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Methicillin-resistant *Staphylococcus aureus* and animals: zoonosis or humanosis?

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Methicillin-resistant *Staphylococcus aureus* (MRSA) is increasing worldwide. Occasionally, animals are colonized or infected incidentally with human strains. Recently, however, new strains of MRSA emerging from within the animal kingdom, particularly in pigs, are causing human infection. MRSA has been reported in species as diverse as companion animals, horses and pigs, through to chinchillas, bats and parrots. In contrast, whereas strains of community-associated MRSA, the majority of which carry genes encoding Panton–Valentine leucocidin, are spreading rapidly in human populations, only sporadic cases have been reported in animals to date. Although MRSA has been found in some meat products, the implications for human infection through consumption are unclear. This review examines the epidemiology of MRSA in animals and human attendants/owners, the diagnosis and management of MRSA colonization, infection and infection control strategies in animals.

Keywords: MRSA, Panton–Valentine leucocidin, companion animals, horses, pigs

Introduction

Methicillin-resistant *Staphylococcus aureus* (MRSA) is no longer primarily a human healthcare-associated problem, but is now a community-associated problem, especially in the USA, where community-associated MRSA (CA-MRSA) is displacing the older 'hospital-associated' MRSA (HA-MRSA) strains.

Methicillin resistance is due to a modified penicillin-binding protein PBP2a, encoded by the *mecA* gene, located on one of six types of staphylococcal chromosomal cassettes (SCCs), which vary greatly in size. With the exception of isolates of sequence type (ST) 22, SCCs in HA-MRSA strains usually contain additional genetic material, including genes encoding resistance to multiple classes of antimicrobials. The smallest cassette containing a *mecA* gene, SCC*mec* type IV, is present in clones of CA-MRSA, which are becoming endemic in many parts of the world.[1] While many human CA-MRSA strains have additional genetic material including genes encoding production of Panton–Valentine leucocidin (PVL), these strains are comparatively rare in animals.

Generally, companion animal strains of MRSA differ from those in livestock and meat production animals. This is probably because in companion animals, MRSA acquisition is primarily a humanosis, the strains carried by human owners being passed on to their animals. Traditional animal husbandry involved far less close contact between animals (which were often not housed) than today's intensively farmed livestock intended for human consumption. The newly emerging MRSA strains such as ST398 found among pigs present a genuine zoonotic risk, as their attendants may become colonized or infected with new strains of MRSA.[2]

History of MRSA infection in animals

In 1972, MRSA was found in milk from Belgian cows with mastitis.[3] However, the MRSA status of the dairymen was not investigated. MRSA has since been reported in many diverse species, including dogs,[4–19] cats,[10,13,15,18–25] sheep,[26] chickens,[27] horses,[20,28–32] rabbits,[15,18,33] seals,[10] psittacine birds,[15,18] and one turtle, bat, guinea pig and chinchilla.[18]

Historically, MRSA infections in companion animals involved strains resembling human nosocomial strains, including epidemic MRSA (EMRSA).[17] When these epidemic HA-MRSA clones were observed in dogs,[9,17,21] the assumption was that the direction of spread had been from man to animals—a 'humanosis'. However, this situation is changing rapidly, with strains of MRSA that are thought to have evolved in animals colonizing and infecting human attendants.[2] Particularly notable are the MRSA strains associated with pigs, which were non-typeable by PFGE using *Sma*I, but were subsequently found to belong to multilocus ST (MLST) ST398. ST398 is associated with a number of different staphylococcal protein A (spa) types, including t011, t034, t108, t567, t899 and t939.[34] The t011 strain is primarily associated with SCC*mec* IV and IVa, whereas t108 is associated with SCC*mec* V.[2] MLST and spa typing of French and Dutch MRSA strains[35] show that ST398 and spa type t108

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are now also emerging in the human population, accounting for 20% of the MRSA occurring in humans in the Netherlands.[36–38]

Prevalence of MRSA in the animal kingdom

MRSA strains differ in their human/animal affiliation and pathogenic potential. Since most reported animal isolates of MRSA are from clinical infections following failure of empirical therapy,[17] there are few epidemiological studies of the prevalence of MRSA in animals. Such sampling bias, inadequate culture methodology and identification methods together with geographical and strain differences may obscure the true carriage rate of MRSA in animals. MRSA was not found in any of 102 dogs screened in one Ontario study,[39] whereas another Ontario veterinary school study found only 1/193 dogs to be carriers.[40]

