

# UC Irvine

## UC Irvine Previously Published Works

### Title

Strategies to Prevent Methicillin-Resistant Staphylococcus aureus Transmission and Infection in Acute Care Hospitals: 2014 Update

### Permalink

<https://escholarship.org/uc/item/6t60k7sj>

### Authors

Calfee, David P  
Salgado, Cassandra D  
Milstone, Aaron M  
et al.

### Publication Date

2014

### DOI

10.1017/S0899823X00193882

Peer reviewed

# Strategies to Prevent Methicillin-Resistant *Staphylococcus aureus* Transmission and Infection in Acute Care Hospitals: 2014 Update

David P. Calfee, MD, MS;<sup>1,a</sup> Cassandra D. Salgado, MD, MS;<sup>2,a</sup> Aaron M. Milstone, MD;<sup>3</sup>  
Anthony D. Harris, MD, MPH;<sup>4</sup> David T. Kuhar, MD;<sup>5</sup> Julia Moody, MS;<sup>6</sup> Kathy Aureden, MS, MT, CIC;<sup>7</sup>  
Susan S. Huang, MD, MPH;<sup>8</sup> Lisa L. Maragakis, MD, MPH;<sup>3</sup> Deborah S. Yokoe, MD, MPH<sup>9</sup>

## PURPOSE

Previously published guidelines are available that provide comprehensive recommendations for detecting and preventing healthcare-associated infections (HAIs). The intent of this document is to highlight practical recommendations in a concise format designed to assist acute care hospitals in implementing and prioritizing their methicillin-resistant *Staphylococcus aureus* (MRSA) prevention efforts. This document updates “Strategies to Prevent Transmission of Methicillin-Resistant *Staphylococcus aureus* in Acute Care Hospitals,”<sup>1</sup> published in 2008. This expert guidance document is sponsored by the Society for Healthcare Epidemiology of America (SHEA) and is the product of a collaborative effort led by SHEA, the Infectious Diseases Society of America (IDSA), the American Hospital Association (AHA), the Association for Professionals in Infection Control and Epidemiology (APIC), and The Joint Commission, with major contributions from representatives of a number of organizations and societies with content expertise. The list of endorsing and supporting organizations is presented in the introduction to the 2014 updates.<sup>2</sup>

## SECTION 1: RATIONALE AND STATEMENTS OF CONCERN

### I. HAIs caused by MRSA in acute-care facilities are common

A. In the United States, the proportion of hospital-associated *S. aureus* infections resistant to methicillin remains high.

1. The most recent data from the National Healthcare Safety Network (NHSN) reports that, from 2009 to 2010, 54.6% of *S. aureus* central line-associated bloodstream infections (CLABSIs), 58.7% of *S. aureus* catheter-associated urinary tract infections, 48.4% of

*S. aureus* ventilator-associated pneumonia (VAP) episodes, and 43.7% of *S. aureus* surgical site infections (SSIs) were caused by MRSA.<sup>3, 4</sup>

2. Compared with data from 2007 and 2008, the proportions caused by MRSA are lower for each of the HAIs, significantly so for VAP and SSI. Additionally, from 2005 through 2011, rates of hospital-onset invasive MRSA infections reportedly decreased 54.2%, with the greatest decreases for BSIs.<sup>5,6</sup> In contrast, among pediatric populations, from 2005 to 2010, there were no significant reductions in healthcare-associated MRSA infections.<sup>7</sup>
3. Although these findings suggest some success in preventing healthcare-associated MRSA transmission and infection, many patient groups continue to be at risk.

### II. Outcomes associated with MRSA HAIs

A. MRSA HAIs have been associated with significant morbidity and mortality.<sup>8-10</sup> Although some investigators have found no difference in morbidity and mortality when comparing infections due to methicillin-susceptible *S. aureus* (MSSA) to those due to MRSA,<sup>11,12</sup> some studies comparing patients with MSSA bacteremia to those with MRSA bacteremia have reported nearly twice the mortality rate, significantly longer hospital stays, and significantly higher median hospital costs for MRSA.<sup>8,13</sup>

1. Compared with patients with an MSSA SSI, one study found that those with an MRSA SSI have a 3.4 times higher risk of death and almost 2 times greater median hospital costs.<sup>9</sup>
2. The higher morbidity and mortality rates associated with MRSA are not necessarily due to increased virulence of resistant strains but rather to other factors, such as delays in initiation of effective antimicrobial therapy, less effective antimicrobial therapy for resistant strains, and higher severity of underlying illness among persons with infection due to resistant strains.

### III. Risk of MRSA HAI among colonized patients

- A. A substantial proportion of colonized patients will subsequently develop an MRSA infection, such as pneumonia, soft tissue, or primary BSI.<sup>14-19</sup> Among adults, this proportion has ranged from 18% to 33%.
    - 1. Risk of infection among those colonized is not limited to the period of concomitant hospitalization but persists beyond discharge. One study of persons in whom MRSA colonization had been identified during a previous hospital stay reported that the risk of developing an MRSA infection within 18 months of detection of MRSA colonization was 29%,<sup>14</sup> and others report that, among those who develop MRSA infections after discharge, these account for a substantial number of readmissions.<sup>17</sup>
  - B. Among pediatric patients, 8.5% of children found to be colonized on admission subsequently developed an MRSA infection. In addition, among patients who acquired MRSA colonization while being cared for in the pediatric intensive care unit (ICU), 47% subsequently developed MRSA infection.<sup>19</sup>
- IV. Risk factors for MRSA colonization and HAI
- A. Risk factors for MRSA colonization include severe underlying illness or comorbid conditions, prolonged hospital stay, exposure to broad-spectrum antimicrobials, presence of invasive devices (such as central venous catheters), and frequent contact with the healthcare system or healthcare personnel (HCP).
  - B. Colonization pressure (the ratio of MRSA carrier–days to total patient–days) has been identified as an independent risk factor for hospital-associated acquisition of MRSA.<sup>20</sup>
  - C. Community-associated MRSA (CA-MRSA) strains, which are genetically and often clinically distinct from typical healthcare-associated strains, are now a significant and growing problem among persons without traditional healthcare-related risk factors;<sup>21-23</sup> however, transmission of CA-MRSA can and does occur in hospitals.<sup>24-29</sup>
    - 1. Recent studies have found that an increasing proportion of hospital-onset invasive MRSA infections are caused by community strains.
    - 2. Some have found specific risks associated with having a healthcare-associated MRSA infection due to a community strain, such as human immunodeficiency virus infection or injection drug use; however, outcomes have been similar, suggesting that community strains in hospitals are behaving similarly to traditional healthcare-associated strains.<sup>30</sup>
- V. Reservoir for MRSA transmission in acute care facilities
- A. In the healthcare facility, antimicrobial use provides a selective advantage for MRSA to survive.
  - B. The reservoir for MRSA in hospitals includes colonized or infected patients and healthcare providers as well as contaminated objects within the patient care environment. Transmission is complex but occurs largely through patient-to-patient spread.
    - 1. MRSA-colonized and MRSA-infected patients readily contaminate their environment, and HCP coming into contact with the patient or their environment readily contaminate their hands, clothing, and equipment.<sup>31-40</sup>
    - 2. The risk for acquisition of MRSA is higher among hospital patients admitted into a room in which the previous occupant was colonized or infected with MRSA than among patients admitted into a room in which the previous patient was not colonized or infected with MRSA.<sup>41</sup>

## SECTION 2: BACKGROUND—STRATEGIES TO DETECT MRSA

### I. MRSA surveillance

- A. Laboratory-identified event surveillance (ie, surveillance based on identification of MRSA laboratory results) and clinical infection surveillance are the 2 commonly used approaches for MRSA surveillance. These 2 surveillance strategies are not mutually exclusive and are often used in conjunction with one another.
  - 1. Regardless of the type of MRSA surveillance selected for use, consistent application of the chosen surveillance definitions is necessary to generate reliable and accurate data that will allow detection of changes in the epidemiology of MRSA within the facility over time.
  - 2. The Centers for Disease Control and Prevention (CDC)/NHSN definitions for laboratory-based surveillance and infection surveillance are frequently used for MRSA surveillance.<sup>42,43</sup> Because surveillance definitions are subject to change and refinement, users should always refer to source documents (eg, NHSN protocols) to determine currently recommended definitions.

- B. *Laboratory-identified event surveillance*. The NSHN’s laboratory-identified event reporting definitions provide proxy measures of MRSA healthcare acquisition, exposure burden (colonization pressure or prevalence), and infection burden based solely on laboratory data and basic admission data (eg, date of admission, inpatient location).<sup>42</sup>
1. These definitions allow classification of clinical MRSA isolates as either hospital or community onset.
  2. Similar definitions have also been published by SHEA and the Healthcare Infection Control Practices Advisory Committee (HICPAC).<sup>44</sup>
- C. *Clinical infection surveillance*. Clinical infection surveillance can also be used to classify MRSA isolates as healthcare or community onset and to identify patients with specific types of healthcare-associated MRSA infections (eg, CLABSI, SSI).<sup>42,43</sup>
1. Unlike laboratory event-based definitions, which classify isolates solely on the basis of the time of specimen collection relative to the time of hospital admission, clinical infection surveillance definitions also include an evaluation of the patient’s clinical history and prior healthcare exposures.
- II. Methods for detecting patients with MRSA
- A. The reservoir for transmission of MRSA is largely composed of 2 groups of patients: those with clinical MRSA infection, and a much larger group of asymptomatic MRSA carriers. Various detection methods can be used to identify one or both of these groups.
    1. *Routine review of data from clinical specimens*. Clinically infected patients and some asymptotically colonized patients can be detected when MRSA is isolated from a clinical specimen obtained for clinical decision-making purposes.
    2. *Review of active surveillance testing (AST) data*. AST for MRSA is defined as performing diagnostic testing for the purpose of identifying persons who are asymptomatic carriers of MRSA. AST is discussed in more detail in section 4.

## SECTION 3: BACKGROUND—STRATEGIES TO PREVENT MRSA TRANSMISSION AND INFECTION

- I. Summary of existing guidelines and recommendations
- A. Several governmental, public health, and professional organizations have published evidence-based guidelines and/or policies for the prevention and control of MRSA.<sup>45-48</sup> These guidelines provide similar recommendations, differing primarily in the emphasis placed on the use of AST to identify patients asymptotically colonized with MRSA and in recommendations for routine decolonization of MRSA carriers.
  - B. The Institute for Healthcare Improvement and APIC have developed practical suggestions for implementation and monitoring of several of the prevention measures specified in evidence-based guidelines.<sup>49,50</sup>
- II. Infrastructure requirements
- A. Infrastructure requirements of an MRSA prevention program include the following:
    1. An infection prevention and control (IPC) program that (1) is staffed by a sufficient number of trained personnel to implement and sustain MRSA surveillance and prevention efforts without compromising other IPC activities and (2) has the authority to implement preventive measures.
    2. Information technology systems that can (1) allow rapid notification of clinical staff and IPC personnel of new MRSA isolates, (2) collect data needed for MRSA surveillance and outcome measure calculations, and (3) identify MRSA-colonized patients on readmission.
    3. Sufficient supplies for hand hygiene, contact precautions (eg, gowns and gloves), environmental cleaning and disinfection, and other infection prevention interventions implemented as part of the facility’s MRSA control program.
    4. Resources to provide appropriate education and training to direct care providers and other HCP, patients, and visitors.
    5. Adequate laboratory support (eg, sufficient staffing and resources for routine clinical testing and for additional testing [ie, active surveillance] when necessary, timely provision of relevant data to clinicians and the infection prevention program).

## SECTION 4: RECOMMENDED STRATEGIES FOR PREVENTING MRSA TRANSMISSION AND INFECTION

Recommendations are categorized as either (1) basic practices that should be adopted by all acute care hospitals or (2) special approaches that can be considered for use in locations and/or populations within hospitals when HAIs are not controlled by use of basic practices. Basic practices include recommendations where the potential to impact HAI risk clearly outweighs the potential for undesirable effects. Special approaches include recommendations where the intervention is likely to reduce HAI risk but where there is concern about the risks for undesirable outcomes, where the quality of evidence is low, or where evidence supports the impact of the intervention in select settings (eg, during outbreaks) or for select patient populations. Hospitals

can prioritize their efforts by initially focusing on implementation of the prevention approaches listed as basic practices. If HAI surveillance or other risk assessments suggest that there are ongoing opportunities for improvement, hospitals should then consider adopting some or all of the prevention approaches listed as special approaches (see Figure 1). These can be implemented in specific locations or patient populations or can be implemented hospital-wide, depending on outcome data,

FIGURE 1. Approach to prevention of methicillin-resistant *Staphylococcus aureus* (MRSA) infection and transmission. CHG, chlorhexidine gluconate.

risk assessment, and/or local requirements. Each infection prevention recommendation is given a quality-of-evidence grade (see Table 1). These recommendations are primarily intended for the control of MRSA in the setting of endemicity; however, they may also be appropriate for epidemic or outbreak settings, with the exception of an accelerated time frame for implementation and the frequency at which outcomes are assessed. These recommendations should be considered complementary to other general infection prevention measures, such as CLABSI and VAP bundles. Of note, some of the interventions discussed here may have broader infection control applications, but the recommendations in this document are based on the evidence to support prevention of MRSA transmission and/or infection.

TABLE 1. Grading of the Quality of Evidence

Grade	Definition
I. High	Highly confident that the true effect lies close to that of the estimated size and direction of the effect. Evidence is rated as high quality when there is a wide range of studies with no major limitations, there is little variation between studies, and the summary estimate has a narrow confidence interval.
II. Moderate	The true effect is likely to be close to the estimated size and direction of the effect, but there is a possibility that it is substantially different. Evidence is rated as moderate quality when there are only a few studies and some have limitations but not major flaws, there is some variation between studies, or the confidence interval of the summary estimate is wide.
III. Low	The true effect may be substantially different from the estimated size and direction of the effect. Evidence is rated as low quality when supporting studies have major flaws, there is important variation between studies, the confidence interval of the summary estimate is very wide, or there are no rigorous studies, only expert consensus.

