

Preventing Infection in MRI

-Best Practices: Infection Control in and around MRI Suites-

Healthcare- and community- associated infections are a major and growing problem in the United States as well as throughout the world.

Healthcare associated infections (HAI's) constitute a major public health problem in the United States affecting 5 to 10 percent of hospitalized patients annually, resulting in approximately 2 million cases of HAI's , 90,000 deaths and adding \$4.5 to \$5.7 billion in healthcare costs^{1,2}.

Most patients with serious infections typically have some type of imaging procedure performed during the course of their treatment. Radiology departments and outpatient imaging centers must take appropriate action to assure patients that their MRI scanner is not a significant hub for microorganisms capable of causing infectious diseases. However, for a multitude of reasons, MRI suites often lack the most basic of safeguards against infection, where, due to its unique environment, it is extremely difficult to implement and maintain an effective infection control policy. Because of the dangers from extremely strong magnetic fields ³, as demonstrated by a well-publicized patient death from an accident in an MRI ^{4, 5}, housekeeping staff and most cleaning equipment are usually prohibited from entering the MRI suite. The resultant lack of thorough cleaning was clearly demonstrated in a recent study from Ireland that cultured MRSA from within the bore of the MRI system⁶.

When one goes to a restaurant there is an assumption of cleanliness and the knowledge that there is an organization (the county health department) that comes in and inspects to assure food safety and cleanliness. However, even though the public assumes the proper infection control procedures are in place, there is no one organization that evaluates these MRI suites for infection control. The author has often found, especially in free standing outpatient centers and mobile MRIs, a complete lack of even the basic infection control procedures, such as hand washing or cleaning the room between patients.

The pictures below are just a few examples of just how unbelievably dirty these MRI suites can be.



Cables in the MRI Room



MRI Floor – Note that only the front half has been cleaned



MRI-Compatible Aluminum IV Pole

Methicillin Resistant Staphylococcus Aureus (MRSA)

MRSA was originally identified in 1961 and is now widespread throughout healthcare facilities, both hospital and outpatient settings⁷. The most common source for transmission of MRSA is by direct or indirect contact with people who have MRSA infections or are asymptomatic carriers.

In 1972 MRSA accounted for only 2% of all *Staphylococcus aureus* infections, but now it is responsible for 50 to 70% of these infections.⁸ MRSA is among those microorganisms commonly referred to as a “super bug”. MRSA may be community associated, CA-MRSA, or healthcare associated HA-MRSA.⁹

The morbidity and mortality of these bacteria is staggering. On average, hospitalizations for the treatment of MRSA versus other infections have a length of stay approximately 3 times longer and are 3 times more expensive^{10,11}. Additionally the risk of death is 3 to 5 times greater for patients infected with MRSA versus methicillin sensitive *Staphylococcus aureus*^{11,12}.

A major concern for imaging centers is that MRSA can be carried by asymptomatic persons. Worldwide, it is estimated that up to 53 million people are asymptomatic carriers of MRSA^{13,14}; of these it is estimated that 2.5 million reside in the United States. Approximately 1% of the US population is colonized with MRSA¹⁵. Both infected and colonized patients contaminate their environment with the same relative frequency¹⁶. Therefore, any patient lying on an imaging table could be a carrier capable of contaminating surfaces in the radiology suite. MRSA and other pathogens can live on inanimate surfaces including common table pads and positioners for periods as long as several months^{17,18,19,20,21}.

Center for Disease Control (CDC)

The Center for Disease Control and Prevention (CDC) has developed guidelines for environmental infection control in healthcare facilities. The CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC) issued a 249 page document extensively detailing their recommendations concerning, in part, the principles of cleaning and disinfecting various surfaces, including surfaces frequently found in radiology suites such as bed linens, pillows, mattresses, carpeting and cloth furnishings²².

The CDC cited numerous well-controlled studies indicating that MRSA can be spread by contaminated surfaces.

In section G, Laundry and Bedding, #8, the authors state: “*Standard mattresses and pillows can become contaminated with body substances during patient care if the integrity of the covers of the items is compromised... A linen sheet placed over the mattress is not considered a mattress cover. Patches for tears or holes in mattress covers do not provide an impermeable surface over the mattress...Wet mattress in particular can be a substantial environmental*

source of microorganisms. Infections and colonization by MRSA have been described.”

