Methicillin-resistant **Staphylococcus aureus** *Backgrounder*

(June 24, 2009)

Causative agent

Methicillin-resistant *Staphylococcus aureus* (MRSA) is a Gram-positive bacterium that is resistant to methicillin (a member of the penicillin family) and many other β-lactam antimicrobials; β-lactam antimicrobials include penicillins and cephalosporins. The description "methicillin-resistant" was first used in 1961, based on the discovery of a human *Staphyloccocus aureus* infection in the United Kingdom that was resistant to methicillin.[1] Since that time, MRSA has emerged as a significant problem worldwide, and the term has evolved to include resistance to additional β-lactam antimicrobials. Currently, the term MRSA is often used to describe multi-drug resistant *Staphylococcus aureus*.

Resistance is mediated by a gene (*mecA*) that encodes the production of an altered penicillin-binding protein (PBP2a), which does not allow for the binding of β-lactams to the bacterial cell wall.[2] Because β-lactams exert antibacterial activity by binding and inhibiting enzymes necessary for bacterial cell wall synthesis, these antimicrobials are not effective against MRSA.

Background

S. aureus bacteria are commonly carried on the skin or in the nasal passages of healthy people and animals. A person (or animal) that carries the bacteria on their body but does not exhibit signs of disease is considered to be "colonized". Approximately 25 to 40% of the human population is colonized by *S. aureus*, mainly in the nasal passages. "Infected" individuals are those who develop signs of disease due to *S. aureus* or MRSA.

Staphylococcus aureus (S. aureus) is a major pathogen in both nosocomial (hospital-acquired) and community-acquired infections worldwide, and according to the Centers for Disease Control and Prevention (CDC), is one of the most common causes of human skin and soft tissue infections in the United States. Clinical signs range from minor skin conditions (e.g., pimples, boils and impetigo) to more severe disease such as cellulitis and postoperative wound infections. *S. aureus* can also cause pneumonia, bacteremia, meningitis, sepsis, and pericarditis. *S. aureus* can also cause food poisoning and toxic shock syndrome. [3]

Although primary MRSA infections in immunocompetent people are quite common, immunocompromised individuals are more likely to develop infection. Non-MRSA *S. aureus* is also more likely to cause infections in people who are in compromised environments such as hospitals, chronic care facilities, prisons, housing projects, or in other crowded settings, such as schools and public events.[4-7]

Penicillin was originally found to be extremely effective in treating *S. aureus* infections, but penicillin-resistant strains of *S. aureus*, mediated by the production of β-lactamase (an enzyme that inactivates the lactam ring of β-lactam antibiotics), began to develop. Methicillin was introduced in 1959 to treat human patients with staphylococcal infections resistant to penicillin. Although methicillin is relatively resistant to β-lactamase, MRSA isolates were reported in Great Britain in 1961.[8] By the mid-1970s MRSA had become endemic in many countries.[2,9] Further, in addition to being resistant to β-lactam antimicrobials, many MRSA strains are resistant to various other antimicrobial classes.

MRSA Terminology

Nomenclature of MRSA strains

Numerous strains of MRSA have been identified based on genetic analysis of the bacteria. MRSA nomenclature varies worldwide, and a standard method for typing and naming MRSA strains has not yet been adopted; therefore, one genetic strain of MRSA may be referred to by several different names. MRSA strains can be typed by both phenotypic and molecular methods. Phenotypic methods include: colonial characteristics, biochemical reactions, antibiotic susceptibility pattern, and the susceptibility to various phages and toxin production. The most prominent molecular (genetic) typing methods are: pulsed field gel electrophoresis (PFGE), multilocus sequence typing(MLST), SCC*mec* and *spa* typing. There is a new typing method that uses several variable number tandem repeat (VNTR) sequences for typing of animal MRSA isolates, but to date there is no published data available.[13] Where possible in this backgrounder, all nomenclature variations for a MRSA strain have been provided.