As in humans, poor skin condition in animals favours staphylococcal carriage. Of cats with inflammatory skin disease examined at the University of Pennsylvania, 58% carried MRSA compared with only 7% of healthy cats.[41] Another study found only 3/148 healthy cats to be MRSA-positive.[42]

In the largest equine study to date, involving 3969 swabs from 2283 Canadian horses, the overall MRSA colonization rate was 2.7%, half the affected horses being colonized nasally.[29] Ninety-nine percent of 120 horses colonized with CA-MRSA had the Canadian EMRSA-5 strain (ST8),[29] whereas the same authors reported the predominant strain in companion animals to be CA-MRSA-2 (ST5).[43]

The nosocomial equine MRSA infection rate was 1.8/1000 Canadian admissions[29] compared with an incidence of 4.8/1000 among equine admissions to a Viennese hospital.[31]

Pigs have increasingly been found to be colonized with MRSA in the Netherlands, France and other countries, although not as yet in the UK. In 2005, monthly screening of batches of 10 pigs from each of nine Dutch abattoirs, found 209/540 pigs (38.7%) to be MRSA-positive overall. In 81% of the 54 batches of pigs tested, at least one pig was nasally colonized with MRSA.[44] Among pigs in Ontario, the ST5 strain of MRSA predominated. Nasal and rectal swabs of 285 pigs from 20 pig farms resulted in 9/20 farms being identified as having pigs carrying MRSA belonging to spa t539 (the USA100 clone; ST5).[45] In another Dutch study, more than 75% of pig-associated strains of MRSA were found on spa sequencing to be t011 and t108, the t011 primarily associated with *SCCmec* IV and IVa, whereas t108 was associated with *SCCmec* V.[2]

Risk factors for colonization and infection of animals

Risk factors for acquisition of MRSA by animals mirror those for human acquisition, namely living in a household with a colonized human or animal, hospitalization and surgery. Repeated veterinary practice or hospital admissions and usage of antimicrobials such as aminoglycosides[29] have all been noted as risk factors. Horizontal spread of MRSA between animals on farms and in veterinary establishments is well recognized,[29] particularly larger establishments with more than 20 horses.[28]

MRSA infection in companion animals

MRSA infections in animals are predominantly skin and soft tissue infections (especially post-surgical). During 1 year in the UK, 1.5% (95/6519) of the clinical samples from infected animals yielded MRSA. These comprised 69 dogs, 24 cats, 1 horse and 1 rabbit.[33] The following year, the same authors reported that of 31 randomly selected MRSA strains, 29 (94%) were indistinguishable from UK EMRSA.[17] The incidence of MRSA infection in a small animal hospital in Berlin was 1.85/1000 admissions.[18] MRSA-infected rabbits are uncommon,[10,30,46] although one rabbit carrying a PVL-producing MRSA strain has been reported.[15]

In an Irish veterinary hospital, more than half of their 25 MRSA animal isolates were of canine origin, with eight horses, one cat, one rabbit and one seal also infected.[10] Whether dogs are more susceptible to carrying certain strains is unclear, but there was a predominance of MRSA infection among dogs. In a UK study, nearly three times as many dogs as cats were actually infected with MRSA.[33]

Perhaps unsurprisingly, MRSA presence is often associated with veterinary surgery. In one report, four dogs suffered post-operative infections following facture repairs after road traffic accidents and one developed infection after a routine posterior cruciate ligament repair. Four of the five recovered after removal of implants and appropriate antimicrobial therapy,[12] suggesting that as with human prosthetic infections, removal of the prosthesis is usually necessary for cure.

MRSA infection in horses

Skin and soft tissue MRSA infections,[20] bacteraemia, septic arthritis,[29,31] osteomyelitis,[31] implant-related infections, metritis,[47] omphalitis,[4,28] catheter-related infections and pneumonia[29] have all been reported in horses. The first outbreak of MRSA infection in horses was noted in 1993, with 11 horses infected post-operatively in a veterinary teaching hospital in Michigan.[20] Subsequent outbreaks occurred in Japan,[47] Austria,[32] the UK,[4] Ireland,[10] the USA and Canada.[29] This latter outbreak involved 14 clinical infections, including 4 cases of septic arthritis, 3 intravenous (jugular) line infections, 2 pneumonias and a mastitis.[29]

Some MRSA strains, e.g. CA-MRSA-5 (ST8), appear adapted to equine colonization[28] and are often gentamicin- and tetracycline-resistant. The most prevalent global isolate is the USA500 strain, although MRSA ST254 was responsible for infection in four horses in an Austrian veterinary school.[31]