In Section G, #2, Epidemiology and General Aspects of Infection Control the authors provide detailed information about contaminated textiles and fabrics, stating:

*“Contaminated textiles and fabrics often contain high numbers of microorganisms from body substances, including blood, skin, stool, urine, vomitus, and other body tissues and fluids. When textiles are heavily contaminated with potentially infective body substances, they can contain bacterial loads of 10^6 – 10^8 CFU/100 cm² of fabric. Disease transmission attributed to health-care laundry has involved contaminated fabrics that were handled inappropriately (i.e., the shaking of soiled linen). Bacteria (*Salmonella* spp., *Bacillus cereus*), viruses (hepatitis B virus [HBV]), fungi (*Microsporum canis*), and ectoparasites (scabies) presumably have been transmitted from contaminated textiles and fabrics to workers via a) direct contact or b) aerosols of contaminated lint generated from sorting and handling contaminated textiles.”*

The American College of Radiology Safe MRI Practices 2007²³

The American College of Radiology (ACR) has developed a document for safe MR Practices, most recently revised in 2007.²³ The ACR has divided up the MRI area into four zones. The most critical zone is Zone IV which is the magnet room itself. To enter this zone without supervision, the person must be Level 2 trained.

Level 2 trained are “those who have been extensively trained and educated in broad aspects of MRI safety issues including issues related to potential for thermal loading or burns and direct neuromuscular excitation from rapidly changing gradients. This is in addition to successfully completing at least one of the MRI safety lectures or pre-recorded presentations approved by the MR medical director. Then it should be repeated at least annually and appropriate documentation should be provided to confirm these ongoing educational efforts.” It goes on to say that it the responsibility of the MR medical director not only to identify the necessary training but also identify those individuals who qualify as Level 2 MR personnel. The ACR also specifically requires that any non-Level 2 personnel entering the scan room must be accompanied by, or under the immediate supervision of and in visual or verbal contact with a specifically identified Level 2 MR personnel for the entirety of the duration within the scan room. Additionally, these non-Level 2 personnel, i.e. cleaners, must also go through a thorough screening to make

sure that they do not have a pacemaker, aneurysm clip or any other dangerous ferromagnetic objects in or on their body. This is why cleaning crews are normally not allowed to go into the scan room.

The number of accidents within MRI suites appears to be a growing problem. Between mid 2005 and mid 2006 the FDA received a 140% increase in reported MRI accidents²⁴. MRI safety has become such an important topic that the American College of Radiology has issued White Papers on MRI safety, most recently updated in 2007²⁵. The Joint Commission has recently released a Sentinel Event Alert titled “Preventing accidents and injuries in the MRI suite”²⁶. Each of these documents emphasize the importance of designating the various areas within the MRI area into Zones I – IV, depending upon the static magnetic field of each zone and the consequent safety precautions that must be taken in each zone. The most dangerous zones are the MRI control room, Zone III, and the MRI suite itself, Zone IV. Both Zone III and Zone IV are within “the region in which free access by unscreened non-MR personnel or ferromagnetic objects or equipment can result in serious injury or death”. They are considered dangerous enough that they “should be physically restricted from general public access by, for example, key locks, passkey locking systems, or any other reliable physically restricting method that can differentiate between MR personnel and non MR personnel.” “Only MR personnel shall be provided free access, such as access keys or passkeys, to Zone III.”²⁷ The major risks involve metallic objects being brought in by unauthorized and untrained personnel. The technologist who runs the MRI is the one responsible for this access control. Therefore, when the technologist is not present, all access should be denied to the MRI suite. This would include after hours cleaning crews. The ACR Guidance Document for Safe MR Practices: 2007 discusses restrictions on housekeeping and cleaning personnel from Zones III and IV.²⁸

The 17 text pages of the ACR Document for Safe MRI Practices 2007 contain only one paragraph of information on Infection Control:

“12. Infection Control (Zone IV)

Because of safety concerns regarding incidental personnel within the MR suite, restricting housekeeping and cleaning personnel from Zone III and/or Zone IV regions may give rise to concerns about the cleanliness of the MR suite. Magnet room finishes and construction details should be designed to facilitate cleaning by appropriately trained staff with non-motorized equipment. Additionally, as the numbers of MR-guided procedures and interventional applications grow, basic infection control protocols, such as seamless floorings, scrubbable surfaces, and hand-washing stations, should be considered.”²⁹

This paragraph confirms the widespread practice of restricting cleaning crews from entering the MRI suite. This author knows of no imaging center or hospital that pays their Level 2 MR personnel (i.e., the technologists) to wait around for the cleaning crews to come in and monitor them the entire time that they are cleaning the room. Therefore, the responsibility to clean the scan room is sometimes assigned to one of the MRI technologist or, more commonly, this responsibility is simply overlooked. However, the paradox is that the MRI technologist, who in almost all imaging centers is the Level 2 trained person, is rarely an experienced or even trained cleaning person with very limited time to clean.