Community-Associated and Hospital-Associated MRSA in Humans

Community-associated MRSA (CA-MRSA) infections occur in otherwise healthy people without a recent history of hospitalization or medical procedures, and are usually associated with skin and soft tissue infection. Risk factors for CA-MRSA include crowding, frequent contact, compromised skin, contaminated surfaces and shared items, and poor hygiene. To date the MRSA strain most commonly associated with CA-MRSA in humans is USA300. [10]

Nosocomial, or hospital-associated MRSA (HA-MRSA) in Humans

Hospital-associated MRSA (HA-MRSA) infections occur most commonly in immunocompromised individuals in hospitals and healthcare centers. Risk factors for HA-MRSA include hospitalization, surgery, dialysis, long-term care, indwelling devices, and history of previous MRSA infection. To date, the majority of clinically significant MRSA infections are HA-MRSA.[11,12] When the infection is acquired during hospitalization, it is considered “nosocomial.” To date, the MRSA strain most commonly associated with HA-MRSA in humans is USA100.

Transmission

For many years, MRSA was considered only a human pathogen, until a report of a MRSA mastitis (udder infection) in a dairy cow surfaced in 1972.[14] It has now become an increasingly urgent problem in veterinary medicine, with MRSA infections reported in horses, dogs, cats, pet birds, cattle and pigs.[2,12,15-23] CA-MRSA in humans is thought to be a major factor in the rise of MRSA infection in companion animals.[2,12,18,23] Infection with the MRSA strain USA100 (CA-MRSA-2, ST5-MRSA-SCC*mecII*) has been shown to be more predominant in small animals, while infection with the MRSA strain USA500 (CMRSA-5, ST8-MRSA SCC*mecIV*) has been shown to be more predominant in large animals.[12] To date, the data is still emerging and the identified strains are subject to change.

It was first thought that the transmission of MRSA was solely from human to animal, with MRSA colonization and infection typically occurring with contact between the hands of the human and anterior nares (nostrils) of the animal. There is now increasing evidence that MRSA can be transmitted in both directions, from animal to human (zoonotic) and human to animal (reverse zoonotic). Once exposed to MRSA, animals can become colonized, and may serve as reservoirs to transmit the infection to other animals and also to their human handlers.[2,12,18,23,24] It has been shown that even apparently healthy animals may be MRSA reservoirs, and therefore may pose a risk to their handlers.[16,23] This has been documented in the general community, and is becoming increasingly documented in health-care settings and in animal environments (eg, veterinary clinics and hospitals, farms, and slaughterhouses).[20,24-26] Data have indicated that owners and veterinary personnel who come into contact with MRSA-colonized or MRSA-infected animals may become colonized by MRSA. There is then a risk that subsequent contact with susceptible animals or human beings will transfer MRSA infection.[2,27,28]

With human-to-animal transmission of MRSA, there is a possibility that until the animal is free of infection, re-transmission from the animal and subsequent human-to-human transmission can occur.[15,18,24] In one reported case of possible dog-to-human transmission, a diabetes mellitus patient and his wife experienced recurrent MRSA infections and difficulty in eliminating MRSA (decolonization). A nares culture of the family dog revealed it was colonized with MRSA, and long-term decolonization for the man and his wife occurred only after the dog was treated.[24] However, there was no clear evidence that the dog was the source of infection. There is a concern that antimicrobial treatment of MRSA in companion animals may increase antimicrobial resistance, and have a subsequent effect on the zoonotic transmission or re-transmission to humans, especially if the humans involved are already in an immunocompromised state.[18,28]

There has been considerable controversy regarding the link between antimicrobial use in livestock and MRSA. Further studies are needed to determine the exact sources of MRSA in animals, and the impact of the use of antimicrobial agents in livestock.

MRSA Prevalence

Humans

Veterinary personnel are at increased risk of being MRSA reservoirs and zoonotic transmission of MRSA and subsequent MRSA colonization should be considered an occupational risk for members of the veterinary healthcare team, particularly those in large animal practices. At the 2005 American College of Veterinary Internal Medicine (ACVIM) Forum, 6.5% of the attending veterinary personnel who volunteered to be tested were found to be colonized with MRSA. In this study, the volunteers provided a nasal swab and completed a questionnaire that identified potential risk factors for MRSA colonization. None of those who tested positive had a recent history of hospitalization or previous diagnosis of MRSA. Large animal practice was the only significant risk factor for MRSA colonization, with 12/271 (4.4%) small animal practice personnel colonized, and 15/96 (15.6%) of large animal practice personnel colonized ($P < 0.001$). A significant difference was found between the MRSA clones found in veterinary personnel from large animal practices (USA500/CMRSA-5) compared to the MRSA clones found in veterinary personnel from small animal practices (USA100/CMRSA-2).[29] To date, the prevalence of MRSA *infection* in veterinary personnel has not been documented.