NOTE. Based on Grades of Recommendation, Assessment, Development, and Evaluation (GRADE)<sup>188</sup> and the Canadian Task Force on Preventive Health Care.<sup>189</sup>

- I. Basic practices for preventing MRSA transmission and infection: recommended for all acute care hospitals
  1. Conduct an MRSA risk assessment (quality of evidence: III).
    - a. The risk assessment should be attentive to 2 important factors: the opportunity for MRSA transmission and estimates of the facility-specific MRSA burden and rates of transmission and infection.
      - i. The opportunity for transmission is affected by the proportion of patients who are MRSA carriers and produce a risk for transmission. Estimates of facility-specific MRSA transmission and infection measure the ability of the facility's current activities to contain MRSA, regardless of the burden of MRSA that is imported into the facility.
      - ii. Both of these factors can be assessed either at the total hospital level or for specific hospital units.
    - b. Findings from the risk assessment should be used to develop the hospital's surveillance, prevention, and control plan and to develop goals to reduce MRSA acquisition and transmission.
    - c. The risk assessment also provides a baseline for subsequent assessments and other data comparisons (metrics that might be used in the MRSA risk assessment are discussed in greater detail in section 5).
  2. Implement an MRSA monitoring program (quality of evidence: III).
    - a. The MRSA monitoring program should have 2 goals:
      - i. Identify any patient with a current or prior history of MRSA to ensure application of infection prevention strategies for these patients according to hospital policy (eg, contact precautions).
      - ii. Provide a mechanism for tracking hospital-onset cases of MRSA for purposes of assessing transmission and infection and the need for response.
  3. Promote compliance with CDC or World Health Organization hand hygiene recommendations (quality of evidence: II).
    - a. Hand hygiene is a fundamental strategy for the prevention of pathogen transmission in healthcare facilities.
    - b. Patient-to-patient transmission of MRSA commonly occurs through transient colonization of the hands of HCP, and some investigators have attributed reduced rates of MRSA among hospital inpatients to efforts made to improve hand

hygiene practices.<sup>51,52</sup>

4. Use contact precautions for MRSA-colonized and MRSA-infected patients (quality of evidence: II).
  - a. Studies have demonstrated that HCP interacting with MRSA-colonized or MRSA-infected patients often become contaminated with the organism.<sup>53</sup> Similarly, studies in acute care hospitals have demonstrated that surfaces and objects in the patient's environment frequently and quickly become contaminated.<sup>54</sup> Placing patients with MRSA colonization or infection under contact precautions may help reduce patient-to-patient spread of MRSA within the hospital.<sup>45,55</sup>
  - b. Studies have suggested that patients may be persistent MRSA carriers for prolonged periods of time (median duration in one study, 8.5 months).<sup>56, 57</sup> Use of contact precautions for patients with a history of MRSA is recommended. The appropriate duration of contact precautions necessary for patients with MRSA, however, remains an unresolved issue
  - c. Several uncontrolled studies have reported conflicting results on whether patients in isolation are examined less frequently and for shorter periods compared with those not in isolation.<sup>58-60</sup> Additional studies have attempted to determine whether the use of contact precautions is associated with an increased incidence of adverse events.
    - i. Some studies have reported significantly increased rates of depression and anxiety among these patients,<sup>61,62</sup> however, a recent study suggests that patients requiring contact precautions have higher rates of depression and anxiety at admission.<sup>62</sup>
    - ii. In another study, patients isolated specifically for MRSA were more likely to experience preventable adverse events, such as pressure ulcers, falls, or electrolyte imbalances, compared with nonisolated patients without MRSA, but this retrospective chart review study may have been limited by unmeasured confounding factors.<sup>63</sup>
    - iii. Authors of these studies emphasized that additional studies are needed to confirm their findings.
    - iv. A cluster-randomized trial of universal glove and gown use in adult ICUs observed a significantly lower frequency of HCP visits per hour (4.28 vs 5.24;  $P = .02$ ) in intervention ICUs compared with ICUs using gowns and gloves only for patients known to be colonized or infected with antimicrobial-resistant organisms and as otherwise required for CDC-defined contact precautions.<sup>64</sup> The incidence of adverse events, however, was not significantly different between the 2 groups. In fact, rates of preventable, nonpreventable, severe, and not severe ICU adverse events were all nonsignificantly lower in the intervention group. Rates of hand hygiene were significantly higher in the universal glove and gown use group.
    - v. Some have also suggested that hospitals monitor adverse events potentially attributable to contact precautions and, more importantly, that hospital policy should ensure that patients who are placed under contact precautions receive the same quality of care as patients not under contact precautions.<sup>65</sup>
5. Ensure cleaning and disinfection of equipment and the environment (quality of evidence: II).
  - a. MRSA contaminates the patient's environment (eg, overbed tables, bedrails, furniture, sinks, and floors) and patient care equipment (eg, stethoscopes, blood pressure cuffs, etc).<sup>38,66-70</sup> MRSA contamination on surfaces around the patient zone varies in bioburden concentration.
  - b. Exposure to this contaminated environment has been associated with acquisition of MRSA.<sup>41,71-73</sup>
  - c. Cleaning and disinfection is part of the bundle of practices to prevent transmission. Objective monitoring has value to optimize effective environmental cleaning practices and techniques in healthcare settings.
6. Educate HCP about MRSA (quality of evidence: III).
  - a. Several key components of an effective MRSA prevention program involve modification of HCP behavior (eg, hand hygiene, environmental cleaning and disinfection).
  - b. HCP should be educated about their role in MRSA prevention and other MRSA-related topics as appropriate.
7. Implement a laboratory-based alert system that notifies HCP of new MRSA-colonized or MRSA-infected patients in a timely manner (quality of evidence: III).
  - a. Timely notification of new MRSA-positive test results to clinical caregivers and/or infection preventionists facilitates rapid implementation of contact precautions and other interventions as appropriate per facility policy, assessment of risk, and timely surveillance for hospital-associated infections.
8. Implement an alert system that identifies readmitted or transferred MRSA-colonized or MRSA-infected patients (quality of

evidence: III).

- a. An alert system allows information regarding the MRSA status of the patient to be available at the first point of contact (eg, emergency department arrival, presentation to admitting department), prior to bed assignment, to promptly initiate appropriate control measures and minimize opportunities for transmission.
  9. Provide MRSA data and outcome measures to key stakeholders, including senior leadership, physicians, nursing staff, and others (quality of evidence: III).
    - a. Provision of MRSA data and other information related to the activities of the MRSA prevention program to key stakeholders on a regular and frequent basis may optimize focus on MRSA prevention efforts and substantiate requests for resources and participation in the program. (See section 5 regarding suggested metrics for assessment of the MRSA prevention program.)
  10. Educate patients and their families about MRSA (quality of evidence: III).
    - a. Education of the patient and the patient's family about MRSA and recommended precautions may help to reduce patient and family anxiety related to precautions, the risk of developing symptomatic infection, and the risk of transmission to family and visitors; improve adherence to recommended practices and visitor policies; and improve patient satisfaction.<sup>74</sup>
    - b. Patient and family education should be provided as quickly as possible where the patient has a history of MRSA or once the patient's MRSA-positive status has been detected.
- II. Special approaches

Special approaches are recommended for use in locations and/or populations within the hospital that have unacceptably high MRSA rates despite implementation of the basic MRSA transmission and infection prevention strategies listed above. There are several controversial issues regarding prevention of MRSA transmission and infection. As a result, implementation of the recommendations beyond the basic practices should be individualized at each healthcare facility, unless there are legislative mandates that specifically require use of one or more special approaches (eg, AST). Facilities may consider a tiered approach in which recommendations are instituted individually or in groups; additional tiers are added if MRSA rates do not improve, with implementation of basic practices as the first tier. When selecting one or more special approaches for MRSA prevention, factors to consider include but are not limited to facility-specific epidemiology of MRSA, effectiveness of the intervention as demonstrated in published studies, cost, the availability of the required resources and the infrastructure needed to implement the intervention, potential adverse effects of the intervention, and other potential benefits that may result from the intervention (eg, potential for prevention of other, non-MRSA-related infections).

#### A. AST

1. Implement an MRSA AST program as part of a multifaceted strategy to control and prevent MRSA (quality of evidence: II).
  - a. AST is based on the premise that clinical cultures identify only a small proportion of hospital patients who are colonized with MRSA and that these asymptomatic carriers serve as a substantial reservoir for person-to-person transmission of MRSA in the acute care hospital.
    - i. Studies have reported that clinical cultures alone may underestimate the overall hospital prevalence of MRSA by as much as 85% and the monthly average prevalence of MRSA in ICUs by 18.6%–63.5%.<sup>29,75,76</sup>
    - ii. AST is used to identify these asymptomatic MRSA carriers so that additional infection control measures (eg, contact precautions, decolonization) can be put into place in an effort to decrease the risk of transmission to other patients and HCP.
  - b. The effectiveness of AST in preventing MRSA transmission and infection has been an ongoing area of controversy, and optimal implementation strategies (including the selection of target populations) are unresolved.
    - i. Several published studies of high-risk or high-prevalence populations (including those in outbreak settings) have shown an association between the use of AST and effective control of MRSA transmission and/or infection.<sup>77-82</sup>
    - ii. Not all studies, however, have come to the same conclusion,<sup>83,84</sup> including the single cluster-randomized trial of targeted MRSA active surveillance where active surveillance and use of barrier precautions in ICU patients was not associated with a reduction in MRSA colonization or infection, although limitations in the study design and suboptimal use of barrier precautions prevent definitive conclusions from being drawn.<sup>84</sup>
    - iii. A recently published comparative effectiveness review of MRSA screening strategies concluded that the strength

of evidence for the use of universal screening for prevention of healthcare-associated MRSA infections was low and that there was insufficient evidence to assess other outcomes associated with universal screening or to assess the comparative effectiveness of other MRSA screening strategies (eg, targeted screening).<sup>85</sup>

- c. Because of conflicting results from recently published studies and the low quality of evidence of many studies as well as differences among acute care hospitals and their associated patient populations, a definitive recommendation for universal screening for MRSA in all hospitals cannot be made.
  - d. AST, however, may be beneficial in hospitals that have implemented and optimized adherence to basic MRSA prevention practices but that continue to experience unacceptably high rates of MRSA transmission or infection.
2. Screen HCP for MRSA infection or colonization if they are epidemiologically linked to a cluster of MRSA infections (quality of evidence: III).
    - a. HCP can become transiently or persistently colonized with MRSA, and this has been determined to be the source of several hospital outbreaks.
    - b. Routine screening of HCP for MRSA is not currently recommended in the endemic setting.
    - c. Screening of HCP can be an important component of an outbreak investigation if HCP have been epidemiologically linked to a cluster of new MRSA cases or if there is continued evidence of transmission despite comprehensive implementation of basic MRSA control measures.<sup>86</sup>
    - d. See section B.1 below and the section on implementation for discussion of targeted decolonization therapy regimens that could be used for the treatment of MRSA-colonized HCP.

#### B. MRSA decolonization therapy

MRSA decolonization therapy can be defined as the administration of topical antimicrobial or antiseptic agents, with or without systemic antimicrobial therapy, for the purpose of eradicating or suppressing the carrier state. MRSA decolonization can be targeted to MRSA-colonized persons or applied universally to populations deemed to be at high risk for infection. Several studies have shown the benefit of decolonization in reducing MRSA carriage, transmission, and subsequent infection in patients known to carry MRSA or to be at risk for MRSA acquisition and/or infection.

Complications of decolonization therapy are relatively uncommon; however, potential adverse effects, such as development of resistance or reduced susceptibility to the agents used (eg, mupirocin and chlorhexidine) and drug-related toxicities, should be considered when a healthcare facility is determining whether to implement an MRSA decolonization program.<sup>87-89</sup> Several different approaches to decolonization therapy have been studied to assess their impact on preventing a variety of MRSA-related outcomes.

1. Provide targeted decolonization therapy to MRSA-colonized patients in conjunction with an AST program (quality of evidence: II).
  - a. The use of MRSA decolonization therapy in conjunction with AST may be a useful adjunctive measure for prevention of MRSA transmission within a hospital.
    - i. One group of investigators observed a 52% reduction in incident cases of MRSA (ie, MRSA isolated from a sample obtained from a patient without a previous history of MRSA more than 48 hours after admission to the ICU) among adult ICU patients after the introduction of a decolonization regimen of intranasal mupirocin (twice daily for 5 days) and bathing with chlorhexidine (daily for 7 days) for all MRSA-colonized patients.<sup>90</sup>
  - b. Targeted decolonization therapy has also been a component of several successful MRSA outbreak control programs.<sup>91-93</sup>
  - c. The optimal decolonization therapy regimen has not been determined. Most experience has been with the intranasal use of 2% mupirocin with or without chlorhexidine bathing.
  - d. Targeted decolonization therapy has also been used in certain patient populations in an attempt to reduce the risk of subsequent *S. aureus* infection among colonized persons.
    - i. These populations have included dialysis patients, patients with recurrent *S. aureus* infections, and patients undergoing certain surgical procedures.<sup>94-99</sup>
  - e. Decolonization therapy for the prevention of SSI is discussed in the SSI section of the Compendium.<sup>100</sup> Further discussion of this topic is beyond the scope of this document.
2. Provide universal decolonization to ICU patients (quality of evidence: I).