MRSA infection in cattle

S. aureus causes mastitis in milking herds, and occasionally purulent dermatitis in their milkers.[48] Since the first report of MRSA in cattle in 1972,[3] cows with mastitis seem the most likely to harbour MRSA. This may be due to horizontal transfer of MRSA via the wet hands of colonized or infected milkmen, and selection by the use of antibiotics to treat mastitis. Recently, none of the 1043 milk and udder swabs from dairy farms in NW England were positive for MRSA,[49] yet 9/12 MRSA samples from mastitic Korean cows were positive in 2002.[50] The only report of PVL-positive MRSA in cattle to date is from Korea.[11]

MRSA infection in pigs

During an outbreak of 'exudative epidermitis' (a disease normally due to *Staphylococcus hyicus*) afflicting Dutch pigs, following unsuccessful therapy with cephalosporins, tylosin and co-trimoxazole, MRSA was found to be the causative organism. All isolates were spa type t011, ST398. *S. hyicus* exudative epidermitis disease has a mortality of 20%, but the MRSA-infected piglets were successfully treated with enrofloxacin.[51]

MRSA contamination of meat products

Of the 540 pigs sampled in Dutch abattoirs in 2005–06, 209 pigs (39%) were MRSA-positive.[44] Whether such MRSA pose a risk to human health is being investigated. The MRSA isolated from 6/717 samples of meat from sheep sampled in Jordan was felt to be due to human contamination.[26] Contamination of chicken with MRSA was uncommon. In the Far East, only 2/119 Korean chicken joints were positive[50] compared with 2/293 samples (1%) in Japan,[27] where in both cases the MRSA attributed to contamination from humans during processing.[27] However, a recent survey of foodstuffs by the VWA (Voedsel en Waren Autoiteit) in Holland found many samples contaminated with MRSA. Of the 1300 samples of different meats examined at commercial outlets, 31% of turkey, 27% of chicken, 17% of veal, 10% of pork and beef and 6% of lamb samples were contaminated with MRSA. The majority (84%) of the MRSA isolates were non-typeable MRSA. In view of the low numbers of non-typeable MRSA in patients, the authors concluded 'foodstuffs play a negligible role, if any, in the spread of MRSA'.[52]

PVL-producing MRSA strains in animals

CA-MRSA, containing *SCCmec* IV, and genes encoding for PVL (a toxin that attacks white blood cells) are increasingly implicated in recurrent skin sepsis and fatal necrotizing pneumonia in humans.[53,54] However, CA-MRSA producing PVL are rarely reported in animals[8] and then usually in companion animals. PVL-producing CA-MRSA have occurred in cats, dogs, rabbits, birds,[15] bats, turtles, pigs[18,36] and cattle.[11] The majority of the new, rapidly spreading pig-associated strains reported to date are PVL-negative.

Transmission between companion animals and companion humans/owners

Like their companion animals, companion humans are more often colonized than infected, providing a reservoir for reinfection of their loved ones, human and animal.[5,6,8] Human skin scales with MRSA are easily shed from leg ulcers, eczematous skin and pressure areas during the activities of daily living. Undetected colonized animals provide a reservoir for continuing relapsing infection in humans.[6,16,24,25]

Intra-hospital MRSA transmission was reported in a UK care of the elderly ward. Three patients were found to be colonized or infected with MRSA. Screening of staff and the resident cat (which often slept on patients' pillows) revealed five nurses, the physiotherapist and the cat to be carriers. The other animal regularly visiting the ward was the physiotherapist's dog, which was proven to be MRSA-negative.[25] The cat, which carried MRSA on paws and back fur, was presumed to have acquired MRSA from skin scales shed from the pressure sore of a heavily colonized patient. MRSA acquisition by staff was assumed to be due to their poor hygiene and lack of hand washing after stroking the cat.[25]

Although the animal equivalent of a 'cloud shedder', a heavily colonized human liberally shedding organisms, has not been reported, the high MRSA loads associated with pyoderma and draining wounds must be a significant risk for acquisition and transmission. American cats with inflammatory skin disease were associated with a far higher incidence of MRSA (58%) than healthy cats (7%) in one study.[41]

Transmission of PVL-producing *S. aureus* between humans and dogs was reported in a family where a diabetic lady, her husband, son and dog were all colonized.[8]