Farmers are also at risk of being MRSA reservoirs. In a survey by Voss et al of pig farrners in the Netherlands, 23% (6/26) of pig farmers were colonized with MRSA, a rate that was 760 times higher than the general Dutch population; however, only 2 of 40 pigs tested were MRSA positive.[22,30] Huijsdens et al noted that the MRSA strains isolated from a pig farmer, his family and farm workers were similar to those seen in pigs; however, the original source of the MRSA (human or swine) was not determined.[23] In a comparative study by Walther et al, human strains of MRSA ST254 displayed molecular-typing results indistinguishable from those for strains of equine origin. Two other equine strains (ST22 and ST1117) showed similarity to ST22 human strains. One equine strain belonged to ST398, a genotype frequently isolated from pigs and pig farmers. The data from this study provide evidence that certain MRSA genotypes have adapted to more than one mammalian species.[31]

Animals

Few data on MRSA colonization rates in non-clinically affected animals are available. Although identification of colonized or infected animals is important in the prevention of the spread of MRSA, the routine screening of all animals is not yet practical, so there remains the possibility that a small percentage of colonized animals will remain undetected upon first admission to a veterinary clinic or hospital.[13]

Dogs

In a survey conducted in Ireland by Abbott et al, a 0.6% prevalence of MRSA colonization was detected in non-clinically infected dogs upon admission to veterinary clinics, and a 0.9% prevalence of MRSA colonization was detected upon admission of non-clinically infected dogs to a veterinary referral hospital.[35]

In 2007, Lefebvre et al conducted a study of 26 pet dog handler teams in Ontario Canada. Twelve of the teams visited acute care facilities, and 14 visited long-term facilities. Swabs of each animal's forepaws and haircoat were obtained before and after each visit. The hand hygiene of the human handlers was also recorded during each visit. Neither MRSA nor *Clostridium difficile* (*C. difficile* –a bacterial infection that causes severe diarrhea) were detected on any of the paws of the therapy dogs, nor were they detected on any of the skin of the handlers who were in contact with the dogs prior to visitation. After visitation, 1 dog (4% of total group) acquired *C. difficile* on its paws during its visit to an acute care center and MRSA was detected on the hands of an investigator after petting a dog that had visited a long-term facility. These results suggest that therapy dogs may become infected with pathogens during their visits to health-care facilities and reinforces the importance of good hand hygiene before and after handling therapy animals.[33]

Cats

A case study by Vitale et al described a 3-year-old, neutered male, domestic shorthaired cat with a 1-year history of multifocal patches of crusted and well-demarcated ulcers on the trunk. Initially, small crusts suspected to be associated with flea allergy and pyoderma were present; however, response was poor to multiple treatments, including repeated corticosteroid therapy and antimicrobial therapy with amoxicillin–clavulanic acid and enrofloxacin. The cat's owner reported having skin abscesses and pneumonia 3 months earlier. Skin biopsy specimens were collected from the cat, and swabs of the exudates were submitted for bacterial culture. The findings demonstrated ulcers and dermal granulation tissue. This pattern of inflammation is distinct from most staphylococcal infections of the skin, and it has been suggested that this uncommon finding in cats is associated with methicillin-resistant staphylococcal infection. MRSA was isolated from the skin lesions and the MRSA strain was identified as USA300. The owner and cat were then tested by swabs of their anterior nares, and MRSA was identified in both the cat and the owner, with the isolates from both being indistinguishable. MRSA was therefore likely to have been transmitted between the cat and the owner, but it could not be definitively confirmed whether it was a case of reverse zoonotic transmission or zoonotic transmission.[19]