- a. Recent studies have demonstrated that universal decolonization of adult ICU patients may reduce the burden and transmission of MRSA. In contrast to targeted decolonization of MRSA carriers, this practice focuses on high-risk patient populations through horizontal rather than vertical pathogen-directed strategies and does not rely on AST to identify carriers.
    - i. This approach has been studied mostly in ICU settings.
    - ii. Universal decolonization using daily chlorhexidine bathing alone and in combination with mupirocin has been studied, and these 2 approaches are discussed in more detail below.
  - iii. Chlorhexidine is active against a range of gram-positive and gram-negative bacteria as well as *Candida*. The effect of chlorhexidine on transmission of bacterial pathogens is likely due to a reduction in the burden of organisms on colonized or infected patients' skin with a subsequent reduction in contamination of environmental surfaces and the hands of healthcare workers.<sup>101</sup>
  - iv. Universal decolonization has been shown to have other potential benefits, such as reducing rates of CLABSI, overall BSIs, and environmental contamination with and acquisition of VRE.<sup>101-108</sup> Use of universal decolonization for the prevention of CLABSI is discussed in the CLABSI section of the Compendium.<sup>109</sup>
  - v. Further discussion of other potential benefits of universal decolonization therapy is beyond the scope of this document.
- b. Universal decolonization of adult ICU patients with daily chlorhexidine bathing.
    - i. Observational studies have shown that routine cleansing of adult ICU patients with chlorhexidine, rather than regular soap, may decrease the incidence of patient acquisition of MRSA.<sup>103,108,110,111</sup>
    - ii. A recent multicenter, cluster-randomized, nonblinded crossover trial conducted in 9 intensive care and bone marrow transplant units found a significant 23% reduction in the combined outcome of MRSA and vancomycin-resistant *Enterococcus* (VRE) acquisition with daily chlorhexidine bathing, although this was driven largely by a reduction in VRE acquisition (25% reduction) with a statistically nonsignificant 19% reduction in acquisition of MRSA.<sup>105</sup> There was also a significant 28% decrease in healthcare-acquired primary BSI; however, possibly because of low numbers of infections due to the organism, there was no significant decrease in MRSA BSI. Also of note, the effect of chlorhexidine bathing seemed to confer greater benefit to patients with a longer length of stay. This study also assessed MRSA strains collected over the study period and found no high-level chlorhexidine resistance.
    - iii. Limited data are available on the use of chlorhexidine for routine patient cleansing for prevention of MRSA outside the adult ICU setting.<sup>112</sup>
  - c. Universal decolonization of adult ICU patients with daily chlorhexidine bathing and intranasal mupirocin.
    - i. A recent cluster-randomized clinical trial conducted in 74 adult ICUs compared outcomes associated with 3 strategies of MRSA control: (1) active surveillance for MRSA with isolation of colonized patients, (2) active surveillance with targeted decolonization of MRSA carriers with topical chlorhexidine and intranasal mupirocin for 5 days, and (3) universal decolonization of all ICU patients with intranasal mupirocin for 5 days and topical chlorhexidine daily for the entire ICU stay without performance of AST.<sup>106</sup>
    - ii. This study found that treating all patients with daily chlorhexidine baths plus 5 days of intranasal mupirocin significantly reduced MRSA-positive clinical cultures attributed to the ICU (an outcome representing a combination of MRSA infection and colonization) by 37% compared with AST and isolation alone (ie, without any type of decolonization therapy).<sup>106</sup>
    - iii. Additionally, a significant reduction in overall BSIs (hazard ratio, 0.56 [95% confidence interval, 0.49–0.65]) and a statistically nonsignificant reduction in MRSA BSIs (hazard ratio, 0.72 [95% confidence interval, 0.48–1.08]) was observed in the universal decolonization group.
    - iv. A potential advantage to the inclusion of mupirocin in a universal decolonization regimen is that mupirocin targets the nasal reservoir of *S. aureus*, which is the most common healthcare-associated pathogen when both MRSA and MSSA are considered.<sup>3</sup>
    - v. A risk, however, is for development of mupirocin resistance with widespread, nonselective use of this agent, as has been described. One study reported that in the 3 years after increased use of mupirocin as an adjunct infection control measure during an epidemic of MRSA there was a marked increase in mupirocin resistance among

MRSA isolates.<sup>87</sup>

- vi. There has not yet been a direct comparison of chlorhexidine alone and chlorhexidine plus mupirocin for universal decolonization.
  - d. Of note, a few quasi-experimental single-center studies in neonatal ICUs have shown a benefit of universal decolonization with topical mupirocin alone in the control of MRSA outbreaks and endemic MRSA disease.<sup>93,113</sup> Outside of neonates, universal decolonization has not been studied in hospitalized children.
- C. Use of gowns and gloves for all contact with patients and the patient care environment
1. Use gowns and gloves when providing care to or entering the room of adult ICU patients (quality of evidence: II).
    - a. A cluster-randomized trial conducted in 20 adult medical and surgical ICUs compared the effect of universal glove and gown use for all patient contact and when entering any patient room with standard practice (ie, the use of gowns and gloves only for patients known to be infected or colonized with antimicrobial-resistant organisms) on the rate of acquisition of antimicrobial resistant gram-positive organisms and healthcare-associated infections.<sup>64</sup> Although the investigators found no difference between the 2 arms in the primary outcome of acquisition of either MRSA or VRE, there was a significantly greater relative reduction in the prespecified secondary outcome of MRSA acquisition in intervention units compared with control units (40.2% vs 15%; *P* .046).
    - i. In addition to the use of gowns and gloves, a lower frequency of HCP visits (4.28 vs 5.24 per hour; *P* .02) and higher hand hygiene compliance (78.3% vs 62.9% on exit; *P* .02) in the intervention arm compared with the control arm may have played a role in the observed difference in MRSA acquisition between the 2 groups.
    - ii. There are a number of potential explanations for the reduction in MRSA acquisition that was observed in the absence of a reduction in VRE acquisition. First, it is possible that HCP contamination played a more important role in the transmission of MRSA than of VRE in the study units. Second, intervention units had a higher baseline rate of MRSA acquisition than control units, suggesting the possibility that regression to the mean contributed to the findings. However, intervention units also had a higher admission prevalence of MRSA and the results remained statistically significant after adjusting for the admission prevalence of MRSA. Because of these uncertainties, the study authors concluded that the findings should be considered hypothesis generating and that replication is needed.

### III. Unresolved issues

There are a number of unresolved issues related to MRSA and its transmission. A full discussion of these issues is beyond the scope of this document, but a brief mention of some of these important topics is worthwhile.

1. *Antimicrobial stewardship*. The impact of antimicrobial stewardship efforts on the risk of MRSA infection and transmission has not been clearly defined.
2. *Universal MRSA decolonization*. Additional study is needed to determine the incremental benefit of the addition of mupirocin to daily chlorhexidine bathing and to further assess the use of this strategy outside the ICU.
3. *Mupirocin and chlorhexidine resistance*. The risk for development of resistance to mupirocin and/or chlorhexidine as they become more widely used is currently unknown, although some centers have reported increased rates of resistance.<sup>87-89</sup>
4. *Universal glove and gown use*. Although this approach was evaluated using a high-quality study design and conducted in a rigorous manner, replication of the findings in other studies and settings, assessment of the impact of this intervention on acquisition of other multidrug-resistant organisms (MDROs), and assessment of the incremental benefit of the addition of this intervention to other interventions (eg, universal decolonization) would provide useful information.<sup>64</sup>
5. *MRSA-colonized HCP*. The optimal use of AST to identify asymptomatic carriage of MRSA among HCP and the optimal management (eg, decolonization therapy, follow-up monitoring) of MRSA-colonized HCP have not been definitively determined.
6. *MRSA among close contacts*. Further study of the epidemiology and prevention of MRSA among family members and other close contacts of persons colonized or infected with MRSA is needed. Recent studies suggest that household members are more likely to carry MRSA than the general population and that multiple strains may circulate in

households.<sup>95,114</sup>

7. *Epidemiology and impact of community-acquired MRSA*. The emergence of CA-MRSA has further complicated the epidemiology of MRSA in healthcare facilities and has generated new questions related to MRSA prevention in hospitals. One study reported that even though there was an increasing proportion of patients found to be colonized with CA-MRSA strains at admission, there was no difference in the risk of developing subsequent MRSA infection dependent on whether the MRSA was community or hospital associated.<sup>16</sup> Another study has found that the CA-MRSA strain does not produce more severe pneumonia or CLABSI infection in hospitalized patients.<sup>30</sup> Nevertheless, further studies are needed to explore strain-specific effects on disease and transmission.
  - a. *Detection of carriers of CA-MRSA*. Current approaches that are largely based on the epidemiology of hospital-associated MRSA (HA-MRSA) may be suboptimal, given differences in risk factors for colonization and the presence of some evidence that suggests that there are differences in the predominant sites of colonization compared with HA-MRSA.
  - b. *Differences in antimicrobial susceptibility and, potentially, virulence between typical HA-MRSA and CAMRSA*. Organism characteristics (eg, antimicrobial susceptibility, virulence determinants) of individual patient MRSA isolates may need to be considered when it becomes necessary to cohort patients with MRSA colonization or infection.
8. These and other aspects of MRSA transmission and control require further investigation.

## SECTION 5: PERFORMANCE MEASURES

### I. Internal reporting

The performance measures described here are intended to support internal hospital quality improvement efforts and do not necessarily address external reporting needs. The process and outcome measures suggested here are derived from published guidelines and other relevant literature. A more detailed description of outcome measures that may be useful for MRSA transmission and infection prevention programs is available in a position paper published in 2008 by SHEA and HICPAC.<sup>44</sup>

#### A. Process measures

Process measures can be used to assess compliance with various components of an MRSA prevention program. Such measures may include compliance with basic practices, such as hand hygiene and contact precautions (eg, use of gown and gloves), as well as compliance with special practices that have been implemented by the hospital (eg, daily bathing with chlorhexidine, AST).

#### B. Outcome measures

In 2008, SHEA and HICPAC published recommendations for monitoring MDROs in healthcare settings.<sup>44</sup> These recommendations are applicable to MRSA as well as other MDROs. That position paper describes the following basic MRSA outcome measures for all acute care hospitals:

1. MRSA-specific line lists (eg, electronic databases) for tracking patients who have MRSA;
2. Annual antibiograms for monitoring antimicrobial susceptibility patterns (eg, rates of methicillin resistance) among isolates recovered from patients;
3. Estimates of the MRSA infection burden that use objective, laboratory-based metrics, such as the incidence (or incidence density) of hospital-onset MRSA bacteremia; and
4. Proxy measures of healthcare-acquisition of MRSA, such as incidence (or incidence density) of hospital-onset MRSA based on clinical culture data.

Supplemental/advanced outcome measures that acute care hospitals can consider utilizing include additional measures of the burden of healthcare-associated infection (eg, incidence or incidence density of hospital-associated MRSA infections), estimates of burden of MRSA exposure within the facility (eg, rates of overall and admission MRSA prevalence, point prevalence), and the burden of hospital-associated acquisition of MRSA (eg, incidence of hospital-onset MRSA based on clinical culture data and AST data). In calculating these outcome measures, guidelines recommend careful consideration of how duplicate isolates from the same patient during the selected surveillance period will be handled. Of note, duplicate isolates may be handled differently depending on the metric being calculated. For example, when creating antibiograms, the Clinical and Laboratory Standards Institute guidelines<sup>115</sup> recommend that “only the first isolate recovered from a patient during a surveillance period

should be included,” whereas current definitions for a laboratory-identified event and clinical infection surveillance address duplicates somewhat differently.<sup>42,43</sup> More specific details regarding these metrics (eg, definitions, methods of calculation) are available in the original SHEA/HICPAC position paper.<sup>44</sup> In addition to calculating outcome measures locally, hospitals that report MRSA data to the CDC’s NHSN Multidrug Resistant Organism and *C. difficile* Infection (MDRO/CDI) Module have the option of having a number of outcome measures calculated automatically using the NHSN system.<sup>42</sup> The metrics included in this NHSN module are similar to some of those described in the SHEA/HICPAC position paper.<sup>44</sup> Relative to MRSA, certain outcome measures are available to hospitals that submit only bloodstream isolate data (eg, hospital-onset MRSA BSI incidence), while additional outcome data are available to those who submit information regarding MRSA isolates from other clinical specimens or from AST.

## II. External reporting

External reporting of healthcare-associated MRSA-related data has become more common in recent years. For example, in January 2013 the Centers for Medicare & Medicaid Services (CMS) Hospital Inpatient Quality Reporting Program began requiring acute care hospitals to report hospital-wide inpatient MRSA bloodstream isolates via the CDC’s NHSN (MDRO/CDI) Module.<sup>116</sup> These data will be made publicly available and will be one of several quality indicators used in the CMS Inpatient Prospective Payment System value-based purchasing program. Other examples include The Joint Commission’s National Patient Safety Goals and the CMS Conditions of Participation for Hospitals, which both define expectations for MDRO surveil-

lance and prevention.<sup>117,118</sup> Specific recommendations for external reporting of process and outcome measures, other than adherence to mandated reporting requirements, cannot be made for several reasons: (1) the current absence of standardized definitions, surveillance methodology, and data validation; (2) the inability to reliably ascertain the specific time and location when MRSA was acquired; and (3) the potential for unintended consequences.