Transmission of MRSA between livestock and owners/attendants

Close human contact with animals provides more opportunity for transmission between the species. Once acquired, further horizontal transmission of MRSA between animals or humans and their families can occur. Transmission of MRSA was reported between Hungarian cows with sub-clinical mastitis and an agricultural worker who was throat swab-positive.[55] In 2004, a Dutch pig farmer's wife developed MRSA mastitis and pleural effusion. Although successfully treated with teicoplanin, eradication therapy failed, and subsequent screening found her husband and daughter to be MRSA carriers. Six months later, with the baby and parents still colonized, wider sampling revealed that 3 co-workers and 10 pigs from the closest holding were carriers of the PFGE non-typeable MRSA, all of which were identical (spa types t108, ST398, SCC*mec* V).[38] With pig strains difficult to type with PFGE, spa typing enabled differentiation of another outbreak involving spa t108, confirming that transmission had occurred between pig farming families, a nurse, a hospital inpatient and between pigs and humans.[36]

MRSA ST398 particularly seems to be associated with pig farming, reported in Holland and Hanover,[2] Singapore,[56] Canada[57] and France.[35] New strains (STs 432–438, ST440 and ST457) have been recognized during the investigation of pig-related outbreaks.[35] Currently, MRSA from pig and cattle reservoirs are responsible for 20% of all human MRSA in the Netherlands.[37]

MRSA carriage by veterinary and medical personnel

Whereas the nasal carriage rate of MRSA among medical staff attending a conference was 0.3%,[58] the baseline nasal carriage rate in vets is much higher. A study of veterinary personnel and students at a livestock conference in the Netherlands found 4.6% to be nasal carriers,[59] compared with a rate of 6.5% at an American international conference.[60] In the latter study (which sampled 417 attendees), 16% of the nasal carriers (15 of 96) were large animal vets, whereas only 4.4% (12 of 271) of those working with small animals were positive. None of the research personnel carried MRSA.[60] A far higher proportion (14/78, 17.9%) of veterinary staff in a small animal referral hospital in the UK carried MRSA,[9] most strains indistinguishable from EMRSA-15 (ST22).

The nasal carriage rates of MRSA among veterinary personnel working with pigs are high.[58,60] Of the 272 attendees at an international pig conference in Denmark, 34 (12.5%) participants from nine countries were carriers, 31 isolates belonging to spa t011, t108, t571, t567 or t899 corresponding to ST398.[60] A questionnaire survey of attendees showed that contact with cattle, country of origin and wearing masks did not influence the rate of colonization.[61]

In an investigation in Northern England, where 11 of 67 horses (16%) were MRSA-positive, including 3 clinical infections, no veterinary staff screened positive.[4] However, prolonged close contact with a heavily colonized foal in intensive care led to three students being infected, and a further 10% (10/103) of the associated personnel colonized with CA-MRSA (ST8).[32] In Ireland, following identification of MRSA in animals (47/133 *S. aureus* isolates), MRSA was isolated from 10 attendant veterinary personnel from four different practices and the veterinary hospital.[10] In Michigan, during an outbreak investigation where only 5 of 20 personnel consented to MRSA screening, 3 were positive.[20]

MRSA carriage among agricultural personnel

In a study comparing carriage rates of staphylococci among 113 farmers and 113 non-pig farmers, 10% (5/50) of the farmers carrying staphylococci were carrying MRSA. However, with such small numbers, the results were not felt to be statistically significant.[62] In a French study of nasal swabs from 44 farmers and 21 controls, 19 strains of *S. aureus* were present. These included six isolates of ST398 of which only one was methicillin-resistant.[35] AFLP analysis of 20 ST398 strains from the nares of slaughterhouse pigs plus 18 strains from hospital inpatient farmer screens and 8 isolates from a veterinary diagnostic centre revealed the highly clonal nature of these pig related strains.[3]

Agricultural workers and their families involved with pig, and (to a far lesser extent) cattle, farming have a high likelihood of MRSA colonization, with up to 23% Dutch pig farmers being nasal carriers of MRSA;[36] hence, with the incidence of MRSA carriage in pig farmers estimated at 760 times that of the normal population,[36] all individuals working with pigs in the Netherlands are now routinely isolated and MRSA screened on entering hospital.