Horses

In a study of horses admitted to the Vienna Veterinary University Hospital between 2006 and 2007, Cuny et al obtained clusters of MRSA strains MRSA ST1, ST254, and ST398 from 25 of 140 horses with suspected wound infections (either upon admission or as a result of surgery). Small clusters of the same infections were found in horses staying in the same clinical department at the same time, suggesting nosocomial transmission. However, there were infected animals with no overlap of times, suggesting infection either from an outside source or from transmission from the veterinary and support staff and students. In addition, nasal swabs were taken from all veterinary staff that had been in contact with these horses; of 131 individuals tested, 18 were positive for MRSA on one or more occasions. The occurrence of this strain in horses and humans suggests it is capable of crossing species, and provides support for the possibility of nosocomial infection in veterinary hospitals.[30] Ongoing MRSA surveillance in animals and their handlers for both colonization and infection is necessary in order to clarify the epidemiology of the transmitted strains as well as develop measures to reduce transmission.[19]

In a survey by Weese et al, the reported colonization incidence rate of MRSA in horses admitted to a veterinary teaching hospital was 27/1000 admissions.[34]

Swine

A study by Khanna et al found MRSA colonization rates of 25% among pigs and 20% among pig farmers in Ontario. MRSA strains ST398 and USA100 were found in both pigs and their human handlers and the predominant (59.2%) strain was ST398, a strain that has been previously reported in pigs in Europe. USA100 is a common strain found associated with CA-MRSA in humans, and the presence of USA100 in pigs may indicate human-to-animal transfer. Although more research is needed, this study suggests possible MRSA transmission between pigs and their human handlers.[36]

In a recent University of Iowa study, 299 swine and 20 swine workers at two different production systems (designated Production Systems A and B) in Iowa and Illinois were tested for MRSA colonization.

At Production System A (PSA), the overall prevalence of MRSA was 70% in swine and 64% in humans. At Production System B (PSB), all swine and swine workers tested negative for MRSA. While the reason for this disparity between the two sites' findings requires additional investigation, there were differences between the two systems: PSA was older and much larger than PSB, the two systems raised different breeds of swine, and both systems imported sows from different sources.[37]

The findings in these studies should provoke more research concerning the role of interaction between livestock and their handlers in the transmission of MRSA.[36,30,37]

Cattle

In a 2007 report, Juhasz-Kaszanyitzky et al described the first suspected case of MRSA transmission between cows and a human handler. They isolated MRSA from cows with subclinical mastitis (inflammation of the udder) and from a nonsymptomatic person who handled these cows. The strains from the cows and the MRSA-colonized human handler were indistinguishable by both phenotyping and genotyping diagnostic methods. The authors suggested that this was the first documented case of MRSA transmission between cows and humans, although the direction of the transmission (ie, zoonotic or reverse zoonotic) could not be established.[38]

Zoo animals

The first confirmed case of MRSA transmission between a zoo animal and its caretakers was reported in March 2009. The USA300 strain of MRSA was confirmed in an African elephant calf that was being treated for skin pustules; three of its caretakers were also colonized. The USA 300 strain, which is the most common type associated with human CA-MRSA infections, has never been reported as originating from animals. The investigation concluded that the calf had acquired the MRSA infection from a colonized human caretaker (reverse zoonotic transmission) during the placement of an intravenous catheter, and that the calf then transmitted the infection to other human caretakers (zoonotic transmission) through contact. No other elephants in the shared living space tested positive for MRSA colonization or skin infections. Although transmission between caretakers cannot be ruled out, several factors support that the transmission occurred from the calf to the other caretakers.[39]

Other sources

The possibility of a transmission route of MRSA from animals to humans via animal food products requires further investigation to determine its public health significance.[17,40] In a recent study, Pu et al investigated the prevalence of MRSA in 120 retail meats from 30 grocery stores in Baton Rouge, Louisiana. MRSA was isolated from six meat samples (5 pork and 1 beef). The MRSA strains identified were USA300 and USA100, but the investigators did not determine if the original source of the bacteria was the meat itself or humans who handled the meat prior to purchase.[41] To date there has been no confirmed cases of MRSA infection in humans resulting from the consumption of animal products.[17] Reported food-borne MRSA outbreaks have occurred through contamination by infected food handlers. These outbreaks can be minimized by proper food handling and hygiene, as well as pasteurization.[41-44]