This paradox is clear when asking the question, “Is the scan room being cleaned and if so by whom?” The answer that this author normally receives is “of course it’s being cleaned by the cleaning crews that come in at night after we leave.” It is crucial to ask the next question, “What Level 2 personnel are present to monitor the cleaning crew to make sure that it is done properly and safely?” This author knows of no cleaning crew that has the background training to be Level 2 personnel. Additionally, the cleaning crews contacted by this author have all stated that they been told or simply assume that they are not to go into the scan room. Cleaners often describe the MRI suite as the room with all the signs on the door warning them not to enter.

The MRI Suite

The area of greatest challenge for preventing the transmission of MRSA and other infections in Radiology is clearly the MRI suite. Due to the high magnetic field, posing a danger to both the personnel and to damaging the MRI itself, and to comply with the American College of Radiology recommendations²³ it is the author’s experience, that many free standing imaging centers and hospitals do not allow cleaning crews to enter the MRI suite. Therefore these MRI suites are rarely, if ever properly cleaned

This is a risk to staff and patients because MRSA can be transmitted by contact with contaminated surfaces such as mattress pads^{30,31}. It has been proven that MRSA can survive on surfaces such as tabletops and charts for up to 11-12 days³². Similarly, Vancomycin-resistant enterococci (VRE) had a 50% survival at seven days on upholstery, furniture and wall coverings and could easily be transferred by touching contaminated surfaces³³. There is an increased risk of VRE/MRSA for patients in the presence of environmental contamination, 5.1% increased risk for MRSA and 6.8% for VRE^{34,35}. There is an increased risk of an MRSA acquired infection for patients admitted to a room that was previously occupied by a patient colonized with MRSA³⁶

At many MRI centers, there exists a false belief that merely placing a clean sheet over the table pads, without actually cleaning them between patients, will prevent the spread of infectious agents. What is most concerning is that very few MRI centers clean their pads even once a day, much less between patients. Cleaning pads during working hours typically has a very low priority, because it is time consuming, decreases throughput and thereby decreases the center's productivity and negatively impacts the financial well being of the center.

Additionally, MRI technologists, especially those who trained in the 1970's and 1980's, had little training in infection control or proper cleaning procedures. An average MRI may scan 3,000 to 5,000 patients a year. CT scanners usually scan double or triple that number. The probability is that at least 50 – 100 of these patients are infected with MRSA or other HAI ^{37,38}, and many more are carriers.

Another area of potential exposure to infectious agents is the use of IV contrast material for both CT and MRI, which significantly increases the risk of blood contamination. The simple task of removing a needle from a patient's arm and placing it into the sharps container has great risk. Blood can drip from the needle or from the puncture wound onto the pads, table and floor. This blood can often be unnoticed by a busy technologist or doctor performing the injection resulting in a contamination risk. It is not uncommon to find dried blood in an imaging suite which is an excellent culture medium for MRSA.

There is also concern for spreading infectious bacteria by direct or indirect contact among the imaging staff and patients within the imaging department or center. MRSA infections can be acquired by staff members through a simple cut or other break in the skin that may not be noticed during a busy day. Therefore, hand-washing between patients as well as hand sanitizer use for the entire staff is of crucial importance^{39,40,41}. Regarding mobile MRI, ensuring proper hygiene is even more difficult since they do not have a sink or running water.

Bacteria and Table Pads

One much overlooked concern is the torn and frayed pads used in imaging departments and centers. Once the covering material has been breached, pads cannot be properly cleaned and should be immediately removed and replaced. This is clearly demonstrated by Oie in his article "Contamination of Environmental Surfaces by *Staphylococcus aureus* in a Dermatological Ward and Its Preventive Measures" In the article the author states, '... items with

a smooth surface can be repeatedly used without problems if disinfected. However, on items with a porous surface made of a spongy material, *S. aureus* was detected even after disinfection had been done. Thus, porous surfaces made of such material cannot be adequately disinfected".⁴²

In the late 1980's and early 1990's when many of the pads systems in use today were developed, they were not designed to take the wear-and-tear of five to ten thousand patients a year for so many years. The fabric covers were coated with some type of plastic to make it water proof. However this plastic wears off especially with cleaning solutions as well as with use. As a result, pad coverings have worn out exposing the foam core or have lost their ability to prevent penetration of bacteria and fluids into the central core, where it is not possible to be cleaned.



Torn and Frayed Table Pad

Only in the last 5 to 10 years have hospital-acquired infections become so significant. Before that time there was very little concern for contamination and MRSA was not as prevalent as today. Therefore, pads on most imaging tables do not incorporate newer technologies developed to assist in infection control. Permanent antimicrobial agents should be incorporated into all table pads and positioners and scanner controls, keyboards, etc. For added protection, the seams of the table pads should not only be tightly sewn, but also welded closed or have another permanent barrier in place in addition to simple stitching. The integrity of these seams is crucial in protecting patients. Another area of concern is that of aerosolization of MRSA bacteria.

