Struelens, A. Deplano, O. Denis, F. Haesebrouke, F. Gasthuys, and K. Hermans.** High occurance of methicillin-resistant *Staphylococcus aureus* ST398 in equine nasal samples. *Vet. Microbiol.* 2009;**133:** 138-144.

18. **VanDuijkeren, E., R. Ikawaty, R. J. Broekhuizen-Stins, M. D. Jansen, E. C. Spalburg, A. J. De Neeling, J. G. Allart, A. van Nes, J. A. Wagenaar, and A. C. Fluit.** Transmission of methicillin-resistant *Staphylococcus aureus* strains between different kinds of pig farms. *Vet. Microbiol.* 2008;**126:** 383-389.

19. **Cuny, C., R. Nathaus, F. Layer, B. Strommengaer, D. Altmann, and W. Witte**. Nasal colonization of humans with methicillin-resistant *Staphylococcus aureus* (MRSA) CC398 with and without exposure to pigs. *PLoS One*. 2009; **4**:e6800. doi:10.1371/journal.pone.0006800.

20. **Smith, T. C., M. J. Male, A. L. Harper, J. S. Kroeger, G. P. tinker, E. D. Moritz. A. W. Capuano, L. A. Herwaldt, and D. J. Diekema.** Methicillin-resistant *Staphylococcus aureus* (MRSA) strain ST398 is present in Midwestern U.S. swine workers. *PLoS One.* 2009; **4**:e4258. doi:10.1371/journal.pone.0004258.

21. **Denis, O., C. Suetens, M. Hallin, B, Catry, I. Ramboer, M. Dispas, G. Willems, B. Gordts, P. Butaye, and J. Struelens**. Methicillin-resistant *Staphylococcus aureus* ST398 in swine farm personnel, Belgium. *Emerg. Infect. Dis*. 2009; **15**:1098-1101.

22. **De Neeling, A. J., M. J. M. Van den Broek, E. C. Spalburg, M. G. Van, Santen- Verheuvel, W. D. C. Dam-Deisz, H. C. Boshuizen, A. W. Van de Giessen, E. Van Duijkeren, and X. W. Huijsdens.** High prevalence of methicillin-resistant *Staphylococcus aureus*in pigs. *Vet. Microbiol.* 2007; **122:** 366-372.

23. **Krziwanek, K., S. Metz-Gercek, and H. Mittermayer**. Methicillin-resistant *Staphylococcus aureus* ST398 from human patients, Upper Austria. *Emerg. Infect. Dis.* 2009; **15**:766-769.

24. **Welinder-Olsson, C., K. Florèn- Johansson, L. Larsson, S. Öberg, L. Karlsson, and C. ĂÅÅ.**

25. **Hujidens, X. W., T. Bosch, M. G. Van Santen – Verheuvel, E. Spalburg, G. N. Pluister, M.vanLuit, M. E. O. C. Heck, A. Haenen, and A. J. De Neeling.** Molecular characterisation of PFGE non-typeable methicillin-resistant *Staphylococcus aureus*in the Netherlands, 2007. *Euro Surveill.* 2009; **14**(38):pii=19335.

26. **Armand-Lefevre, L., R. Ruimy, and A. Andremont**. Clonal comparison of *Staphylococcus aureus* from healthy pig farmers, human controls, and pigs. *Emerg. Infect. Dis*. 2005; **11**:711-714.

27. **Van Belkum, A., D. C. Melles, J. K. Peeters, W. B. van Leeuwan, E. van Duijkeren, X. W. Huijsdens, E. Spalburg, A. J. de Neeling, and H. A. Verbrugh on behalf of the Dutch Working Party on Surveillance and Research of MRSA (SOM).** Methicillin-resistant and –susceptible *Staphylococcus aureus* sequence type 398 in pigs and humans. *Emerg. Infect. Dis*. 2008; **14**:478-483.

28. **Hsieh, J. M., R. S. Chen, T. Y. Tsai, T. M. Pan, and C. C. Chou**. Phylogenetic analysis of livestock oxacillin-resistant *Staphylococcus aureus*. *Vet. Microbiol*. 2008; **126**:234-242.

29. **De Neeling, A. J., M. J. M. van de Broek, E. C. Spalburg, M. G. van Giessen, E. van Duijkeren, and X. W. Huijsdens**. High prevalence of methicillin-resistant *Staphylococcus aureus* in pigs. *Vet. Microbiol*. 2007; **122**:366-372.

30. **Wulf, M., and A. Voss**. MRSA in livestock animals – an epidemic waiting to happen? *Clin. Microbiol. Infect.* 2008; **14**:519-521.

31. **Tong, S.Y.C., M. I. McDonald, D. C. Holt, and B. J. Currie.** Global implications of the emergence of community-associated methicillin-resistant *Staphylococcus aureus*in indigenous populations. *Clin. Infect. Dis.* 2008; **46:** 1871-1878.