Clinical Signs of MRSA Infection of Animals

Not all animals who encounter MRSA develop clinical signs or illness. While research is ongoing, it appears that only a small percentage become ill, while most eliminate the organism or become colonized without developing clinical signs. Among animals, the most commonly reported clinical signs are postoperative and wound infections, with less-reported incidences of intravenous catheter site infections, urinary tract infections, pneumonia, skin, and ear infections; skin and ear infections have been most commonly reported.[2,19] CA-MRSA strains that cause skin and soft tissue infections (SSTIs) sometimes contain Panton-Valentin leukocidin exotoxin (PVL). It is unclear whether PVL is a relevant virulence factor or a marker for some other factor, a toxin that produces tissue necrosis (tissue death). CA-MRSA infection may present as a red, swollen, painful site with drainage.[3,19,28]

Diagnosis

Proper MRSA diagnosis may be a potential problem since samples are sent to different diagnostic laboratories that may not be uniform in the testing of the bacterial species and their antibiotic sensitivities. Diagnosis should involve the identification of coagulase-positive *Staphylococci* to the species level, and all *S. aureus* isolates should then be tested for oxacillin resistance, since methicillin is less stable *in vitro*. Veterinary laboratories that are not familiar with oxacillin-resistant *S. aureus* should make sure that their routine screens for oxacillin resistance are supplemented with multiple tests to confirm the presence of PBP2a (*mecA*) in isolates that exhibit borderline susceptibility.[45]

If there is a recurrent or persistent case of skin infection in the animal, a small biopsy of either the infected skin or a sample of the exudate (drainage) from the site may be submitted for laboratory diagnosis. A sputum culture is recommended for pneumonia. Blood or urine cultures are recommended for bloodstream and urinary infections, respectively. If *S.aureus* is isolated, further tests are needed to determine if it is a MRSA strain and start appropriate antibiotic selection.[3]

Rapid diagnosis of MRSA in animals is still in its early stages of development, and to date there is still a significant delay between sample collection and obtaining test results for animals, as compared to humans.[2] Rapid tests that have been validated for use in human cases (i.e. real time PCR) do not necessarily perform adequately in animal cases, so species-specific validation is required.[46]

Prevention and Treatment

In June 2009, a joint scientific report on MRSA in livestock, pets and food was issued by the European Food Safety Authority (EFSA), the European Centre for Disease Control and Prevention (ECDC), and the European Medicines Agency (EMEA). The report concluded that as animal movement and contact with humans is likely to be important factors in the transmission of MRSA, the most effective control is at the farm level. Judicious use of antimicrobials in animals should remain a key measure. The report also recommended that medicines of last resort for MRSA treatment in humans should be avoided in animals so as to ensure their continued efficacy in humans.

Despite reported MRSA colonization and infection of animals, there has been minimal research into the risk factors involved and what treatment regimens are needed in MRSA-infected animals.[2] When animals are found to be colonized with MRSA based on swabs of the animal's nostrils, there is currently no recognized method of decolonizing these animals. Based on clinical cases observed, some experts have indicated that companion animals are generally transient carriers of MRSA, and decolonization is either unnecessary or the treatment could be as simple as isolation from the individual who keeps transferring the MRSA back to the animal.[47] Weese et al suggested that the decolonization of horses with MRSA may be accomplished without the use of antimicrobial therapy by using segregation and repeated screening.[20]

In cases of skin infections, which are the most common manifestations of MRSA infection in animals, it has been suggested that a combination of systemic therapy with topical antimicrobial treatment of mucosal sites may have some effect.[27] However, van Duijkeren et al have suggested that while systemic therapy is needed, topical treatment with antimicrobials may be impractical based on cost and the difficulty in adequate application of topical ointment into the nasal passages. It has been speculated that both of these treatments may lead to further microbial resistance.[48,49] If antibiotic treatment is necessary, it should be guided by the susceptibility profile of the organism.[3] However, there are alternative methods that may be used in place of or in combination with antimicrobial therapy. Leonard et al suggested the removal of the imbedded devices (such as intravenous catheters) may be a proper step in removing the source of MRSA infection.[13] Other procedures for managing bacterial infection, such as drainage and debridement, may be necessary and should be based on the type and severity of infection.[50]