TABLE 2. Fundamental Elements of Accountability for Healthcare-Associated Infection Prevention

---

Senior management is responsible for ensuring that the healthcare system supports an infection prevention and control (IPC) program that effectively prevents healthcare-associated infections (HAIs) and the transmission of epidemiologically important pathogens

Senior management is accountable for ensuring that an adequate number of trained personnel are assigned to the IPC program and adequate staffing of other departments that play a key role in HAI prevention (eg, environmental services)

Senior management is accountable for ensuring that healthcare personnel, including licensed and nonlicensed personnel, are adequately trained and competent to perform their job responsibilities

Direct healthcare providers (such as physicians, nurses, aides, and therapists) and ancillary personnel (such as environmental service and equipment processing personnel) are responsible for ensuring that appropriate IPC practices are used at all times (including hand hygiene, standard and isolation precautions, and cleaning and disinfection of equipment and the environment)

Senior and unit leaders are responsible for holding personnel accountable for their actions

IPC leadership is responsible for ensuring that an active program to identify HAIs is implemented, that HAI data are analyzed and regularly provided to those who can use the information to improve the quality of care (eg, unit staff, clinicians, and hospital administrators), and that evidence-based practices are incorporated into the program

Senior and unit leaders are accountable for ensuring that appropriate training and educational programs to prevent HAIs are developed and provided to personnel, patients, and families

Personnel from the IPC program, the laboratory, and information technology departments are responsible for ensuring

---

that systems are in place to support the surveillance program

## SECTION 6: EXAMPLES OF IMPLEMENTATION STRATEGIES

Accountability is an essential principle for preventing HAIs. It provides the necessary translational link between science and implementation. Without clear accountability, scientifically based implementation strategies will be used in an inconsistent and fragmented way, decreasing their effectiveness in preventing HAIs. Accountability begins with the chief executive officer and other senior leaders who provide the imperative for HAI prevention, thereby making HAI prevention an organizational priority. Senior leadership is accountable for providing adequate resources needed for effective implementation of an HAI prevention program. These resources include necessary personnel (clinical and nonclinical), education, and equipment (Table 2).

In addition to the examples provided below, please refer to the appendix for a more detailed discussion of factors to consider during the implementation of an MRSA AST program. Guidance for the implementation of an effective hand hygiene program is available in the Compendium's section on strategies for optimizing hand hygiene.<sup>119</sup>

## I. Engage

- A. Collaborate with representatives from departments and groups appropriate for the strategy being implemented  
(eg, hospital administration, nursing staff, medical staff, environmental services/housekeeping, facilities management, procurement, clinical laboratory, admitting and bed assignment department, case management, human resources, risk management, community and/or patient education specialists, and information technology).
- B. Include opinion leaders, role models, and unit champions.
- C. Consultation with a trained individual with expertise in MRSA control and prevention may be useful for program development and assessment if such a person is not available within the hospital.
- D. Engage executive leadership on the basis of clinical outcome data, public reporting requirements (eg, CMS-required reporting of hospital-onset MRSA bacteremia, state-level MRSA-related legislation [<http://www.apic.org/Advocacy/Legislative-Map>]), and locally determined return on investment calculations.

## II. Educate

- A. Provide an educational program to foster desired behavior changes and include a discussion of MRSA risk factors, routes of transmission, outcomes associated with infection, prevention measures (and the evidence supporting their use), local MRSA epidemiology (MRSA infection rates, etc), the potential adverse effects of contact isolation, roles that HCP play in MRSA prevention, and current data regarding HCP compliance with IPC measures.<sup>120</sup>
- B. Target educational programs on the basis of HCP needs (ie, healthcare practitioner, support personnel). Given the wide range of educational backgrounds and job descriptions among hospital personnel, several educational programs will be needed to provide the necessary information at the appropriate level for all relevant personnel.
- C. Provide evidence that supports use of selected strategies.
- D. Education may be accomplished via unit-based and other meetings (eg, case management, patient safety, laboratory, etc), Internet-based training resources, newsletters, communication board postings on inpatient units, and other communication means. Provide HCP education using coaching sessions, one-on-one engagement, specific patient scenarios, and so on as appropriate.
- E. Provide standardized educational materials, such as guidelines, templates, observation tools, skills training, scripting, and soon.
- F. External educational resources for HCP include but are not limited to the following:
  - 1. Centers for Disease Control and Prevention: [http:// www.cdc.gov/mrsa/healthcare/clinicians/index.html](http://www.cdc.gov/mrsa/healthcare/clinicians/index.html)
  - 2. Agency for Healthcare Research and Quality: [http:// www.ahrq.gov/health-care-information/topics/topic-mrsa.html](http://www.ahrq.gov/health-care-information/topics/topic-mrsa.html)

## III. Execute

- A. MRSA monitoring program
  - 1. A common detection strategy used by IPC programs to identify and track patients from whom MRSA has been isolated from any clinical or AST specimen includes a daily review of laboratory results to identify patients from whom MRSA has been isolated.
  - 2. A common method of tracking MRSA is a line list.
    - a. The line list includes each patient's first (and often subsequent) MRSA isolate, regardless of body site, and includes isolates identified by clinical cultures and AST, when available.
    - b. Initial isolates as well as subsequent clinical infections should be classified as either hospital or community onset using prespecified definitions (see section 2).

- c. In addition, patients known to be MRSA colonized or infected on the basis of testing performed at another healthcare facility should be included in the linelist.
  - d. Additional information commonly contained in the line list includes date of collection of specimen from which MRSA was isolated, site from which specimen was obtained, and hospital location at time of collection.
  - e. Ideally, the line list is an electronic database that is integrated into relevant hospital data systems (eg, the ADT [admission, discharge, transfer] data).
- B. Contact precautions
- 1. Place patients in a single or private room when available.
  - 2. Cohorting of MRSA patients is acceptable when a single or private room is not available.
    - a. Cohorting does not eliminate the need for compliance with hand hygiene and other infection prevention measures between patient contacts.
  - 3. Don gown and gloves on entry into the patient's room, and remove gown and gloves before exiting the room.
  - 4. HCP should have a thorough understanding of the benefits and potential adverse effects associated with the use of contact precautions.
    - a. Patients placed under contact precautions should continue to receive the same level and quality of care as those who are not under contact precautions.
  - 5. Dedicate noncritical patient care items, such as blood pressure cuffs, stethoscopes, and so on, to a single patient when they are known to be colonized or infected with MRSA. When equipment must be shared among patients, clean and disinfect the equipment between patients.
  - 6. Establish institutional criteria for discontinuation of contact precautions.
    - a. A single negative surveillance test may not adequately detect persistence of MRSA colonization. A reasonable approach to subsequent discontinuation would be to document clearance of the organism with 3 or more surveillance tests in the absence of antimicrobial exposure.<sup>45</sup> When to consider retesting MRSA patients to document clearance is debatable, but waiting at least a few months (eg, 4–6 months) since the last positive test is often advised. Some hospitals may choose to consider MRSA-colonized patients to be colonized indefinitely.
- C. Cleaning and disinfection
- 1. Current guidelines outline environmental and equipment disinfection and sterilization standards.<sup>55,121,122</sup>
  - 2. Develop written protocols for daily and terminal cleaning and disinfection of patient rooms. Protocols should address the type of equipment or surface, persons responsible for performing the tasks, frequency, disinfectant product appropriate to the device or surface, and required contact time to achieve effective disinfection.
  - 3. Pay close attention to cleaning and disinfection of high-touch surfaces in patient care areas (eg, bed rails, carts, bedside commodes, doorknobs, and faucet handles).
  - 4. Disinfect portable, reusable healthcare equipment after each use.
  - 5. The use of supplemental disinfection methods, such as hydrogen peroxide vapor and UV light, and antimicrobial surfaces has been shown in some nonrandomized studies to have potential benefit in reducing the burden of organisms in the healthcare environment. However, these additional technologies are costly, and their clinical effectiveness has not yet been demonstrated by high-quality studies.<sup>123-125</sup> It should be noted that these methods, if used, should be used as supplements to but not as replacements for routine cleaning and disinfection.
- D. Alert systems: laboratory alerts for new MRSA-positive patients and alerts to identify MRSA-positive patients on readmission or transfer<sup>126-128</sup>
- 1. Patients with newly identified MRSA
    - a. A commonly used manual system includes an immediate phone call from the laboratory to the patient's caregiver or nursing unit.
    - b. The laboratory-based manual alerting system may also include immediate notification of IPC staff via fax, phone, pager, e-mail, or notification in electronic medical record (EMR) or electronic surveillance system.
  - 2. Readmission or intrafacility transfer of patients with MRSA
    - a. Manual or computer-based databases of patients' MRSA status may be used to identify known MRSA-positive patients at the time of readmission and bed assignment. A designated field in the EMR may be used to indicate a patient's MRSA-positive status.

- b. The receiving unit should be notified of the patient's MRSA-positive status prior to the patient's arrival in the unit.
  - c. The alert should remain in effect until the facility's MRSA clearance criteria have been met.
3. Interfacility transfer of patients with MRSA
- a. A patient's MRSA-positive status should be communicated to a receiving healthcare facility prior to the patient's transfer.
  - b. Collaborate with nursing, discharge planning, and case management to include relevant infection control data, such as MRSA infection or colonization, on communication tools.
  - c. Create an infection prevention interfacility transfer tool, such as the one developed by the CDC: <http://www.cdc.gov/HAI/toolkits/InterfacilityTransferCommunicationForm11-2010.pdf>.
  - d. When receiving patients in transfer from another healthcare facility, require the transferring healthcare facility to provide MRSA status information and other relevant infection control information during the transfer handoff communication process.
- E. Educate patients and their families about MRSA
- 1. Provide standardized information about MRSA and contact precautions. Methods of information dissemination might include patient education sheets in appropriate languages, patient education channels, websites, or video presentations. A member of the care team should assess the patient's understanding and answer specific questions that remain.
  - 2. Include information that addresses concerns and anticipates questions, such as general information about MRSA, the difference between colonization and infection, the hospital's MRSA prevention program, the components of and rationale for contact precautions, and the risk of transmission to family and visitors.<sup>74,129</sup>
  - 3. To alleviate MRSA-related concerns that remain after patient discharge, provide education and helpful tips about managing MRSA in the home setting.<sup>130</sup>
  - 4. Determine whether educational materials will be developed by facility personnel or obtained from an external resource (eg, professional societies, public health authorities, and commercial vendors). Some external resources related to MRSA patient education include the following:
    - a. <http://www.cdc.gov/mrsa/healthcare/patient/index.html>
    - b. <http://www.cdc.gov/mrsa/community/posters/index.html>
    - c. [http://www.shea-online.org/Assets/files/patient%20guides/NNL\\_MRSA.pdf](http://www.shea-online.org/Assets/files/patient%20guides/NNL_MRSA.pdf)
    - d. <http://www.health.state.mn.us/divs/idepc/diseases/mrsa/book.pdf>

F. AST among patients

Please refer to the appendix for a more detailed discussion of the issues outlined below.

- 1. Select the patient population that will be included in the screening program (eg, all patients or only high-risk patients or patients in high-risk units).
- 2. Develop a reliable system to identify patients who meet the criteria for screening.
- 3. Determine how screening specimens will be ordered (eg, standardized nursing protocol, admission order set, or individual patient order), who will initiate the order (eg, physician or nurse), and who will obtain the specimens (eg, unit-based nursing personnel, designated MRSA monitoring program personnel, or patient).
- 4. Determine when screening will be performed.
- 5. Determine the anatomic sites that will be sampled.
- 6. Select the laboratory method that will be used to detect MRSA.
- 7. Determine how to manage patients while awaiting the results of screening tests.
- 8. Assess the availability of single rooms and develop a plan and protocol for situations in which the number of single rooms is insufficient.<sup>45,55</sup> When there is not a sufficient number of single rooms, the following options may be considered:
  - a. Prioritize patients with MRSA who are at greater risk for transmission (eg, those with draining wounds) for a single room.
  - b. Cohort MRSA-colonized or MRSA-infected persons (ie, group multiple MRSA-positive patients in the same room). Ideally, MRSA patients who are cocolonized or coinfecting with other MDROs should not be cohorted with other MRSA patients unless those patients are also cocolonized or coinfecting with the same organism(s).

- c. When neither placement in a single room nor cohorting with another patient with MRSA is possible, options include keeping the patient with the existing roommate or identifying a low-risk patient with whom the MRSA-positive patient can share a room and keeping the patients physically separated (eg, keep privacy curtains drawn).<sup>55</sup>

#### G. AST among HCP

1. Select HCP to be included in a screening program on the basis of epidemiologic findings.
  - a. Consideration should be given to testing epidemiologically linked personnel when transmission continues despite implementation of basic control measures.
2. HCP may serve as a primary source of MRSA in a healthcare-associated outbreak<sup>131-133</sup> (ie, active MRSA infection or persistent colonization with transmission to patients) or as a vector<sup>134-136</sup> (secondary source) of transmission (ie, transient MRSA colonization of a provider with transmission between patients). It is important to be aware of these distinctions, as it may affect the selection of management options.
3. Data on optimal anatomic sites for screening among HCP are not readily available. There is no evidence to suggest that anatomic screening sites among personnel should be different than those sampled in patients for the purpose of detecting colonization (see the appendix). Many published reports of MRSA outbreak investigations that included AST of HCP sampled the nares to detect colonization. Some reports sampled other sites, either alone or in addition to the nares, including the fingertips, the skin (areas of dermatitis), the perineum, and the pharynx.<sup>137</sup>
4. The timing of collection of screening specimens may impact the results of HCP screening. Screening during or at the end of a work shift may identify transiently colonized HCP in addition to persistently colonized HCPs who may be a source of ongoing transmission.<sup>138</sup> Thus, collection of specimens at the beginning of a shift or after several days away from the clinical setting may optimize the specificity of testing.
5. Considerations regarding optimal laboratory tests for detection of MRSA carriage are discussed in the appendix.
  - a. Molecular testing (eg, pulse-field gel electrophoresis) to establish clonality of MRSA isolates has been useful in some investigations.<sup>131,139-142</sup>
  - b. Ideally, molecular analysis of MRSA isolates should be performed to determine whether patient isolates and isolate(s) obtained from HCP(s) are related.
6. Determine how to manage personnel who are identified as an ongoing primary or secondary source of MRSA transmission.
  - a. Develop a facility policy to manage HCP who are either infected or colonized with an outbreak strain of MRSA in a standard fashion. Most published reports of MRSA transmission from colonized HCP have indicated that transmission was interrupted after the introduction of several simultaneous interventions.<sup>133,137</sup> There are no controlled studies that examine the specific impact of isolated interventions on interrupting HCP to patient transmission of MRSA. Thus, there are no evidence-based recommendations for the management of MRSA-colonized HCP who have been associated with ongoing MRSA transmission within a healthcare facility. Consideration of the MRSA-colonized HCP's specific job-related activities may help to determine the course of action. Interventions that may be considered include the following:
    - i. Evaluate the MRSA-colonized HCP's infection prevention practices for opportunities for education and improvement. For example, in one report a healthcare worker with chronic sinusitis linked to a cluster of MRSA cases was identified as a carrier of the outbreak strain, and breaches in recommended infection control practices were identified.<sup>132</sup>
    - ii. Ensure appropriate treatment of active MRSA infection.
    - iii. Decolonization therapy may be considered for personnel with persistent MRSA colonization. Refer to the discussion of decolonization therapy below for more details on decolonization therapy.
    - iv. HCP work restrictions have been used as a part of outbreak management in some but not all reports. Work restrictions include approaches such as furlough, restriction from patient care activities, and temporary reassignment. Work restrictions have been used for some but certainly not all MRSA-colonized HCP who have been sources of ongoing MRSA transmission. Other approaches that have been used successfully include education and implementation of additional infection control measures.