32. **Wulf, M. W. H., E. Tiemersma, J. Kluytmans, B. Bogaers, A. C. A. P. Leenders, M. W. H. Jansen, J. Berkhout, E. Ruijters, D. Haverkate, M. Isken, and A. Voss**. MRSA carriage in healthcare personnel in contact with farm animals. *J. Hosp. Infect*. 2008; **70**:186-190.

33. **VanRijen, M. M. L., T. Bosch, M. E. O. C. Heck, and J. A. J. W. Kluytmans**. Methicillin-resistant *Staphylococcus aureus* epidemiology and transmission in a Dutch hospital. *J. Hosp. Infect*. 2009; **36**:81-95.

34. **Van Loo, I., X. Huijsdens, E. Tiemersma, A. de Neeling, N. van de Sande-Bruinsma, D. Beaujean. A. Voss, and J. Kluytmans.** Emergence of methicillin-resistant *Staphylococcus aureus* of animal origin in humans. *Emerg. Infect. Dis*. 2007; **12**:1834-1839.

35. **Huijdens, X. W., T. Bosch, M. G. van Santen-Verheuvel, E. Spalburg, G. N. Pluister, M. van Luit, M. E. O. C. Heck, A. Haenen, and A. J. de Neeling**. Molecular characterisation of PFGE non-typable methicillin-resistant *Staphylococcusaureus* in the Netherland. Euro Surveill. 2007; 14(38): pii = 19335. http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId = 19335.

36. **Weese, J. S., L. McCarthy, M. Mossop, H. Martin, and S. Lefebvre**. Observation of practices at petting zoos and the potential impact on zoonotic disease transmission. *Clin. Infect. Dis*. 2007; **45**:10-15.

37. **Weese, J. S., and S. L. Lefebvre**. Risk factors for methicillin-resistant *Staphylococcus aureus* colonization in horses admitted to a veterinary teaching hospital. *Can. Vet. J*. 2007; **48**:921-926.

38. **Hanselman, B. A., S. Kruth, and J. S. Weese**. Methicillin-resistant staphylococcal colonization in dogs entering a veterinary teaching hospital. *Vet. Microbiol*. 2008; 126:277-281.

39. **Armand-Lefevre, L., R. Ruimy, and A. Andremont.** Clonal comparison of *Staphylococcus aureus*from healthy pig farmers, human controls, and pigs. *Emerg. Infect. Dis.* 2005;**11:**711-714.

40. **Seguin, J. C., R. D. Walker, J. P. Caron, W. E. Kloos, C. G. George, R. J. Hollis, R. N. Jones, and M. A. Pfaller**. Methicillin-resistant *Staphylococcus aureus* outbreak in a veterinary teaching hospital: potential human-to-animal transmission. *J. Clin. Microbiol*. 1999; **37**:1459-1463.

41. **Walther, B., S. Monecke, C. Ruscher, A. W. Friedrich, R. Ehricht, P. Slickers, A. Soba, C. G. Wleklinski, L. H. Wieler, and A. Lubke-Becker**. Comparative molecular analysis substantiates zoonotic potential of equine methicillin-resistant *Staphylococcus aureus*. *J. Clin. Microbiol*. 2009; **47**:704-710.

42. **Wulf, M., A. van Nes, A. Eikelenboom-Boskamp, J. de Vries, W. Melchers, C. Klaasen, and A. Voss**. Methicillin-resistant *Staphylococcus aureus* in veterinary doctors and students, the Netherlands. *Emerg. Infect. Dis*. 2006; **12**:1939-1941.

43. **Hanselman, B. A., S. A. Kruth, J. Rousseau, D. E. Low, B. M. Willey, A. McGeer, and S. Weese**. Methicillin-resistant *Staphylococcus aureus* colonization in veterinary personnel. *Emerg. Infect. Dis*. 2006; **12**:1933-1938.

44. **Anderson, M. E. C., S. L. Lefebvre, and J. S. Weese**. Evaluation of prevalence and risk factors for methicillin-resistant *Staphylococcus aureus* colonization in veterinary personnel attending an international equine veterinary conference. *Vet. Microbiol*. 2008; **129**:410-417.

45. **Wulf, M. W. H. Sorum, A. van Nes, R. Skov, W. J. G. Melchers, C. H. W. Klaasen, and A. Voss**. Prevalence of methicillin resistant *Staphylococcus aureus* among veterinarians: an international study. *Clin. Microbiol. Infect*. 2008; **14**:29-34.

46. **Zemlickova, H., M. Fridrichova, K. Tyllova, V. Jakubu, and I. Machova**. Carriage of methicillin-resistant *Staphylococcus aureus* in veterinary personnel. *Epidemiol. Infect*. 2009; **137**:1233-1236.

47. **Heller, J., S. K. Armstrong, E. K. Girvan, S. W. J. Ried, A. Moodley, and D. J. Mellor**. Prevalence and distribution of methicillin-resistant *Staphylococcus aureus* within the environment and staff of a university veterinary clinic. *J. Small. Anim. Pract*. 2009; **50**:168-173.