Morbidity and Mortality

In the United States, MRSA is the 10th leading cause of death in humans, and is the most frequently identified antimicrobial drug-resistant pathogen in hospitals and other healthcare facilities.[51] In a 2007 report, Klevens et all reviewed the 8987 observed cases of invasive MRSA reported to the Active Bacterial Core surveillance (ABCs)/Emerging Infections Program Network from July 2004 through December 2005. Most (58.4%) of the MRSA infections were health care-associated: 6484 (72.1%) were CA-MRSA infections, 2389 (26.6%) were HA-MRSA infections, and 114 (1.3%) could not be classified. In 2005, the standardized incidence rate of invasive MRSA was 31.8 per 100,000 (interval estimate, 24.4-35.2).[11] The increasing prevalence of MRSA in humans is in part a result of the infection emerging from a mainly HA-MRSA source into a CA-MRSA source over the last 10 years.[2,51] While the use of catheters has always been cited as a primary source of MRSA infection, researchers from the Centers for Diseases Control and Prevention (CDC) found that rather than increasing, the incidence of ISU catheter-associated MRSA bloodstream infections between the years 1997 and 2007 decreased about 50%. In this 10-year retrospective study, Burton et al discovered that although the overall percentage of central bloodstream staph infections increased by 25.8%, the overall incidence rate declined 49.6%.[52]

Morbidity and mortality data in animals are lacking, and further study is necessary. Morris et al reported that MRSA appeared only as a secondary infection in domestic cats that had predisposing diseases, which suggests that, like humans, MRSA infections are more common in immunocompromised animals.[21] MRSA is an emerging pathogen in animal species, and should be closely monitored. The major threat of MRSA for animals and their handlers appears to be in zoonotic and interspecies transmission.[3,18]

Prevention and Control

Humans

In humans, MRSA rates worldwide have shown a dramatic increase since the end of the last century. In the United States, MRSA prevalence among all hospital *S. aureus* isolates increased from 2.4% in 1975 to 29% in 1991.[53] Between 1992 and 2003, the proportion of methicillin resistant *S. aureus* isolates from patients in intensive care units rose from 35.9% to 64.4% in the United States.[54] A report published in 2008 estimated that 1.5% of the US population (~4.1 million people) is colonized with MRSA.[55] In England and Wales, the proportion of *S. aureus* bacteremia due to MRSA increased from 1% to 2% in 1990–1992 to approximately 40% in 2000.[56]

Caution is advised when extrapolating the guidelines for MRSA control in people to animals because there may be significant differences in the epidemiology of the disease.[29] At present no controlled studies have been conducted to provide data on key issues such as prevalence and persistence of colonization and infection in animals, the ease of transmission between animals and humans, and the efficacy of decolonization procedures in animals.[13]

Therapeutic animals

Due to the prevalence of MRSA in health-care environments, therapeutic animals involved in animal-assisted intervention programs (AAIs) may be at risk for MRSA infection or colonization. A Canadian study found that dogs enrolled in AAI programs in healthcare settings were 6 times as likely to become colonized with MRSA as dogs who participated in non-healthcare AAI programs. There is an increased likelihood that these colonized dogs may become infectious.[57] Lefebvre et al developed a consensus document that put forth standard, evidence-based guidelines for handling AAIs in healthcare settings.[58] These guidelines are mainly directed at health-care facility staff members and the handlers of the therapeutic animals.

Because veterinarians are involved in the AAI process through the screening of therapeutic animals prior to participation in an AAI program, and in providing ongoing veterinary care to these animals, the AAI guidelines were supplemented with additional information that directly targets veterinarians.[59]

In the case of MRSA and therapeutic animals, the guidelines:

- do **not** recommend routine screening for MRSA and other potentially zoonotic pathogens in therapeutic animals, as that would be impractical if not impossible.
- recommend that screening for MRSA or other zoonotic pathogens may be indicated in situations where the animal is known to have had physical contact with a known human carrier, or when epidemiological evidence shows that the animal may have transmitted MRSA to the patient or the handler.
- encourage veterinarians to pursue culture and susceptibility testing whenever therapeutic animals develop opportunistic infections.