Table pads inherently have air within them. When a patient lies down on the pads, this air is forced out through any hole or seam in the covering materials. This can cause the bacteria contaminating the central foam core to become ejected from the pad and aerosolize into the room environment. Of course the reverse air flow caused by the patient arising off the pads causes infectious materials to be drawn into the foam core from the surface, which is then re-ejected into the air when the next patient lies on the pad. There have been numerous articles discussing the possibility of MRSA or other pathogenic microorganisms becoming airborne during activities such as bed making⁴³ and thus the possibility that MRSA can be transmitted among patients through the air (Shiomori.)⁴⁴. There is also a suggestion that airborne MRSA may play a role in MRSA colonization of the nasal cavity or respiratory tract⁴⁵. Wilson showed that the presence of airborne MRSA in an area is strongly related to the presence and number of MRSA colonies and infected patients in that area⁴⁶. Shiomori states that measures should be taken to prevent the spread of airborne MRSA to control nosocomial MRSA infection⁴⁷.

This is clearly another reason why all pads must be inspected with a magnifying glass, and if any holes or loss of integrity of the covering material in any way is detected, the pads *must be replaced*.

Black (ultraviolet) Light Detection of Body Fluid Contamination that may Indicate Fraying

It is also important that all pads be periodically tested using a black light to detect biologic contamination. A black light provides light in the ultraviolet wavelengths that is especially sensitive in detecting biological material such as blood, fingerprints, body fluids, etc. Biological material remaining on the pads will light up under black light exposure. This is an excellent way to confirm that the cleaning procedures are adequate. If biological material remains after proper cleaning it may indicate the covering material has been frayed or breached, thus allowing fluids to seep into the fabric itself and possibly penetrate to the underlying foam. Experiments performed by Ryan Whitney (a medical student who experimented with MRSA and MRI pads) (personal communication) have shown that MRSA could even go through frayed fabric covers without a tear and get into the central core where it is not possible to disinfect. This also demonstrates the necessity for pads and positioners to contain permanent antimicrobial agents in the covers and foam cores. More studies are needed to more thoroughly understand the depth of this problem and exactly how many pads in use today are contaminated.

A product called **Glo Germ™ Kit** which contains plastic “simulated germs” can be used for hand washing training. **Glo Germ™ Liquid** is rubbed onto one’s hands like lotion. For surface cleaning, **Glo Germ™ Powder** is dusted onto surfaces and generally throughout the entire area. Next wash your hands or clean the area as normal. Under normal light, hands and the surfaces will appear clean. However, ultraviolet light will show any “Glo Germs” remaining. This is an excellent way to train personnel in proper hand washing and pad cleaning procedures.

The Magnet Bore

An area of proven risk of MRSA⁶ is the inside of the MRI itself, often referred as the magnet bore or tunnel. The risk of MRSA transmission is increased in this area because the patient is often touching or in very close contact with the surface of the bore. It is obvious that cleaning inside the bore of an MRI unit is a difficult, dangerous and cumbersome task. The fact that most cleaning tools can not even be brought inside the MRI room, and especially into the bore, makes this task even more difficult. The best possible way to clean the bore is to physically crawl inside to clean and disinfect the entire bore by hand. Unfortunately this also puts the technologist in very close contact with the contaminated surfaces and is yet another reason this is almost never done. In fact, the author, in over 25 years, has never seen a cleaning crew or technologist clean the inside of the MRI bore.

One alternative for cleaning, sanitizing and disinfecting inside the MRI bore and its surroundings, is to use a cleaning tool long enough to reach well inside the bore that has some kind of pad or sponge at its end soaked with a disinfectant.

MagnaWand Inc. has invented such a cleaning tool that is completely non-magnetic, and designed exclusively to clean and disinfect the MRI bore and its surroundings. With the MagnaWand tool, technologists can easily reach inside the bore and clean, using the disinfectant, directly onto the surface. Once the area of interest has been cleaned and disinfected the disposable pad is simply ejected from the tool without being touched by the technologist’s hands, eliminating the risk of further contamination.

Personal Experience

The issue of infection control became very personal when my wife, who is also a physician, suffered an injury last year and was at a well-known medical

center. Like many patients she needed an MRI before she could be discharged.

When my wife arrived for her MRI, they were running late. This is very common situation, which puts tremendous pressure on the Technologist operating the MRI to keep up and get back on time.

The patient before her was clearly a patient from isolation ward and appeared to have been squeezed into the schedule. Everyone was wearing a mask and gloves. She over heard that the patient had a possible unknown virus infection and was felt to be contagious.

My wife insisted that the technologist thoroughly clean the pads and especially the head coil that was used on the previous sick patient and would be used on her. He said that there was absolutely no time for this and if she would not get on the table right away, that he would just go on and scan the next patient and she would be able to explain to her doctors and insurance company why she refused her MRI. My wife desperately needed the MRI so she could be discharged from the hospital.