#### H. Decolonization therapy

1. Select the population(s) to be included in the decolonization therapy protocol and determine which decolonization strategy will be used.
  - a. Targeted decolonization of MRSA-positive patients who have been identified through AST or clinical cultures using intranasal mupirocin with or without daily bathing with chlorhexidine.<sup>90,143</sup>
  - b. Universal decolonization of all patients in high-risk units as identified in the MRSA risk assessment using daily bathing with chlorhexidine with or without intranasal application of mupirocin.<sup>103,106,108,110</sup> A detailed protocol for implementation of universal decolonization is available at [http://www.ahrq.gov/professionals/systems/hospital/universal\\_icu\\_decolonization/index.html](http://www.ahrq.gov/professionals/systems/hospital/universal_icu_decolonization/index.html).
2. Consider developing standardized or protocol-based order sets to optimize compliance.
3. Standardize care processes.
  - a. Determine the method of chlorhexidine application. A variety of chlorhexidine products that could be used for patient bathing are available. These include single-use bottles of aqueous chlorhexidine that can be added to a basin of water or applied in the shower and 2% no-rinse chlorhexidine-impregnated cloths. It should be noted that the use of undiluted no-rinse 4% aqueous chlorhexidine solution for skin cleansing has been associated with a relatively high rate of reversible adverse skin effects (eg, skin fissures, itching, and burning of the skin).<sup>143</sup> In contrast, lower skin concentrations of chlorhexidine are inversely associated with bacterial microbial density on the skin, suggesting a benefit for ensuring that application achieves effective microbicidal skin concentrations.<sup>144</sup> Issues to consider when selecting among chlorhexidine products may include available supporting clinical data, cost, ease of use, and consistency of application.
  - b. When using a chlorhexidine-containing product, the manufacturer's recommendations should be followed. These recommendations include avoidance of direct contact with nervous tissue, including direct contact with the eyes and middle ear (eg, in patients with perforated tympanic membranes). Chlorhexidine is widely used in children less than 2 months old.<sup>145</sup> For chlorhexidine gluconate-based topical antiseptic products, the Food and Drug Administration recommends "use with care in premature infants or infants under 2 months old; these products may cause irritation or chemical burns." Concerns in children less than 2 months old include skin irritation and systemic absorption following topical exposure, events that may be more likely in preterm infants.<sup>146</sup> Providers must carefully weigh the potential benefit in preventing MRSA related-outcomes in children less than 2 months old and the risks of CHG, recognizing that term and preterm infants may have different risks.<sup>105,107</sup>
  - c. Provide physical barriers to prevent chlorhexidine solution from depositing onto linens to minimize staining when linens come in contact with bleach oxidizers during commercial laundering.
  - d. If the decolonization regimen will include intranasal application of mupirocin, determine how mupirocin will be provided (eg, in single-dose or multidose tubes).
4. Ensure adequate supplies of products used for decolonization (eg, chlorhexidine bottles or cloths) to reduce barriers to implementation.
5. Review chlorhexidine compatibility of patient hygiene and skin care products and remove incompatible products that are used on the body below the neckline.

#### IV. Evaluate

- A. Assess compliance with infection prevention practices, such as hand hygiene, gown and glove use, appropriate room placement, environmental cleaning and disinfection protocols, AST protocol (when applicable), and decolonization protocols (when applicable).<sup>41,45,71,118,147,148</sup>
- B. Review and update educational materials when there are changes in process; when indicated based on feedback from healthcare staff, patient, and families; when new clinical data become available; and per facility policies for recurring review.
- C. Monitor MRSA outcomes.
  1. For further discussion of monitoring MRSA outcomes, please refer to section 5, where performance measures are discussed.
  2. Additional resources related to MRSA outcome measures include the following:

- a. The CDC NHSN (MDRO/CDI) Module<sup>42</sup>
  - b. SHEA/HICPAC's position paper on recommendations for metrics for multidrug-resistant organisms in healthcare settings<sup>44</sup>
- D. Provide healthcare providers and hospital leadership with feedback regarding MRSA-related process and outcomes measures.
  - E. If decolonization is included in the MRSA prevention program, consider monitoring for the development of resistance to the agents used for decolonization (eg, mupirocin).
  - F. If AST among HCP is performed, then the following should be done:
    1. Assess HCP compliance with recommended screening.
    2. For personnel determined to be a vector or source of MRSA outbreak, assess for compliance with the recommended prevention strategy (eg, infection control practices, decolonization therapy).
    3. Assess for changes in the incidence of MRSA that are temporally associated with identification and management of colonized HCP.
    4. If decolonization therapy is administered, assess response to therapy.
      - a. Consider retesting HCP who received decolonization therapy to document eradication of carriage.
      - b. The optimal timing for retesting HCP who received decolonization therapy is unclear. Although there are no strong data to support a specific approach, one relatively common approach is to retest the HCP 1–2 weeks after completion of decolonization therapy to document clearance of MRSA. Subsequent testing of the HCP to detect relapse or recurrent colonization should be considered if there is evidence of ongoing transmission despite initially successful decolonization of colonized HCP.

## ACKNOWLEDGMENTS

*Disclaimer.* D.K.—The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

*Potential conflicts of interest.* A.M. reports receiving a research grant/ contract from Sage Products. A.D.H. reports serving in an advisory/consultant role for Cubist, UpToDate, and Premier. S.S.H. reports leading a clinical trial in which participating hospitals received contributed product from Sage Products. J.M. reports conducting a clinical trial in which participating hospitals received contributed product from Sage Products. S.S.H. and J.M. report conducting a clinical trial in which participating hospitals receive contributed product from Sage Products and Molnlycke; this disclosure arose after the manuscript was completed but before publication. C.S., D.C., D.K., K.A., D.S.Y., and L.L.M. report no conflicts of interest.

Address correspondence to David Calfee, MD, MS, Weill Cornell Medical College, 525 East 68th Street, Box 265, New York, NY 10065 (dpc9003@ med.cornell.edu).

## APPENDIX

### STRATEGIES FOR IMPLEMENTATION OF AN MRSA AST PROGRAM

The information provided in this appendix is intended to supplement the recommendations provided in section 6 for the implementation of an MRSA AST program. Specifically, the information provided below addresses many of the complex issues that are encountered when designing and implementing an AST program.

- I. Select the patient population that will be included in the screening program (eg, all patients vs high-risk patients or units)
  - A. Use the MRSA risk assessment to determine whether all patients, patients admitted to specific high-risk units (eg, ICUs), or high-risk patient populations (regardless of location) will be included in the screening program. The prevalence of MRSA and the proportion of MRSA that are community associated may influence the choice of populations to be included and the risk factors to be used in identifying patients to be screened.<sup>123</sup> State legislative requirements for active surveillance, where applicable, should be considered when selecting the patient population to be screened.
  - B. Patient-level risk factors for MRSA colonization (eg, recent hospital or skilled nursing facility admission, chronic

hemodialysis, and recent antimicrobial therapy) may also be used to determine inclusion in the screening program.<sup>149-153</sup>

- C. Consider available infrastructure and hospital-specific characteristics (size, staffing for laboratory and nursing, patient population, MRSA prevalence, and information technology support) when selecting the patient population(s) to be screened.
  - D. Consider piloting the program in one location before expanding to other locations. Select the pilot unit on the basis of the risk or prevalence of MRSA in the unit or the presence of motivated leadership and frontline personnel.
  - E. Expand the program to additional units once the pilot program has been evaluated and adjusted and initial goals have been met (eg, more than 90% compliance with specimen acquisition).
- II. Develop a reliable system to identify patients who meet the criteria for screening
- A. Identification of patients who meet criteria for MRSA screening may be more difficult when patient-level risk factors, rather than patient care unit, are used to determine inclusion in the surveillance program. Take this into consideration during the planning stages of the screening program. Hospitals with well-developed electronic medical records and other computer databases may be able to identify such patients using a computer algorithm.<sup>149,152</sup>
    - B. Consider developing and implementing a checklist to be completed at admission to assist in identifying patients to be screened for MRSA.
  - III. Determine how screening specimens will be ordered (eg, standardized nursing protocol, admission order set, or individual patient order), who will initiate the order (eg, physician, nurse), and who will obtain the specimens (eg, unit-based nursing personnel, designated MRSA monitoring program personnel, or patient).
    - A. These decisions will need to take into account relevant hospital policies, staffing, and infrastructure.
    - B. Although AST samples have historically been collected by HCP, one study that compared the results of healthcare provider-collected and patient-collected specimens demonstrated concordance rates of 82%–95% between provider and patient-collected specimens.<sup>154</sup> Of note, among those with discordant results, patient-collected samples more frequently had positive results than provider-collected samples. Although this approach is probably not feasible or desirable in many settings, this may at least provide an acceptable alternative for patients who are unwilling to have AST specimens collected by their healthcare providers.
  - IV. Determine when screening will be performed
    - A. At a minimum, MRSA surveillance should be performed on admission to the hospital or to the specific unit in which surveillance is being performed.
    - B. Although not always included in AST programs, additional testing of patients with initial negative surveillance test results can be done either at regular intervals (eg, weekly) or on discharge or transfer from the hospital or unit to detect patients who have acquired MRSA while in the hospital. One study demonstrated that patients identified as MRSA carriers by screening at the time of ICU discharge accounted for 27% of MRSA carriers detected by active surveillance and for 27% of the total number of MRSA colonization-days in non-ICU wards for patients discharged from the ICU.<sup>155</sup>
    - C. Testing at regular intervals has the potential to detect patients who have acquired MRSA during their hospitalization earlier than testing only at discharge and thus allows implementation of contact precautions to prevent further transmission.
    - D. When testing is to be performed at regular intervals, consider identifying a specific day of the week when specimens will be collected. This will simplify the process and allow the microbiology laboratory to anticipate the increased volume of specimens and plan staffing and supplies accordingly.
  - V. Determine the anatomic sites that will be sampled
    - A. The sensitivity of surveillance specimens obtained from a variety of anatomic sites has been evaluated in several settings and patient populations. Although no single site will detect all MRSA-colonized persons, most studies have found the anterior nares to be the most frequently positive site, with sensitivity ranging from 48% to 93%.<sup>154,156-160</sup> Because of this and the accessibility of the site, the anterior nares have generally been considered the primary site for sampling in MRSA screening programs. However, collection of samples from other sites, such as skin (groin, perineum, wounds), foreign body (eg, gastrostomy or tracheostomy tube) exit sites, throat, and the perianal area, will allow identification of additional colonized patients who would not be identified by nasal specimens alone. Several recent studies have demonstrated that sampling

from one or more additional sites, such as the throat and/or perineum, was required to increase the sensitivity of AST to more than 90%.<sup>154,156,158,159</sup> The proportion of MRSA carriers that must be detected to optimize the effectiveness of the AST program has not been determined.

- B. Nonnasal colonization appears to be particularly common with CA-MRSA. Recent studies have reported that 38%–41% of carriers of CA-MRSA would have remained undetected if only samples from the anterior nares were collected.<sup>114,161</sup> As CA-MRSA continues to represent an increasingly large proportion of hospital-onset MRSA infections, including nonnasal sampling sites in the AST program will likely become increasingly important.
- C. The neonatal ICU has a number of unique features that should be considered when an AST program is being planned for that setting.<sup>29</sup> While a published consensus statement for management of MRSA outbreaks in neonatal ICUs suggests that nasal or nasopharyngeal samples alone are sufficient to detect MRSA-colonized neonates,<sup>162</sup> some studies performed in the setting of outbreaks of healthcare-associated and CA-MRSA have demonstrated that a sampling strategy that includes collection of specimens from the nares and umbilicus has much greater sensitivity for detection of MRSA (92%–100%) than does sampling the nares alone (68%–72%).<sup>163</sup>
- D. To simplify the specimen collection procedure and optimize resource utilization, some hospitals performing multisite sampling use a single swab to collect specimens from multiple sites (eg, nose, axillae, and groin).<sup>164</sup> When this is done, the order in which sites are to be sampled should be specified to avoid contaminating clean sites. When using molecular-based testing methods, confirm with laboratory personnel that the test has been validated for use with all sampling sites.