Pitfalls in detection of MRSA in animals

Lack of standardization regarding culture methodology, susceptibility testing, genetic profiling and sampling methods often make meaningful comparisons of reported studies difficult. Mass animal screening is logistically difficult and expensive, and hitherto felt to be largely impracticable. Where screening has been done, combinations of nasal, perineal and throat or wound swabs were taken.[19]

It can be physically difficult to screen animals properly. In an MRSA outbreak involving a hospital cat, ‘nose swabs were not possible without suitable restraint’, so only paw and fur swabs were taken.[25]

Direct culture of dry swabs of skin or hair may yield less staphylococci than enrichment cultures of pre-moistened swabs. Cutting the animal hair and then culturing the scalpel blades after gently scraping the skin have been advocated as a method for culturing MRSA carriage in cats.[42]

The conventional typing methodology for newer animal strains has had to be adapted, since some pig-associated MRSA are not typeable by PFGE. When spa typing, involving the X region of the protein A gene, is used, the majority of such ‘non-typeable’ pig strains are spa t011 or t108, ST398.[2]

Animals may be only transiently colonized with MRSA[7] or harbour several types of coagulase-positive staphylococci. Animal-associated species of staphylococci that may be confused with MRSA include *Staphylococcus intermedius*, which has been particularly associated with canine pyoderma, *Staphylococcus schlieferi*, *S. hyicus*, *Staphylococcus delphini* and *Staphylococcus pseudointermedius*.[63] *S. intermedius* derived its name from possessing phenotypic properties of both. *S. aureus* and *Staphylococcus epidermidis*.[64] *S. intermedius* has been reportedly isolated from dogs, cats, mink, pigeons and foxes and is estimated to cause >90% of coagulase-positive staphylococcal animal infections.[16] Interestingly, owners of infected dogs are reportedly seven times more likely to carry *S. intermedius* than non-dog owners.[65]

An additional complicating factor is the emergence of *S. pseudointermedius*, which phenotypically resembles *S. intermedius* and *S. delphini*. *S. pseudointermedius* cannot be distinguished from *S. intermedius* using commercial identification kits and colonizes veterinary staff.[64] Early reports of *S. intermedius* and canine pyoderma should be interpreted with caution, as there is some confusion regarding the terminology and differentiation of *S. intermedius* and *S. pseudointermedius*. It has been suggested that many of the *S. intermedius* isolates reported from dogs and cats may have actually been *S. pseudointermedius*[66] and that true *S. intermedius* is more likely to be found in wild pigeons.[67] One investigation of methicillin-resistant staphylococci isolated from dogs found methicillin-resistant *S. pseudointermedius* in four dogs and MRSA only in one.[40]

Management of MRSA in animals

Infection control and prevention of acquisition of MRSA

Common sense, good hygiene and education are key, especially in veterinary practices. Environmental contamination with MRSA acts as a reservoir for infection. Ten percent of the environmental swabs in a veterinary hospital yielded MRSA, including doorknobs and a board marker—all ‘touch sites’ where hand contact would be expected.[9]

Ninety-seven percent of the Canadian hospitals allowed dogs to visit patients, some animals having unrestricted access to all wards. Thirty-two (36%) owners were lamentably ignorant of infection control practices and possible zoonotic infections with 20% not practising hand hygiene and 40% unable to name one zoonotic disease.[39]

Known MRSA-positive animals should be nursed apart from other animals, with strict hand washing and gloves and gowns if in close contact. It seems sensible to adopt the human infection control precautions of seeing known MRSA-positive patients last in the clinic, then cleaning the room thoroughly and thus avoiding any unnecessary exposure of the animal to other animals in the waiting room.

The importance of applying infection control precautions as routine was highlighted in an outbreak relating to students nursing a sick foal in intensive care. After the foal was found to be MRSA-positive, despite introduction of barrier precautions, three personnel developed skin sepsis, impetigo or folliculitis.[33] One of the students suffered with pre-existing eczema. All humans were treated successfully.

Treatment of MRSA infection in animals

Treatment options may be limited for the more resistant human EMRSA strains. Equine strains are likely to be gentamicin-resistant.[4,29] High-level mupirocin resistance[43] and variable levels of erythromycin, fluoroquinolone and inducible clindamycin resistance have been reported. It is essential to ensure that apparently clindamycin-susceptible strains are tested for inducible clindamycin resistance since nearly 72% of the strains proved clindamycin-resistant on D testing.[68]

Occasionally, antimicrobials less commonly used in human medicine may be useful. A horse in Wisconsin with an osteitis and draining sinus due to mixed organisms, including MRSA, was discharged only after 2 weeks of oral chloramphenicol, although the long-term outcome was not reported.[30]

MRSA decolonization of animals and owners

The natural history of MRSA colonization in the different animal species is largely unknown. Close liaison between vets and physicians is essential to coordinate swabbing and decolonization, particularly if simultaneous animal and human decolonization is to be attempted. No controlled trials have been performed, but case reports suggest that decolonization of animals is possible.[5,6,16] Clinically infected animals are often treated with co-trimoxazole and may be decolonized with topical decolonization lotions similar to those used in humans.