When she came back after completing MRI she was absolutely in tears. She knew that she make a mistake, but like many patients felt pressure to complete her study.

This is just one example of what happens daily in busy hospitals and imaging centers throughout the country. I have talked with numerous patients, many of which have MRSA and they express very similar experiences when they underwent their MRI's.

Technologists have also expressed frustration that they are pressured from management to scan as many patients as possible and keep on schedule no matter what. Technologists have been let go because they were "slow" and could not keep up with an unrealistic number patients to be scanned during their shift.

This is why there **must** be a written infectious disease policy not only to protect patients but also the technologist

How did it get so bad?

A question frequently asked is "how did the standard of practice for infection control become so overlooked in MRI suites?" There are several reasons. First, the dangers presented by the extremely strong magnetic field make it

imperative that all personnel put magnetic safety first. Unfortunately, the focus has become solely on the dangers of the magnetic field, and infection control has taken a back seat.

Another factor is that the significant decrease in reimbursement for MRI has forced MRI centers to rush patients through in order to scan more patients per day. Relative to this latter issue, it is now a common practice to provide financial incentives for the MRI technologist to increase patient throughput, i.e., the number of patients scanned during a certain amount of time. That is, the technologist receives a bonus based upon scanning more patients in less time.

The other practice that contributes to this situation is that MRI center often will overbook, that is put patients in time slots that are too short to perform a complete study, or add patients on to a full schedule. This is similar to the airlines overbooking, knowing that a number of patients will not show up for their appointment. Unless an MRI center overbooks patients, the “no shows” will have a disastrous effect on the bottom line since they take up time slots which cannot be charged for. Merely two “no shows” a day, can mean up to \$300,000 loss from the bottom line each year for an MRI center that may already be struggling.

The profit of these imaging centers, which is a fixed cost business, is directly proportional to the number of scans completed in a day. The difference between scanning two patients an hour and three patients an hour can be significant, accounting for as much as an additional \$1 – 2 million in annual revenue.

This is why the technologists and staff are being rewarded for improved efficiency and reducing the time between scans. Taking time to clean the table and pads or even wash their hands between patients interferes with the technologists’ incentive to decrease the room turn around time and thereby increase the total number of scans completed. Even without cash incentives, technologists are under intense pressure to get the patients on and off the table and the room turned around as fast as possible. Technologists have been terminated because they were “too slow”. The overbooking issue only adds to the problem.

To save money and time, many imaging centers have elected to allow patients to wear their street clothes during their MRI instead of having them change into clean gowns or scrubs. This significantly reduces patient turn-around time and associated costs, i.e. laundry and staff time to assist patients. However, this also allows any bacteria on the patient’s clothes to cross contaminate the next patient scanned in the magnet.

An important area that patients and their doctors are often not aware, is that since MRI does not use any ionizing radiation, these centers are not required to adhere to state regulations concerning x-ray. This means that the person who operates the MRI does **not** need to be a registered radiologic technologist (RT) as with an X-ray device. Basically, anyone can scan a patient on an MRI, without any formal training, much less an understanding of infection control. This is seen most commonly in small imaging centers, MRIs in physician's offices and mobile MRIs. There have been situations where the truck driver who moves the mobile MRI, also scans the patients, as well as front desk personnel being cross trained to operate the MRI. There are tremendous cost benefits to using a less qualified individual than a highly trained and highly paid registered radiologic technologist. Unfortunately, one often has no way to know the qualification of the person scanning without specifically asking, which most patients are very uncomfortable in doing.

Conclusion

Patient safety should be the primary concern of any healthcare organization. Protecting patients and staff takes a concerted effort by all the parties involved in diagnostic imaging. There is no question that infection control has not received the attention it deserves. There is a growing concern that at least some of the spread of infectious agents could be coming from outpatient imaging centers and radiology departments in hospitals.

However, almost no attention has been paid to infection control inside these MRIs. This is demonstrated by the fact that there has been only one published research project ever to even explore the possibility of infectious disease inside an MRI and this study was performed in Ireland and presented in 2006. The study only tested one magnet, but found that there was MRSA present in the magnet. It is quite telling that there have been no follow up studies since that time.

Further research is now required to determine the percentage of MRIs in this country that harbor MRSA. It is crucial that we assure patients that proper infection control procedures are being performed in the MRI suite to ensure the future success of MRI. It is understandable that this would be somewhat painful and expensive for MRI centers and hospitals, however in the long run, it will be crucial to address this issue before it becomes a national problem requiring government intervention and regulations. Imaging centers and hospitals owe it to their patients, to assure that their safety is the top concern during their MRI experience.