#### VI. Select the laboratory method that will be used to detect MRSA

- A. MRSA can be detected using culture-based methods or molecular diagnostic testing methods, such as polymerase chain reaction (PCR). Many factors must be considered when determining which laboratory method(s) will be used in an MRSA screening program. These factors include but are not limited to performance characteristics of the test (eg, sensitivity, specificity), turnaround time, capabilities of the laboratory that will be providing the service (whether an in-house or reference lab), number of specimens that will be processed, and facility-specific cost-benefit calculations.
- B. A detailed discussion of the various laboratory methods for MRSA detection is beyond the scope of this guideline, but some of the key features of the most common methods are discussed below.
  1. *Culture-based methods.* Numerous microbiologic media and culture techniques have been described for use in the detection of MRSA colonization. One of the more commonly used selective media is mannitol salt agar with or without antimicrobial (eg, oxacillin or cefoxitin) supplementation to increase specificity for methicillin-resistant organisms. The time required for detection of MRSA is approximately 48 hours using most culture-based techniques. Several chromogenic agar media have been developed that allow more rapid detection of MRSA than conventional media, usually within 24 hours. Studies using established collections of isolates and clinical specimens have shown that these chromogenic media rival or outperform more conventional microbiological techniques.<sup>165-171</sup> Additional enrichment steps, such as overnight incubation in trypticase soy broth, can further increase the yield of standard and chromogenic culture-based methods.<sup>172-174</sup>
  2. *Molecular testing methods.* In recent years, there have been advances in molecular diagnostic testing methods, such as real-time PCR, for detection of MRSA colonization. Earlier evaluations of these PCR assays found them to be highly sensitive (90%–100%) and specific (91.7%–98.4%) compared with standard culture-based methods.<sup>164,175-177</sup> Several recent reports, however, have demonstrated the possibility of increased rates of false-positive or false-negative results due to changes in the genetic targets of the assays, such as *mecA* deletions and *SCCmec* variants, respectively.<sup>178-181</sup> Although more costly than culture-based techniques, one potential advantage of these molecular tests is their ability to provide a result in less than 2 hours from the time of specimen collection, although in actual practice the turnaround time may be longer due to batching of samples. Although at least one uncontrolled study<sup>182</sup> and 3 mathematical models<sup>183-185</sup> have suggested that rapid testing may allow for more effective use of isolation precautions and enhanced prevention of MRSA transmission, a cluster-randomized crossover trial of universal screening in general wards failed to identify a difference in MRSA acquisition rates with the use of rapid testing compared with the use of a culture-based method.<sup>186</sup>

These data suggest that the clinical and economic benefits of rapid testing may vary among individual hospitals and settings.

VII. Determine how to manage patients while awaiting the results of screening tests<sup>54</sup>

- A. Before implementing a screening program, a decision should be made as to how a patient will be managed while waiting for the result of the admission MRSA screening test. There are 2 common approaches: (1) await the test result and implement contact precautions only if the screening test is positive and (2) place the patient under empiric contact precautions until a negative admission screening test result is documented.
  1. It has been shown that patients colonized with MRSA often contaminate the hospital environment prior to the availability of AST results.<sup>54</sup> Thus, empiric use of contact precautions could minimize the risk of MRSA transmission from unrecognized sources, and some have suggested that this approach has contributed to more effective control of MRSA.<sup>187</sup> However, a number of logistical difficulties may be associated with this approach. Empiric use of contact precautions substantially increases the need for single rooms and the amount of supplies needed to practice contact precautions. When only a small proportion of screened patients are colonized with MRSA and single rooms are of limited quantity, a large number of patients whose screening test results are negative will need to be moved so that their single room can be used for another patient. These room reassignments and the necessary cleaning before the vacated room can be reoccupied can impede patient flow within the hospital. In many acute care hospitals, implementing contact precautions at the time of receipt of a positive screening test result is a reasonable initial approach. The empiric use of contact precautions for all tested patients while awaiting test results may be most feasible in hospitals where a relatively large proportion of screened patients are MRSA positive or where a large proportion of patient rooms are single rooms and in individual hospital units, such as many ICUs, where each patient is in an individual room or bay.
  2. Despite its potential logistic difficulties, empiric use of contact precautions should be considered if transmission continues despite introduction of a screening program in which contact precautions are implemented only after a positive MRSA screening test.

## REFERENCES

1. Calfee DP, Salgado CD, Classen D, et al. Strategies to prevent transmission of methicillin-resistant *Staphylococcus aureus* in acute care hospitals. *Infect Control Hosp Epidemiol* 2008; 29(suppl 1):S62–S80.
2. Yokoe DS, Anderson DJ, Berenholtz SM, et al. Introduction to “A Compendium of Strategies to Prevent Healthcare-Associated Infections in Acute Care Hospitals: 2014 Updates.” *Infect Control Hosp Epidemiol* 2014;35(5):455–459.
3. Sievert DM, Ricks P, Edwards JR, et al. Antimicrobial-resistant pathogens associated with healthcare-associated infections: summary of data reported to the National Healthcare Safety Network at the Centers for Disease Control and Prevention, 2009–2010. *Infect Control Hosp Epidemiol* 2013;34:1–14.
4. Hidron AI, Edwards JR, Patel J, et al. NHSN annual update: antimicrobial-resistant pathogens associated with healthcare-associated infections: annual summary of data reported to the National Healthcare Safety Network at the Centers for Disease Control and Prevention, 2006–2007. *Infect Control Hosp Epidemiol* 2008;29:996–1011.
5. Kallen AJ, Mu Y, Bulens S, et al. Health care–associated invasive MRSA infections, 2005–2008. *JAMA* 2010;304:641–648.
6. Dantes R, Mu Y, Belflower R, et al. National burden of invasive methicillin-resistant *Staphylococcus aureus* infections, United States, 2011. *JAMA Intern Med* 2013;173(21):1970–1978.
7. Iwamoto M, Mu Y, Lynfield R, et al. Trends in invasive methicillin-resistant *Staphylococcus aureus* infections. *Pediatrics* 2013;132:e817–e824.
8. Cosgrove SE, Sakoulas G, Perencevich EN, Schwaber MJ, Karchmer AW, Carmeli Y. Comparison of mortality associated with methicillin-resistant and methicillin-susceptible *Staphylococcus aureus* bacteremia: a meta-analysis. *Clin Infect Dis* 2003; 36:53–59.
9. Engemann JJ, Carmeli Y, Cosgrove SE, et al. Adverse clinical and economic outcomes attributable to methicillin resistance among patients with *Staphylococcus aureus* surgical site infection. *Clin Infect Dis* 2003;36:592–598.
10. Abramson MA, Sexton DJ. Nosocomial methicillin-resistant and methicillin-susceptible *Staphylococcus aureus* primary bacteremia: at what costs? *Infect Control Hosp Epidemiol* 1999;20: 408–411.
11. McHugh CG, Riley LW. Risk factors and costs associated with methicillin-resistant *Staphylococcus aureus* bloodstream infections. *Infect Control Hosp Epidemiol* 2004;25:425–430.
12. Harbarth S, Rutschmann O, Sudre P, Pittet D. Impact of methicillin resistance on the outcome of patients with bacteremia caused by *Staphylococcus aureus*. *Arch Intern Med* 1998;158: 182–189.
13. Cosgrove SE, Qi Y, Kaye KS, Harbarth S, Karchmer AW, Carmeli Y. The impact of methicillin resistance in *Staphylococcus aureus* bacteremia on patient outcomes: mortality, length of stay, and hospital charges. *Infect Control Hosp Epidemiol* 2005; 26:166–174.
14. Huang SS, Platt R. Risk of methicillin-resistant *Staphylococcus*

- aureus* infection after previous infection or colonization. *Clin Infect Dis* 2003;36:281–285.
15. Garrouste-Orgeas M, Timsit JF, Kallel H, et al. Colonization with methicillin-resistant *Staphylococcus aureus* in ICU patients: morbidity, mortality, and glycopeptide use. *Infect Control Hosp Epidemiol* 2001;22:687–692.
  16. Freitas EA, Harris RM, Blake RK, Salgado CD. Prevalence of USA300 strain type of methicillin-resistant *Staphylococcus aureus* among patients with nasal colonization identified with active surveillance. *Infect Control Hosp Epidemiol* 2010;31:469–475.
  17. Huang SS, Hinrichsen VL, Datta R, et al. Methicillin-resistant *Staphylococcus aureus* infection and hospitalization in high-risk patients in the year following detection. *PLoS ONE* 2011;6: e24340.
  18. Datta R, Huang SS. Risk of infection and death due to methicillin-resistant *Staphylococcus aureus* in long-term carriers. *Clin Infect Dis* 2008;47:176–181.
  19. Milstone AM, Goldner BW, Ross T, Shepard JW, Carroll KC, Perl TM. Methicillin-resistant *Staphylococcus aureus* colonization and risk of subsequent infection in critically ill children: importance of preventing nosocomial methicillin-resistant *Staphylococcus aureus* transmission. *Clin Infect Dis* 2011;53: 853–859.
  20. Merrer J, Santoli F, Appere de Vecchi C, Tran B, De Jonghe B, Outin H. “Colonization pressure” and risk of acquisition of methicillin-resistant *Staphylococcus aureus* in a medical intensive care unit. *Infect Control Hosp Epidemiol* 2000;21:718–723.
  21. Moran GJ, Krishnadasan A, Gorwitz RJ, et al. Methicillin-resistant *S. aureus* infections among patients in the emergency department. *N Engl J Med* 2006;355:666–674.
  22. King MD, Humphrey BJ, Wang YF, Kourbatova EV, Ray SM, Blumberg HM. Emergence of community-acquired methicillin-resistant *Staphylococcus aureus* USA 300 clone as the predominant cause of skin and soft-tissue infections. *Ann Intern Med* 2006;144:309–317.
  23. Maree CL, Daum RS, Boyle-Vavra S, Matayoshi K, Miller LG. Community-associated methicillin-resistant *Staphylococcus aureus* isolates causing healthcare-associated infections. *Emerg Infect Dis* 2007;13:236–242.
  24. Klevens RM, Morrison MA, Nadle J, et al. Invasive methicillin-resistant *Staphylococcus aureus* infections in the United States. *JAMA* 2007;298:1763–1771.
  25. Popovich KJ, Weinstein RA, Hota B. Are community-associated methicillin-resistant *Staphylococcus aureus* (MRSA) strains replacing traditional nosocomial MRSA strains? *Clin Infect Dis* 2008;46:787–794.
  26. Jenkins TC, McCollister BD, Sharma R, et al. Epidemiology of healthcare-associated bloodstream infection caused by USA300 strains of methicillin-resistant *Staphylococcus aureus* in 3 affiliated hospitals. *Infect Control Hosp Epidemiol* 2009;30:233–241.
  27. Park SH, Park C, Yoo JH, et al. Emergence of community-associated methicillin-resistant *Staphylococcus aureus* strains as a cause of healthcare-associated bloodstream infections in Korea. *Infect Control Hosp Epidemiol* 2009;30:146–155.
  28. Carey AJ, Della-Latta P, Huard R, et al. Changes in the molecular epidemiological characteristics of methicillin-resistant *Staphylococcus aureus* in a neonatal intensive care unit. *Infect Control Hosp Epidemiol* 2010;31:613–619.

29. Milstone AM, Carroll KC, Ross T, Shangraw KA, Perl TM. Community-associated methicillin-resistant *Staphylococcus aureus* strains in pediatric intensive care unit. *Emerg Infect Dis* 2010;16:647–655.
30. Lessa FC, Mu Y, Ray SM, et al. Impact of USA300 methicillin-resistant *Staphylococcus aureus* on clinical outcomes of patients with pneumonia or central line-associated bloodstream infections. *Clin Infect Dis* 2012;55:232–241.
31. Bhalla A, Pultz NJ, Gries DM, et al. Acquisition of nosocomial pathogens on hands after contact with environmental surfaces near hospitalized patients. *Infect Control Hosp Epidemiol* 2004; 25:164–167.
32. Smith MA, Mathewson JJ, Ulert IA, Scerpella EG, Ericsson CD. Contaminated stethoscopes revisited. *Arch Intern Med* 1996; 156:82–84.
33. Cohen HA, Liora H, Paret G. Auriscope earpieces—a potential vector of infection? *Int J Pediatr Otorhinolaryngol* 1998;45: 47–50.
34. Bernard L, Kereveur A, Durand D, et al. Bacterial contamination of hospital physicians' stethoscopes. *Infect Control Hosp Epidemiol* 1999;20:626–628.
35. Embil JM, McLeod JA, Al-Barrak AM, et al. An outbreak of methicillin resistant *Staphylococcus aureus* on a burn unit: potential role of contaminated hydrotherapy equipment. *Burns* 2001;27:681–688.
36. Breathnach AS, Jenkins DR, Pedler SJ. Stethoscopes as possible vectors of infection by staphylococci. *BMJ* 1992;305:1573–1574.
37. 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;18:622–627.
38. Sexton T, Clarke P, O'Neill E, Dillane T, Humphreys H. Environmental reservoirs of methicillin-resistant *Staphylococcus aureus* in isolation rooms: correlation with patient isolates and implications for hospital hygiene. *J Hosp Infect* 2006;62:187–194.
39. Weber DJ, Anderson D, Rutala WA. The role of the surface environment in healthcare-associated infections. *Curr Opin Infect Dis* 2013;26:338–344.
40. Weber DJ, Rutala WA. Understanding and preventing transmission of healthcare-associated pathogens due to the contaminated hospital environment. *Infect Control Hosp Epidemiol* 2013;34:449–452.
41. Huang SS, Datta R, Platt R. Risk of acquiring antibiotic-resistant bacteria from prior room occupants. *Arch Intern Med* 2006;166:1945–1951.
42. National Healthcare Safety Network. *Multidrug-Resistant Organism and Clostridium difficile Infection (MDRO/CDI) Module*. 2014. [http://www.cdc.gov/nhsn/PDFs/pscManual/12pscMDRO\\_CDADcurrent.pdf](http://www.cdc.gov/nhsn/PDFs/pscManual/12pscMDRO_CDADcurrent.pdf). Accessed March 11, 2014.
43. National Healthcare Safety Network. *CDC/NHSN Surveillance Definition of Healthcare-Associated Infection and Criteria for Specific Types of Infections in the Acute Care Setting*. 2014. [http://www.cdc.gov/nhsn/PDFs/pscManual/17pscNosInfDef\\_current.pdf](http://www.cdc.gov/nhsn/PDFs/pscManual/17pscNosInfDef_current.pdf). Accessed March 11, 2014.
44. Cohen AL, Calfee D, Fridkin SK, et al. Recommendations for metrics for multidrug-resistant organisms in healthcare settings: SHEA/HICPAC position paper. *Infect Control Hosp Epidemiol* 2008;29:901–913.
45. Siegel JD, Rhinehart E, Jackson M, Chiarello L. Management