- urge veterinarians to obtain contact information for AAI program liaisons at the health-care facilities the therapeutic animal visits, and obtain the clients' consent to communicate with those liaisons as needed.
- recommend temporary suspension of visitation by any animal that tests positive for MRSA (or any other pathogen) until results of bacterial culture of at least 2 samples obtained 1 week apart indicate the animal is free of the pathogen.
- that veterinarians provide advice for the handling of animals in an AAI program, such as:
    - good hand hygiene by all who encounter the animal, both before and after touching the animal
    - licking should be prevented, as well as "shaking paws" – even if the animal's paws are clean before they enter the health-care facility, the floors may be contaminated
    - handlers are restricted to bringing one animal during each visit, and must keep the animal on a leash or in a carrier
    - animals should be restricted to interaction only with the patients and their families
    - when placing an animal on a bed, a clean towel or absorbent pad should be placed between the pet and the bed linens
    - no animals should visit patients in isolation units
    - although therapeutic animals are expected to be clean, bathing an animal prior to each visit is **not** recommended, unless the animal smells or is soiled

When any animal presents with clinical signs indicating possible MRSA indications, such as non-healing wounds or infections that do not respond to antibiotic therapy, it should be considered for MRSA screening.[13] Animals identified as, or suspected to be, positive should be admitted directly into a separate examination room to prevent contact with other animals. The examination room must then be cleaned and disinfected prior to admitting another patient to the room. Upon entry into a veterinary hospital, a known or suspected MRSA-infected animal should be isolated and barrier precautions should be implemented when handling or treating the animal.[13]

In a 2005 survey conducted by Hanselman et al of veterinary personnel attending the annual American College of Veterinary Internal Medicine Forum, nasal swabs were obtained from 417 attendee volunteers from 19 countries. CMRSA-5 (ST8-MRSA-IV, similar to USA500) was isolated from 13 (48%) of 27 colonized persons, all of whom were in large-animal practice. CMRSA-2 (ST5-MRSA-II, similar to USA100) was isolated from 13 (48%) of 27 colonized persons: 11 in small animal practice and 2 in large animal practice. One other isolate, possibly related to CMRSA-2. was found in a US veterinarian in small animal practice. Overall, CMRSA-5 was more commonly isolated from persons in large animal practice than persons in small animal practice.[12]

In large animal practices, veterinary personnel routinely wear coveralls and boots as protective clothing. However, MRSA colonization and transmission usually occurs through contact from the hands of the human to the anterior nares (nostrils) of the animal, so masks and gloves should be considered as additional protective measures.[22] Anderson et al reported a significant protective effect of hand hygiene in equine veterinarians. Multivariable analysis showed an increased risk of MRSA colonization associated with having been diagnosed with or having treated a patient diagnosed with MRSA colonization or infection in the last year $P = 0.015$, $P = 0.039$, respectively), whereas hand washing between infectious cases ($P = 0.009$) and hand washing between farms ($P = 0.047$) were protective. The prevalence of MRSA colonization among equine veterinary personnel found in this study was high compared to that of other studies of the general population. These data support previous suggestions that equine veterinary personnel are at increased risk of colonization with MRSA, and provided a statistically significant association between hand hygiene practices and a measurable clinical outcome in veterinary medicine[60]

In a Netherlands study by Wulf et al, 80 veterinary students and 99 veterinarians attending a livestock conference were screened for MRSA. None of the subjects displayed symptoms of MRSA infection. Seven (3.9%) of 179 tested were positive for MRSA. Subjects who reported livestock contact had a 4.6% prevalence of MRSA, whereas none of the students who reported no contact with livestock tested positive for MRSA. The overall prevalence of MRSA colonization in veterinary doctors and students in large animal practice was 160 times the rate of MRSA prevalence in hospitalized human patients; which indicates that animal handlers, including veterinary personnel, farmers (a MRSA-colonized son of a swine farmer transmitted the pathogen to a hospital nurse), and their families should be screened upon checking into a hospital.[22]

In order to stop the cycle of transmission and re-transmission between humans and their companion animals, efforts are needed to decontaminate their shared surroundings.[13] Factors involved in MRSA transmission among humans include crowding, compromised skin surfaces (open wounds, scrapes, etc.), contaminated items or surfaces, and poor hygiene.[4] This is an area of concern that needs to be addressed in both the human and the veterinary medical fields.[49]