Suggestions for Infection control procedures for free-standing imaging centers and hospital radiology departments

The cleanliness of free-standing imaging centers and hospital radiology departments is crucial for reducing the spread of MRSA and other acquired infections. The following are 11 simple procedures to implement that can prevent the spread of these infections.

1. Have a written infectious control policy to include MRI cleaning procedures as well as the cleaning schedule and have it posted throughout the center.
2. Implement a mandatory hand washing / hand sanitizing procedure between patient exams for technologists and any others who come into contact with patients.
3. Clean the MRI tables, inside the bore of the magnet and any other items that come into contact with a patient. Infection control experts recommend this be done between each patient.
4. Clean all pads and positioners with an approved disinfectant. Infection control experts recommend cleaning after each patient.
5. Periodically inspect the pads with a magnifying glass, particularly at the seams, to identify fraying or tearing. If present, the pads should be replaced.
6. Regularly check all padding material with an ultraviolet (black) light and make sure that any biological material detected on the pads can be removed.
7. Replace damaged or contaminated pads with new pads incorporating permanent antimicrobial agents.
8. Use pillows with a waterproof covering that is designed to be surface wiped. Replace pillows when their barrier is compromised.
9. Promptly remove body fluids, and then surface disinfect all contaminated areas.

10. If a patient has an open wound or any history of MRSA/other infection:
 - a. Gloves and gowns should be worn by all staff coming in contact with the patient. These barriers must be removed before touching other areas not coming in contact with the patient, i.e. door knobs, scanner console, computer terminals, etc.
 - b. The table and all the pads should be completely cleaned with disinfectant before the next patient is scanned, if it is not already being performed between every patient. For patients with any known infectious process add 10-15 minutes onto the scheduled scan time to assure there is enough time to thoroughly clean the room and all the pads.
11. All furniture should be periodically cleaned. Ideal surfaces are those that are waterproof and wipeable. Infection control experts recommend this be done between each patient.

References

- ¹ Cosgrove SE, Qi Y, Kaye KS, Harbarth S, Karchmer AW, Carmeli Y. Infect Control Hosp Epidemiol. 2005 Feb;26(2):166-74. Comment in: Infect Control Hosp Epidemiol. 2006 Sep;27(9):994-5. The impact of methicillin resistance in Staphylococcus aureus bacteremia on patient outcomes: mortality, length of stay, and hospital charges
- ² Engemann JJ, Carmeli Y, Cosgrove SE. Clin Infect Dis. 2003 Mar 1;36(5):592-8. Epub 2003 Feb 7. Related Articles, Adverse clinical and economic outcomes attributable to methicillin resistance among patients with Staphylococcus aureus surgical site infection.
- ³ Chaljub G, Kramer LA, Johnson RF III, Singh H, Crow WN. Projectile cylinder accidents resulting from the presence of ferromagnetic nitrous oxide or oxygen tanks in the MR suite. AJR 2001; 177:27-30
- ⁴ Fatal MRI Accident is First of its Kind. Peggy Peck. WebMD News. August 1, 2001. <http://www.webmd.com/news/20010801/fatal-mri-accident-is-first-of-its-kind>
- ⁵ ECRI Hazard Report. Patient Death Illustrates importance of adhering to safety precautions in magnetic resonance environments. Health Devices 2001;30:311-314.
- ⁶ Scanlon T, Murray J. MRSA Detection in the Radiology Department, code LL-HS4369-L04, presented at the RSNA meeting 2006
- ⁷ Understanding MRSA. WebMD. <http://webmd.com/skin-problems-and-treatments/understanding-mrsa-methicillin-resistance-staphylococcus-aureus>. Accessed March 9, 2008
- ⁸ Soule, B. Avoiding the Drama of Hospital Acquired Infections. Hospitals and Health Networks. January 29, 2008 http://www.hhnmag.com/hhnmag_app/jsp/articledisplay.jsp?dcrpath=HHNMAG/Article/data/01JAN2008/080129HHN_Online_Soule&domain=HHNMAG
- ⁹ Healthcare-associated infections (HAIs). Centers for Disease Control and Prevention Web site. <http://www.cdc.gov/ncidod/dhqp/healthDis.html>. Updated February 23, 2006.
- ¹⁰ Lodise, Diag Micro Inf Dis, 2005
- ¹¹ Kaye K, Engmann J, Mozaffari E, Carmeli Y. Reference Group Choice and Antibiotic Resistance Outcomes. Emerg Infect Dis (serial on internet) 2004 June [date cited] available from <http://www.cdc.gov/ncidodEID/vol10no6/02-0665.htm>
- ¹² Whitby et al., Med J Aust 2001; 75:264-7 Whitby M, McLaws M-L, Berry G. The risk of death from methicillin resistant Staphylococcus aureus bacteraemia: a meta-analysis. Med J Aust 2001; 175: 264-267.
- ¹³ Salgado CD, Farr BM, What proportion of hospital patients colonized with methicillin-resistant Staphylococcus aureus are identified by clinical microbiology cultures? et al., ICHE Infect Control Hosp Epidemiol 2006;27:116-21
- ¹⁴ Lucet JC, Grenet K, Armand-Lefevre L, et al., High prevalence of carriage of methicillin-resistant staphylococcus aureus at Hospital admissions in elderly patients; Implications for Infection Control Strategies. Infection Control Hospital Epidemiology 2005;26:121-6