Failure to eradicate MRSA carriage from humans may be due to reacquisition of the strains from close human or animal contacts. Hence, the possibility of an animal reservoir should be considered, and if proven, decolonization of all carriers was considered.

Decolonization of a husband and wife team of intensive care nurses and their dog with triclosan and nasal mupirocin finally resulted in clearance.[5] A 48 year old male diabetic, responding to intravenous vancomycin for an MRSA stump cellulitis, remained MRSA-positive after decolonization. When his wife, a renal transplantee, developed MRSA cellulitis, further screening revealed the dog to be colonized with MRSA too. Both wife and the dog were decolonized, and the couple was advised to avoid intimate contact with the dog. However, having failed to decolonize the dog, a second bout of decolonization of the trio was undertaken. Despite this, the husband developed another stump infection, necessitating a third and successful bout of decolonization of the whole family.[6] Interestingly, this study reported the use of topical vancomycin cream intra-nasally as the isolate was mupirocin-resistant. Worries about encouraging resistance have led the Scandinavians to ban mupirocin in animals, and nowadays, topical antibiotics are usually recommended only as a last resort.

MRSA clearance of patients and their animals was successfully carried out using oral antimicrobials in two different settings, in the first family using rifampicin and ciprofloxacin,[16] and in the second family group, using rifampicin and clarithromycin.[8]

Decolonization of people colonized with pig-associated strains can be difficult, and repeatedly unsuccessful.[36] Repeated efforts at eradication of a PVL-associated strain of MRSA from a husband, wife, son and dog necessitated resorting to the usage of ciprofloxacin and rifampicin.[8] When a 31 year old nurse with MRSA and psoriasis failed decolonization, she was treated with oral doxycycline and rifampicin, and repeated topical decolonization. Her dog and daughter proved to be reservoirs, although interestingly, the grandmother—also a psoriatic—remained free of MRSA, despite considerable childcare exposure. Finally, only after both mother and dog received oral rifampicin and clarithromycin was the strain eradicated.[16]

Decolonization of companion animals

For transient MRSA carriage, such as that resulting from hospital visits of pet therapy dogs, washing the dogs' paws with chlorhexidine may suffice.[7] Topical decolonization of furry felines is especially difficult, and ingestion of disinfectants may be harmful to them. Hence, if attempted, animals should be rinsed thoroughly afterwards. In the geriatric ward outbreak, and with the offending cat reluctant even to be swabbed, no attempt at decolonization was made. The cat was simply removed.[25]

Official detailed guidance for management of MRSA in animals and the potential for decolonization is available from the British Small Animals Veterinary Association (BSAVA) web site.[69] Guidelines advocate decolonization only 'if the human companion is immunosuppressed or otherwise vulnerable' but suggested that regimens include antibacterial shampoos and 2% fusidic acid or 2% mupirocin intranasal cream two to three times daily.[69]

Decolonization of large animals

Topical chlorhexidine/1% acetic acid has been used to decolonize horses with systemic and incisional infections. However, overall, the efficacy of topical antimicrobials for decolonization is unclear,[28] as sometimes instigating screening and good infection control standards alone may result in disappearance of carriage.[70] The efficacy of any decolonization is more effective when re-exposure to MRSA is prevented.[28,70]

Discussion

MRSA is now increasingly recognized in the animal world. New types of MRSA appear to be evolving in animals. These pose a potential threat to human health through occupational exposure and ease of spread during the increased international movement of livestock and agricultural personnel. Asymptomatic colonization and shedding of MRSA by veterinary and agricultural personnel, together with selection pressures due to antimicrobial feed additives and injudicious usage of antibiotics may contribute to the establishment of MRSA in the food chain and domestic animals. The true scale of the problem is unknown, and more surveillance studies, particularly of animal products in the food chain, are in progress. However, there is no substitute for good hygiene practices, both in the household and in human and animal healthcare environments. A history of contact with animal or human MRSA, and early culture of wounds not responding to first-line therapy would enable earlier recognition of MRSA and appropriate management. When faced with repeated and inexplicable failures of decolonization in humans, a history of close exposure to animals and birds should be sought. Where sharing of MRSA between species is suspected, a combined diagnostic and therapeutic approach with veterinary colleagues is advised.

Transparency declarations

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