In veterinary hospitals, the use of a chlorhexidine surgical scrub has proven effective in eradicating transmission of *S. aureus*. Surgical scrubs containing both chlorhexidine and alcohol have been more effective against multiple strains of MRSA.[61] In a Japanese study, seven disinfectants for hand scrubs and soaks were evaluated against multiple MRSA strains: glutaraldehyde, povidone iodine, and ethanol proved effective. Sodium hypochlorite, benzalkonium chloride, and alkyldiaminoethylglycine hydrochloride were not effective against all strains using the prescribed concentration conditions and exposure time.[62]

In 2005 the American Veterinary Medical Association (AVMA), in partnership with the CDC, conducted an anonymous survey via a questionnaire sent to veterinarians randomly selected from the AVMA membership. The survey group was comprised of US veterinarians in small animal, large animal, and equine clinical practice, and was conducted to assess both precaution awareness (PA), which involves both proactive protective behaviors and the use of personal protective equipment; and the veterinarians' perceptions of zoonotic disease risks. Results indicated that, in general, the respondents did not engage in protective behaviors or use personal protective equipment considered sufficient to protect against zoonotic disease transmission. Small animal and equine veterinarians employed in practices that had no written infection control policy were significantly more likely to have low PA scores. Male gender was associated with low PA score among small animal and large animal veterinarians, and equine practitioners in clinical practice were more likely to have lower PA ranking than equine practitioners working in teaching or referral hospitals.[63] This study emphasizes a need for increased awareness and precautions within the veterinary medical profession.

Veterinarians should be aware of the concerns regarding MRSA and should develop an understanding of appropriate disease surveillance, diagnostic testing, and infection control in order to lessen the impact of MRSA on both animals and their caretakers.[2,12,20,30] Veterinarians not only need to practice proper hygiene and prevention of transmission of zoonotic disease in their work environments, they also have a duty to educate the owners/handlers of MRSA-colonized or -infected animals on the risks and proper hygiene prevention when dealing with these animals.

Precautionary measures include the following:

- As in human medicine, hand hygiene is an integral part of the prevention of the spread of MRSA between animals and between animals and humans. Frequent hand washing and proper disinfection of hard surfaces and equipment between patients is essential.
- Hand sanitizers should be provided in all consulting rooms and kennels to remind staff of the need for frequent hand sanitization.
- Uniforms, including gloves, disposable aprons and masks, should be worn when changing dressings on infected wounds or to prevent potential contact with body fluids or contaminated tissues.
- Eye protection is indicated if splashing or aerosols are expected.
- All surroundings in the clinic should be kept to a high standard of cleanliness. Although the cleanliness of floors does not appear to be as important as hand-touch sites in the control of human MRSA infections, the situation may be different in veterinary medicine because many animals are examined or treated on the clinic floor.[13]

With the rise of MRSA as a zoonotic disease in both human-to-animal and animal-to-human transmission, both human healthcare and veterinary care providers are advised to review the infection control guidelines for the prevention and control of MRSA infections in both animals and humans at the AVMA's Infection control practices and zoonotic disease risks among veterinarians in the United States and the CDC's Overview of Healthcare-associated MRSA.

It is incumbent upon the veterinary and human medical professions to improve communication regarding the roles of both animals and humans in MRSA transmission. The pressing need for judicious antimicrobial use and a good general infection control program in human and veterinary healthcare cannot be overstated. The judicious use of antimicrobials in animals and humans is essential in order to prevent the spread of MRSA strains that are increasingly resistant to known antimicrobials.

This backgrounder was developed in cooperation with the American College of Veterinary Internal Medicine (ACVIM)

Links to More Scientific Information About MRSA

AVMA

MRSA FAQs
MRSA FAQs for Human Healthcare Providers
Compendium of Veterinary Standard Precautions
Model Infection Control Plan for Veterinary Practices
Podcast: MRSA and Pets

CDC MRSA

Community-Associated MRSA Information for Clinicians
Overview of Healthcare-associated MRSA
Community-Associated MRSA Information for the Public
Methicillin-Resistant Staphylococcus aureus (MRSA) in Schools: FAQs

USDA MRSA

Methicillin- resistant Staphylococcus aureus: A Growing Concern for Animal and Human Health

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Information for those who care about animal welfare and MRSA infection

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