48. **Normanno, G., M. Corrente, G. La Salandra, A. Dambrosio, N. C. Quaglia, A. Parisi, G. Greco, A. L. Bellaciccio, S. Virgilio, and G. V. Celano**. Methicillin-resistant *Staphylococcus aureus* (MRSA) in foods of animal origin product in Italy. *Int. J. Food Microbiol*. 2007; **117**:219-222.

49. **Kitai, S., A. Shimizu, J. Kawano, E. Sato, C. Nakano, Y. Uji, and H. Kitagawa.** Characterization of *Staphylococcus aureus* isolated from retail raw chicken meat in Japan. *J. Vet. Med. Sci*. 2005; **67**:107-110.

50. **Kwon, N. H., K.T. Park, J.S.Moon, W. K. Jung, S. H. Kim, J. M. Kim, S. K. Hong, H. C. Koo, Y. S. Joo, and Y. H. Park.** Staphylococcal cassette chromosome *mec (*SCC*mec*) characterization and molecular analysis for methicillin-resistant *Staphylococcus aureus*and novel SCC*mec* subtype IVg isolated from bovine milk in Korea. *J. Antimicrob. Chemother.* 2005; **56:** 624-632.

51. **Van Loo, I. H. M., B. M. W. Diederen, P. H. M. Savelkoul, J.H. C. Woudenberg, R. Roosendaal, A. van Belkum, N. Lemmens-den Toom, C.Verhulst, P. H. J. van Keulen, and J. A. J. W. Kluytmans.** Methicillin-resistant *Staphylococcus aureus*in meat products, the Netherlands. *Emerg. Infect Dis.* 2007; **13:** 1753-1755.

52. **Pu, S., F. Han, and B. Ge**. Isolation and characterization of methicillin-resistant *Staphylococcus aureus* from Louisiana retail meats. *Appl. Environ. Microbiol*. 2009; **75**:265-267.

53. **Cefai, C., S. Ashurst, and C. Owens.** Human carriage of methicillin resistant *Staphylococcusaureus* linked with a pet dog. *Lancet*. 1994; **344**:539-540.

54. **Rutland, B. E., J. S. Weese, C. Bolin, J. Au, and A. N. Malani**. Human-to-dog transmission of methicillin-resistant *Staphylococcus aureus*. *Emerg. Infect. Dis*. 2009; **15**:1328-1330.

55. **VanDuijkeren, E., M. J. H. M. Wolfhagen, A. T. Box, M. E. O. Heck, and W. J. B. Wannet**. Transmission of a Panton-Valentine leucocidin-positive, methicillin-resistant *Staphylococcus aureus* strain between humans and a dog. *J. Clin. Microbiol*. 2005; **43**:6209-6211.

56. **Wang, J. L., S. Y. Chen, J. T. Wang, G. H. Wu, W. C. Chiang, P. R, Hsueh, T. C. Chen, and S. C. Chang**. Comparison of both clinical features and mortality risk associated with bacteremia due to community-acquired methicillin-resistant *Staphylococcus aureus* and methicillin-susceptible *S. aureus. Clin. Infect. Dis*. 2008; **46**:799-806.

57. **Nienhoff, U., K. Kadlec, I. F. Chanberny, J. Versphol, G. F. Gerlach, S. Schwarz, D. Simon, and I. Nolte**. Transmission of methicillin-resistant *Staphylococcus aureus* strains between humans and dogs: two case reports. *J. Antimicrob. Chemoter*. 2009; **64**:660-662.

58. **Morris, D. O., E. A. Maudlin, K. O'Shea, F. S. Shofer, and S. C. Rankin**. Clinical, microbiological, and molecular characterization of methicillin-resistant *Staphylococcus aureus* infections in cats. *Am. J. Vet. Res*. 2006; **67**:1421-1425.

59. **Boost, M. V., M. O'Donoghue, and A. James**. Prevalence of *Staphylococcus aureus* carriage among dogs and their owners. *Epidemiol. Infect*. 2008; **136**:953-964.

60. **Vengust, M., M. E. Anderson, J. Rousseau, and J. S. Weese.** Methicillin-resistant staphylococcal colonization n clinically normal dogs and horses in the community. *Lett. Appl. Microbiol.* 2006; **43:** 602-606.

61. **Van de Gissen, A. W., M. G. van Santen-Verhuevel, P. D. Hengeveld, T. Bosch, E. M. Broens, and C. B. E. M. Reusken**. Occurence of methicillin-resistant *Staphylococcus aureus* in rats living on pig farms. *Prev. Vet. Med*. 2009; **91**:270-273.

62. **Lloyd, D. H.** Reservoirs of antimicrobial resistance in pet animals. **Clin. Infect. Dis**. 2007; **45**:S148-S152.