- of multidrug-resistant organisms in health care settings, 2006. *Am J Infect Control* 2007;35:S165–S193.
46. Coia JE, Duckworth GJ, Edwards DI, et al. Guidelines for the control and prevention of methicillin-resistant *Staphylococcus aureus* (MRSA) in healthcare facilities. *J Hosp Infect* 2006; 63(suppl 1):S1–S44.
  47. Infection Prevention Working Party. *MRSA in Hospitals*. 2012. [http://www.wip.nl/UK/free\\_content/Richtlijnen/110530%20MRSA%20hospital%20def.pdf](http://www.wip.nl/UK/free_content/Richtlijnen/110530%20MRSA%20hospital%20def.pdf). Accessed June 4, 2013.
  48. Dutch Working Party on Antibiotic Policy. *Optimization of the Antibiotic Policy in the Netherlands XI: Revision Swab Guideline for the Treatment of MRSA Carriage*. 2012. [http://www.swab.nl/swab/cms3.nsf/uploads/51DB72E670CAC33BC12579BF00342A95/\\$FILE/SwabrichtlijnMRSAAherziening%2015022012\\_EN.pdf](http://www.swab.nl/swab/cms3.nsf/uploads/51DB72E670CAC33BC12579BF00342A95/$FILE/SwabrichtlijnMRSAAherziening%2015022012_EN.pdf). Accessed June 4, 2013.
  49. Institute for Healthcare Improvement. *How to Guide: Reduce MRSA Infection*. 2011.
  50. Association for Professionals in Infection Control and Epidemiology. *Guide to the Elimination of Methicillin-Resistant Staphylococcus aureus (MRSA) Transmission in Hospital Settings*. 2nd ed. 2010.
  51. Johnson PD, Martin R, Burrell LJ, et al. Efficacy of an alcohol/ chlorhexidine hand hygiene program in a hospital with high rates of nosocomial methicillin-resistant *Staphylococcus aureus* (MRSA) infection. *Med J Aust* 2005;183:509–514.
  52. Gopal Rao G, Jeanes A, Osman M, Aylott C, Green J. Marketing hand hygiene in hospitals—a case study. *J Hosp Infect* 2002; 50:42–47.
  53. Morgan DJ, Rogawski E, Thom KA, et al. Transfer of multidrug-resistant bacteria to healthcare workers' gloves and gowns after patient contact increases with environmental contamination. *Crit Care Med* 2012;40:1045–1051.
  54. Chang S, Sethi AK, Stiefel U, Cadnum JL, Donskey CJ. Occurrence of skin and environmental contamination with methicillin-resistant *Staphylococcus aureus* before results of polymerase chain reaction at hospital admission become available. *Infect Control Hosp Epidemiol* 2010;31:607–612.
  55. Siegel JD, Rhinehart E, Jackson M, Chiarello L. 2007 Guideline for isolation precautions: preventing transmission of infectious agents in health care settings. *Am J Infect Control*. 2007;35:S65–S164.
  56. Scanvic A, Denic L, Gaillon S, Giry P, Andremont A, Lucet JC. Duration of colonization by methicillin-resistant *Staphylococcus aureus* after hospital discharge and risk factors for prolonged carriage. *Clin Infect Dis* 2001;32:1393–1398.
  57. Sanford MD, Widmer AF, Bale MJ, Jones RN, Wenzel RP. Efficient detection and long-term persistence of the carriage of methicillin-resistant *Staphylococcus aureus*. *Clin Infect Dis* 1994; 19:1123–1128.
  58. Kirkland KB, Weinstein JM. Adverse effects of contact isolation. *Lancet* 1999;354:1177–1178.
  59. Saint S, Higgins LA, Nallamothu BK, Chenoweth C. Do physicians examine patients in contact isolation less frequently? a brief report. *Am J Infect Control* 2003;31:354–356.
  60. Evans HL, Shaffer MM, Hughes MG, et al. Contact isolation in surgical patients: a barrier to care? *Surgery* 2003;134:180–188.
  61. Catalano G, Houston SH, Catalano MC, et al. Anxiety and depression in hospitalized patients in resistant organism isolation. *South Med J* 2003;96:141–145.

62. Day HR, Perencevich EN, Harris AD, et al. Do contact precautions cause depression? a two-year study at a tertiary care medical centre. *J Hosp Infect* 2011;79:103–107.
63. Stelfox HT, Bates DW, Redelmeier DA. Safety of patients isolated for infection control. *JAMA* 2003;290:1899–1905.
64. Harris AD, Pineles L, Belton B, et al. Universal glove and gown use and acquisition of antibiotic-resistant bacteria in the ICU: a randomized trial. *JAMA* 2013;310:1571–1580.
65. Diekema DJ, Edmond MB. Look before you leap: active surveillance for multidrug-resistant organisms. *Clin Infect Dis* 2007;44:1101–1107.
66. 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. *Infect Control Hosp Epidemiol* 2006;27:127–132.
67. French GL, Otter JA, Shannon KP, Adams NM, Watling D, Parks MJ. Tackling contamination of the hospital environment by methicillin-resistant *Staphylococcus aureus* (MRSA): a comparison between conventional terminal cleaning and hydrogen peroxide vapour decontamination. *J Hosp Infect* 2004;57:31–37.
68. Oie S, Hosokawa I, Kamiya A. Contamination of room door handles by methicillin-sensitive/methicillin-resistant *Staphylococcus aureus*. *J Hosp Infect* 2002;51:140–143.
69. Rampling A, Wiseman S, Davis L, et al. Evidence that hospital hygiene is important in the control of methicillin-resistant *Staphylococcus aureus*. *J Hosp Infect* 2001;49:109–116.
70. Vajravelu RK, Guerrero DM, Jury LA, Donskey CJ. Evaluation of stethoscopes as vectors of *Clostridium difficile* and methicillin-resistant *Staphylococcus aureus*. *Infect Control Hosp Epidemiol* 2012;33:96–98.
71. Carling P. Methods for assessing the adequacy of practice and improving room disinfection. *Am J Infect Control* 2013;41:S20–S25.
72. Dancer SJ. Importance of the environment in methicillin-resistant *Staphylococcus aureus* acquisition: the case for hospital cleaning. *Lancet Infect Dis* 2008;8:101–113.
73. Carling PC, Parry MF, Bruno-Murtha LA, Dick B. Improving environmental hygiene in 27 intensive care units to decrease multidrug-resistant bacterial transmission. *Crit Care Med* 2010; 38:1054–1059.
74. Abad C, Fearday A, Safdar N. Adverse effects of isolation in hospitalised patients: a systematic review. *J Hosp Infect* 2010; 76:97–102.
75. Salgado CD, Farr BM. What proportion of hospital patients colonized with methicillin-resistant *Staphylococcus aureus* are identified by clinical microbiological cultures? *Infect Control Hosp Epidemiol* 2006;27:116–121.
76. Huang SS, Rifas-Shiman SL, Warren DK, et al. Improving methicillin-resistant *Staphylococcus aureus* surveillance and reporting in intensive care units. *J Infect Dis* 2007;195:330–338.
77. Jain R, Kralovic SM, Evans ME, et al. Veterans Affairs initiative to prevent methicillin-resistant *Staphylococcus aureus* infections. *N Engl J Med* 2011;364:1419–1430.
78. West TE, Guerry C, Hiott M, Morrow N, Ward K, Salgado CD. Effect of targeted surveillance for control of methicillin-resistant *Staphylococcus aureus* in a community hospital system. *Infect Control Hosp Epidemiol* 2006;27:233–238.
79. Huang SS, Yokoe DS, Hinrichsen VL, et al. Impact of routine

- intensive care unit surveillance cultures and resultant barrier precautions on hospital-wide methicillin-resistant *Staphylococcus aureus* bacteremia. *Clin Infect Dis* 2006;43:971–978.
80. Lucet JC, Paoletti X, Lolom I, et al. Successful long-term program for controlling methicillin-resistant *Staphylococcus aureus* in intensive care units. *Intensive Care Med* 2005;31:1051–1057.
  81. Marshall C, Richards M, McBryde E. Do active surveillance and contact precautions reduce MRSA acquisition? a prospective interrupted time series. *PLoS ONE* 2013;8:e58112.
  82. Perlin JB, Hickok JD, Septimus EJ, Moody JA, Englebright JD, Bracken RM. A bundled approach to reduce methicillin-resistant *Staphylococcus aureus* infections in a system of community hospitals. *J Healthc Qual* 2013;35:57–68.
  83. Harbarth S, Fankhauser C, Schrenzel J, et al. Universal screening for methicillin-resistant *Staphylococcus aureus* at hospital admission and nosocomial infection in surgical patients. *JAMA* 2008;299:1149–1157.
  84. Huskins WC, Huckabee CM, O’Grady NP, et al. Intervention to reduce transmission of resistant bacteria in intensive care. *N Engl J Med* 2011;364:1407–1418.
  85. Agency for Healthcare Quality Research. *Screening for Methicillin-Resistant Staphylococcus aureus (MRSA)*. 2013. <http://www.effectivehealthcare.ahrq.gov/ehc/products/228/1550/MRSA-screening-report-130617.pdf>. Accessed July 18, 2013.
  86. Gurieva TV, Bootsma MC, Bonten MJ. Decolonization of patients and health care workers to control nosocomial spread of methicillin-resistant *Staphylococcus aureus*: a simulation study. *BMC Infect Dis* 2012;12:302.
  87. Miller MA, Dascal A, Portnoy J, Mendelson J. Development of mupirocin resistance among methicillin-resistant *Staphylococcus aureus* after widespread use of nasal mupirocin ointment. *Infect Control Hosp Epidemiol* 1996;17:811–813.
  88. Lepointeur M, Royer G, Bourrel AS, et al. Prevalence of resistance to antiseptics and mupirocin among invasive coagulase-negative staphylococci from very preterm neonates in NICU: the creeping threat? *J Hosp Infect* 2013;83:333–336.
  89. Teo BW, Low SJ, Ding Y, Koh TH, Hsu LY. High prevalence of mupirocin-resistant staphylococci in a dialysis unit where mupirocin and chlorhexidine are routinely used for prevention of catheter-related infections. *J Med Microbiol* 2011;60:865–867.
  90. Ridenour G, Lampen R, Federspiel J, Kritchevsky S, Wong E, Climo M. Selective use of intranasal mupirocin and chlorhexidine bathing and the incidence of methicillin-resistant *Staphylococcus aureus* colonization and infection among intensive care unit patients. *Infect Control Hosp Epidemiol* 2007;28:1155–1161.
  91. Saiman L, Cronquist A, Wu F, et al. An outbreak of methicillin-resistant *Staphylococcus aureus* in a neonatal intensive care unit. *Infect Control Hosp Epidemiol* 2003;24:317–321.
  92. Nambiar S, Herwaldt LA, Singh N. Outbreak of invasive disease caused by methicillin-resistant *Staphylococcus aureus* in neonates and prevalence in the neonatal intensive care unit. *Pediatr Crit Care Med* 2003;4:220–226.
  93. Hitomi S, Kubota M, Mori N, et al. Control of a methicillin-resistant *Staphylococcus aureus* outbreak in a neonatal intensive care unit by unselective use of nasal mupirocin ointment. *J Hosp Infect* 2000;46:123–129.
  94. Herwaldt LA. Reduction of *Staphylococcus aureus* nasal carriage and infection in dialysis patients. *J Hosp Infect* 1998;40(suppl B):S13–S23.