- ¹⁵ Understanding MRSA. WebMD. <http://webmd.com/skin-problems-and-treatments/understanding-mrsa-methicillin-resistance-staphylococcus-aureus>. Accessed March 9, 2008
- ¹⁶ Karchmer, CID TB, Editorial Commentary: Prevention of Healthcare-associated Methicillin-resistant staphylococcus aureus (MRSA) Infections: Adapting to a Changing Epidemiology, *Clinical Infectious Diseases* 2005;41:15:167-9
- ¹⁷ Dietze B, Rath A, Wendt C, Martiny H. Survival of MRSA on sterile goods packaging. *J Hosp Infect.* 2001 Dec; 49 (4): 255-61
- ¹⁸ Hardy KJ, Oppenheim BA, Gossain S, Gao F, Hawkey PM. A Study of the Relationship Between Environmental Contamination with Methicillin-Resistant Staphylococcus Aureus (MRSA) and Patients' Acquisition of MRSA. *Infection Control and Hospital Epidemiology.* February 2006, Vol. 27 No. 2
- ¹⁹ Blythe D, Keenlyside D, Dawson SJ, Galloway A. Environmental contamination due to methicillin-resistant Staphylococcus aureus (MRSA). 1: *J Hosp Infect.* 1998 Jan;38(1):67-9. Comment in: *J Hosp Infect.* 1998 Jul;39(3):243-4.
- ²⁰ Boyce JM, Potter-Bynoe G, Chenevert C, King T. Environmental contamination due to methicillin-resistant Staphylococcus aureus: possible infection control implications. *Infect Control Hosp Epidemiol.* 1997 Sep;18(9):622-7.
- ²¹ Wagenvoort JH, Sluijsmans W, Penders RJ. Better Environmental survival of outbreak vs. sporadic MRSA isolates. *J. Hosp Infect.* 2000 Jul;45 (3):231-234
- ²² Guidelines for Environmental Infection Control and Healthcare Facilities Recommendations of CDC and Healthcare Infection Control Practices Advisory Committee (HICPAC) 2003. This is available from the Center for Disease Control and Prevention website www.cdc.gov.
- ²³ ACR Guidance Document for Safe MR Practices: 2007. *AJR* 2007; 188:1-27. http://www.acr.org/SecondaryMainMenuCategories/quality_safety/MRSafety/safe_mr07.aspx
- ²⁴ Gilk, T., Bell, R. The State of MRI Safety. *Imaging Economics.* Sept. 2007 http://www.imagingeconomics.com/issues/articles/2007-09_04.asp accessed March 9, 2008
- ²⁵ ACR Guidance Document for Safe MR Practices: 2007. *AJR* 2007; 188:1-27. http://www.acr.org/SecondaryMainMenuCategories/quality_safety/MRSafety/safe_mr07.aspx
- ²⁶ Sentinel Event Alert. Preventing accidents and injuries in the MRI suite. Issue 38, February 14, 2008. http://www.jointcommission.org/SentinelEvents/SentinelEventAlert/sea_38.htm
- ²⁷ ACR Guidance Document for Safe MR Practices: 2007. *AJR* 2007; 188:1-27. http://www.acr.org/SecondaryMainMenuCategories/quality_safety/MRSafety/safe_mr07.aspx Page 3.
- ²⁸ ACR Guidance Document for Safe MR Practices: 2007. *AJR* 2007; 188:1-27. http://www.acr.org/SecondaryMainMenuCategories/quality_safety/MRSafety/safe_mr07.aspx Page 23.
- ²⁹ ACR Guidance Document for Safe MR Practices: 2007. *AJR* 2007; 188:1-27. http://www.acr.org/SecondaryMainMenuCategories/quality_safety/MRSafety/safe_mr07.aspx pg. 23.
- ³⁰ Blythe D, Keenlyside D, Dawson SJ, Galloway A. Environmental contamination due to methicillin-resistant Staphylococcus aureus (MRSA). 1: *J Hosp Infect.* 1998 Jan;38(1):67-9. Comment in: *J Hosp Infect.* 1998 Jul;39(3):243-4.
- ³¹ Boyce JM, Potter-Bynoe G, Chenevert C, King T. Environmental contamination due to methicillin-resistant Staphylococcus aureus: possible infection control implications. *Infect Control Hosp Epidemiol.* 1997 Sep;18(9):622-7
- ³² Huang , SS, Mehta, S., Weed, D and Price, C.S. Methicillin-Resistant Staphylococcus aureus survival on Hospital Fomites. *Infect Control Hosp Epidemiol* 2006;27:1267-69 et al., *Infect Control Hosp Epidemiol* 2006;27:1267-69

- ³³ Lankford et al., Assessment of Materials Commonly Used in Healthcare: Implications for survival and transmission. *Am J Infect Control* 2006;34:258-63
- ³⁴ Martinez et al., Role of Environmental Contamination as a Risk Factor for Acquisition of Vancomycin-Resistant Enterococci in Patients Treated in a Medical Intensive Care Unit. *Arch Intern Med* 2003;163:1905-12 *Arch Intern Med* 2003;163:1905-12
- ³⁵ Huang, SS, Datta R, Platt, R. Risk of Acquiring Antibiotic-Resistant Bacteria From Prior Room Occupants. *Arch Intern Med* 2006;166:1945-51 et al., *Arch Intern Med* 2006;166:1945-51
- ³⁶ Huang, SS, Datta R, Platt, R. Risk of Acquiring Antibiotic-Resistant Bacteria From Prior Room Occupants. *Arch Intern Med* 2006;166:1945-51 Huang et al., *Arch Intern Med* 2006;166:1945-51
- ³⁷ Cosgrove SE, Qi Y, Kaye KS, Harbarth S, Karchmer AW, Carmeli Y. *Infect Control Hosp Epidemiol*. 2005 Feb;26(2):166-74. Comment in: *Infect Control Hosp Epidemiol*. 2006 Sep;27(9):994-5. The impact of methicillin resistance in *Staphylococcus aureus* bacteremia on patient outcomes: mortality, length of stay, and hospital charges.
- ³⁸ Engemann JJ, Carmeli Y, Cosgrove SE, *Clin Infect Dis*. 2003 Mar 1;36(5):592-8. Epub 2003 Feb 7. Related Articles, Adverse clinical and economic outcomes attributable to methicillin resistance among patients with *Staphylococcus aureus* surgical site infection.
- ³⁹ Boyce P. Guideline for hand hygiene in health-care settings. *MMWR Morb Mortal Wkly Rep* 2002;51(16):1-44.[Medline]
- ⁴⁰ Delaney LR, and Gunderman, RB. Hand Hygiene. *Biological & Pharmaceutical Bulletin*. Vol. 28 (2005), No. 1 120
- ⁴¹ Kihlstrom J. Hand washing by health care providers. Institute for the Study of Healthcare Organizations & Transactions Web site. http://www.institute-shot.com/hand_washing_by_health_care_providers.htm.
- ⁴² Oie S, Yanagi C, Matsui H, Nishida T, Tomita M and Kamiya A. Contamination of Environmental Surfaces by *Staphylococcus aureus* in a Dermatological Ward and Its Preventive Measures. *J Hosp Infect*. 1998 Oct;40(2):135-40.
- ⁴³ Guidelines for Environmental Infection Control and Healthcare Facilities Recommendations of CDC and Healthcare Infection Control Practices Advisory Committee (HICPAC) 2003. This is available from the Center for Disease Control and Prevention website www.cdc.gov. section G no 2.
- ⁴⁴ Shiomori T, Miyamoto H, Makishima K, Yoshida M, Fujiyoshi T, Udaka T, Inaba T, Hiraki N. Evaluation of bedmaking-related airborne and surface methicillin-resistant *Staphylococcus aureus* contamination. *J Hosp Infect*. 2002 Jan;50(1):30-5
- ⁴⁵ Kerr KG, Beggs CB, Dean SG, Thornton J, Donnelly JK, Todd NJ, Sleight PA, Qureshi A, Taylor CC. Air ionisation and colonisation/infection with methicillin-resistant *Staphylococcus aureus* and *Acinetobacter* species in an intensive care unit. *Intensive Care Med*. 2006 Feb;32(2):315-7. Epub 2006 Jan 24. Comment in: *Intensive Care Med*. 2006 Sep;32(9):1438; author reply 1439.
- ⁴⁶ Wilson RD, Huang SJ, McLean AS. The correlation between airborne methicillin-resistant *Staphylococcus aureus* with the presence of MRSA colonized patients in a general intensive care unit. *Anaesth Intensive Care*. 2004 Apr;32(2):202-9
- ⁴⁷ Shiomori T, Miyamoto H, Makishima K. Significance of airborne transmission of methicillin-resistant *Staphylococcus aureus* in an otolaryngology-head and neck surgery unit. *Arch Otolaryngol Head Neck Surg*. 2001 Jun;127(6):644-8