95. Miller LG, Eells SJ, Taylor AR, et al. *Staphylococcus aureus* colonization among household contacts of patients with skin infections: risk factors, strain discordance, and complex ecology. *Clin Infect Dis* 2012;54:1523–1535.
96. Kluytmans JA, Mouton JW, VandenBergh MF, et al. Reduction of surgical-site infections in cardiothoracic surgery by elimination of nasal carriage of *Staphylococcus aureus*. *Infect Control Hosp Epidemiol* 1996;17:780–785.
97. Pofahl WE, Goettler CE, Ramsey KM, Cochran MK, Nobles DL, Rotondo MF. Active surveillance screening of MRSA and eradication of the carrier state decreases surgical-site infections caused by MRSA. *J Am Coll Surg* 2009;208:981–986.
98. Wilcox MH, Hall J, Pike H, et al. Use of perioperative mupirocin to prevent methicillin-resistant *Staphylococcus aureus* (MRSA) orthopaedic surgical site infections. *J Hosp Infect* 2003; 54:196–201.
99. Schweizer M, Perencevich E, McDanel J, et al. Effectiveness of a bundled intervention of decolonization and prophylaxis to decrease gram positive surgical site infections after cardiac or orthopedic surgery: systematic review and meta-analysis. *BMJ* 2013;346:f 2743.
100. Anderson DJ, Podgorny K, Berríos-Torres SI, et al. Strategies to prevent surgical site infections in acute care hospitals: 2014 update. *Infect Control Hosp Epidemiol* 2014;35(6):605–627.
101. Vernon MO, Hayden MK, Trick WE, Hayes RA, Blom DW, Weinstein RA. Chlorhexidine gluconate to cleanse patients in a medical intensive care unit: the effectiveness of source control to reduce the bioburden of vancomycin-resistant enterococci. *Arch Intern Med* 2006;166:306–312.
102. Munoz-Price LS, Hota B, Stemer A, Weinstein RA. Prevention of bloodstream infections by use of daily chlorhexidine baths for patients at a long-term acute care hospital. *Infect Control Hosp Epidemiol* 2009;30:1031–1035.
103. Evans HL, Dellit TH, Chan J, Nathens AB, Maier RV, Cuschieri J. Effect of chlorhexidine whole-body bathing on hospital-acquired infections among trauma patients. *Arch Surg* 2010; 145:240–246.
104. Popovich KJ, Hota B, Hayes R, Weinstein RA, Hayden MK. Effectiveness of routine patient cleansing with chlorhexidine gluconate for infection prevention in the medical intensive care unit. *Infect Control Hosp Epidemiol* 2009;30:959–963.
105. Climo MW, Yokoe DS, Warren DK, et al. Effect of daily chlorhexidine bathing on hospital-acquired infection. *N Engl J Med* 2013;368:533–542.
106. Huang SS, Septimus E, Kleinman K, et al. Targeted versus universal decolonization to prevent ICU infection. *N Engl J Med* 2013;368:2255–2265.
107. Milstone AM, Elward A, Song X, et al. Daily chlorhexidine bathing to reduce bacteraemia in critically ill children: a multicentre, cluster-randomised, crossover trial. *Lancet* 2013;381: 1099–1106.
108. Climo MW, Sepkowitz KA, Zuccotti G, et al. The effect of daily bathing with chlorhexidine on the acquisition of methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus*, and healthcare-associated bloodstream infections: results of a quasi-experimental multicenter trial. *Crit Care Med* 2009;37:1858–1865.
109. Marschall J, Mermel LA, Fakih M, et al. Strategies to prevent central line-associated bloodstream infections in acute care

- hospitals: 2014 update. *Infect Control Hosp Epidemiol* 2014; 35(7):753–771 (in this issue).
110. Karki S, Cheng AC. Impact of non-rinse skin cleansing with chlorhexidine gluconate on prevention of healthcare-associated infections and colonization with multi-resistant organisms: a systematic review. *J Hosp Infect* 2012;82:71–84.
  111. Derde LP, Cooper BS, Goossens H, et al. Interventions to reduce colonisation and transmission of antimicrobial-resistant bacteria in intensive care units: an interrupted time series study and cluster randomised trial. *Lancet Infect Dis* 2013;14(1):31–9.
  112. Rupp ME, Cavalieri RJ, Lyden E, et al. Effect of hospital-wide chlorhexidine patient bathing on healthcare-associated infections. *Infect Control Hosp Epidemiol* 2012;33:1094–1100.
  113. Delaney HM, Wang E, Melish M. Comprehensive strategy including prophylactic mupirocin to reduce *Staphylococcus aureus* colonization and infection in high-risk neonates. *J Perinatol* 2013;33:313–318.
  114. Fritz SA, Hogan PG, Hayek G, et al. *Staphylococcus aureus* colonization in children with community-associated *Staphylococcus aureus* skin infections and their household contacts. *Arch Pediatr Adolesc Med* 2012;166:551–557.
  115. Clinical and Laboratory Standards Institute (CLSI). *Performance Standards for Antimicrobial Susceptibility Testing: TwentyThird Informational Supplement*. Wayne, PA: CLSI, 2013. CLSI document M100-S23.
  116. Center for Medicare & Medicaid Services. *Federal Register*. 2012. <http://www.gpo.gov/fdsys/pkg/FR-2012-05-11/pdf/2012-09985.pdf>. Accessed July 18, 2013.
  117. The Joint Commission. *National Patient Safety Goals*. 2013. [http://www.jointcommission.org/standards\\_information/npsgs.aspx](http://www.jointcommission.org/standards_information/npsgs.aspx). Accessed July 18, 2013.
  118. Center for Medicare & Medicaid Services. *State Operations Manual: Appendix A—Survey Protocol, Regulations and Interpretive Guidelines for Hospitals*. Rev. 84, 06-07-13. 2013. [http://www.cms.gov/RegulationsandGuidance/Guidance/Manuals/downloads/som107ap\\_a\\_hospitals.pdf](http://www.cms.gov/RegulationsandGuidance/Guidance/Manuals/downloads/som107ap_a_hospitals.pdf). Accessed July 18, 2013.
  119. Ellingson K, Hass JP, Aiello AE, et al. Strategies to prevent healthcare-associated infections through hand hygiene. *Infect Control Hosp Epidemiol* 2014 (forthcoming).
  120. Seto WH. Training the work force—models for effective education in infection control. *J Hosp Infect* 1995;30(suppl):241–247.
  121. Sehulster L, Chinn RY. Guidelines for environmental infection control in health-care facilities: recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). *MMWR Recomm Rep* 2003;52:1–42.
  122. Rutala WA, Weber DJ; Healthcare Infection Control Practices Advisory Committee (HICPAC). *Guideline for Disinfection and Sterilization in Healthcare Facilities, 2008*. [http://www.cdc.gov/hicpac/pdf/guidelines/Disinfection\\_Nov\\_2008.pdf](http://www.cdc.gov/hicpac/pdf/guidelines/Disinfection_Nov_2008.pdf). Accessed July 18, 2013.
  123. Otter JA, Yezli S, Perl TM, Barbut F, French GL. The role of “no-touch” automated room disinfection systems in infection prevention and control. *J Hosp Infect* 2013;83:1–13.
  124. Passaretti CL, Otter JA, Reich NG, et al. An evaluation of environmental decontamination with hydrogen peroxide vapor for reducing the risk of patient acquisition of multidrug-resistant organisms. *Clin Infect Dis* 2013;56:27–35.
  125. Salgado CD, Sepkowitz KA, John JF, et al. Copper surfaces

- reduce the rate of healthcare-acquired infections in the intensive care unit. *Infect Control Hosp Epidemiol* 2013;34:479–486.
126. Kac G, Grohs P, Durieux P, et al. Impact of electronic alerts on isolation precautions for patients with multidrug-resistant bacteria. *Arch Intern Med* 2007;167:2086–2090.
127. Halpin H, Shortell SM, Milstein A, Vanneman M. Hospital adoption of automated surveillance technology and the implementation of infection prevention and control programs. *Am J Infect Control* 2011;39:270–276.
128. Wright MO. Automated surveillance and infection control: toward a better tomorrow. *Am J Infect Control* 2008;36:S1–S6.
129. Mozzillo KL, Ortiz N, Miller LG. Patients with methicillin-resistant *Staphylococcus aureus* infection: twenty-first century lepers. *J Hosp Infect* 2010;75:132–134.
130. Briggs JJ, Milstone AM. Changes over time in caregivers' knowledge, attitudes, and behaviors regarding methicillin-resistant *Staphylococcus aureus*. *J Pediatr* 2011;158:1039.
131. Wang JT, Chang SC, Ko WJ, et al. A hospital-acquired outbreak of methicillin-resistant *Staphylococcus aureus* infection initiated by a surgeon carrier. *J Hosp Infect* 2001;47:104–109.
132. Faibis F, Laporte C, Fiacre A, et al. An outbreak of methicillin-resistant *Staphylococcus aureus* surgical-site infections initiated by a healthcare worker with chronic sinusitis. *Infect Control Hosp Epidemiol* 2005;26:213–215.
133. Coombs GW, Van Gessel H, Pearson JC, Godsell MR, O'Brien FG, Christiansen KJ. Controlling a multicenter outbreak involving the New York/Japan methicillin-resistant *Staphylococcus aureus* clone. *Infect Control Hosp Epidemiol* 2007;28:845–852.
134. Pittet D, Allegranzi B, Sax H, Dharan S, Pessoa-Silva CL, Donaldson L, Boyce JM. Evidence-based model for hand transmission during patient care and the role of improved practices. *Lancet Infect Dis* 2006;6:641–652.
135. Thompson RL, Cabezudo I, Wenzel RP. Epidemiology of nosocomial infections caused by methicillin-resistant *Staphylococcus aureus*. *Ann Intern Med* 1982;97:309–317.
136. Cox RA, Conquest C. Strategies for the management of healthcare staff colonized with epidemic methicillin-resistant *Staphylococcus aureus*. *J Hosp Infect* 1997;35:117–127.
137. Albrich WC, Harbarth S. Health-care workers: source, vector, or victim of MRSA? *Lancet Infect Dis* 2008;8:289–301.
138. Cookson B, Peters B, Webster M, Phillips I, Rahman M, Noble W. Staff carriage of epidemic methicillin-resistant *Staphylococcus aureus*. *J Clin Microbiol* 1989;27:1471–1476.
139. Bertin ML, Vinski J, Schmitt S, et al. Outbreak of methicillin-resistant *Staphylococcus aureus* colonization and infection in a neonatal intensive care unit epidemiologically linked to a healthcare worker with chronic otitis. *Infect Control Hosp Epidemiol* 2006;27:581–585.
140. Stein M, Navon-Venezia S, Chmelnitsky I, et al. An outbreak of new, nonmultidrug-resistant, methicillin-resistant *Staphylococcus aureus* strain (SCCmec type IIIA variant-1) in the neonatal intensive care unit transmitted by a staff member. *Pediatr Infect Dis J* 2006;25:557–559.
141. Meier PA, Carter CD, Wallace SE, Hollis RJ, Pfaller MA, Herwaldt LA. A prolonged outbreak of methicillin-resistant *Staphylococcus aureus* in the burn unit of a tertiary medical center. *Infect Control Hosp Epidemiol* 1996;17:798–802.
142. Blok HE, Troelstra A, Kamp-Hopmans TE, et al. Role of healthcare workers in outbreaks of methicillin-resistant *Staphylococ-*

- cus aureus*: a 10-year evaluation from a Dutch university hospital. *Infect Control Hosp Epidemiol* 2003;24:679–685.
143. Wendt C, Schinke S, Wurttemberger M, Oberdorfer K, BockHensley O, von Baum H. Value of whole-body washing with chlorhexidine for the eradication of methicillin-resistant *Staphylococcus aureus*: a randomized, placebo-controlled, doubleblind clinical trial. *Infect Control Hosp Epidemiol* 2007;28:1036–1043.
  144. Popovich KJ, Lyles R, Hayes R, et al. Relationship between chlorhexidine gluconate skin concentration and microbial density on the skin of critically ill patients bathed daily with chlorhexidine gluconate. *Infect Control Hosp Epidemiol* 2012;33:889–896.
  145. Tamma PD, Aucott SW, Milstone AM. Chlorhexidine use in the neonatal intensive care unit: results from a national survey. *Infect Control Hosp Epidemiol* 2010;31:846–849.
  146. Chapman AK, Aucott SW, Milstone AM. Safety of chlorhexidine gluconate used for skin antisepsis in the preterm infant. *J Perinatol* 2012;32:4–9.
  147. Sitzlar B, Deshpande A, Fertelli D, Kundrapu S, Sethi AK, Donskey CJ. An environmental disinfection odyssey: evaluation of sequential interventions to improve disinfection of *Clostridium difficile* isolation rooms. *Infect Control Hosp Epidemiol* 2013;34:459–465.
  148. Carling PC, Parry MF, Von Beheren SM. Identifying opportunities to enhance environmental cleaning in 23 acute care hospitals. *Infect Control Hosp Epidemiol* 2008;29:1–7.
  149. Morgan DJ, Day HR, Furuno JP, et al. Improving efficiency in active surveillance for methicillin-resistant *Staphylococcus aureus* or vancomycin-resistant *Enterococcus* at hospital admission. *Infect Control Hosp Epidemiol* 2010;31:1230–1235.
  150. Reilly JS, Stewart S, Christie P, et al. Universal screening for methicillin-resistant *Staphylococcus aureus* in acute care: risk factors and outcome from a multicentre study. *J Hosp Infect* 2012; 80:31–35.
  151. Haley CC, Mittal D, Laviolette A, Jannapureddy S, Parvez N, Haley RW. Methicillin-resistant *Staphylococcus aureus* infection or colonization present at hospital admission: multivariable risk factor screening to increase efficiency of surveillance culturing. *J Clin Microbiol* 2007;45:3031–3038.
  152. Riedel S, Von Stein D, Richardson K, et al. Development of a prediction rule for methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant *Enterococcus* carriage in a Veterans Affairs medical center population. *Infect Control Hosp Epidemiol* 2008;29:969–971.
  153. Harbarth S, Sax H, Fankhauser-Rodriguez C, Schrenzel J, Agostinho A, Pittet D. Evaluating the probability of previously unknown carriage of MRSA at hospital admission. *Am J Med* 2006;119:275.e215–275.e223.
  154. Lautenbach E, Nachamkin I, Hu B, et al. Surveillance cultures for detection of methicillin-resistant *Staphylococcus aureus*: diagnostic yield of anatomic sites and comparison of provider and patient-collected samples. *Infect Control Hosp Epidemiol* 2009;30:380–382.
  155. Furuno JP, Harris AD, Wright MO, et al. Value of performing active surveillance cultures on intensive care unit discharge for detection of methicillin-resistant *Staphylococcus aureus*. *Infect Control Hosp Epidemiol* 2007;28:666–670.
  156. Senn L, Basset P, Nahimana I, Zanetti G, Blanc DS. Which anatomical sites should be sampled for screening of methicillin-

- resistant *Staphylococcus aureus* carriage by culture or by rapid PCR test? *Clin Micro Infect* 2012;18:E31–E33.
157. McKinnell JA, Huang SS, Eells SJ, Cui E, Miller LG. Quantifying the impact of extranasal testing of body sites for methicillin-resistant *Staphylococcus aureus* colonization at the time of hospital or intensive care unit admission. *Infect Control Hosp Epidemiol* 2013;34:161–170.
  158. Shurland SM, Stine OC, Venezia RA, et al. Colonization sites of USA300 methicillin-resistant *Staphylococcus aureus* in residents of extended care facilities. *Infect Control Hosp Epidemiol* 2009;30:313–318.
  159. Matheson A, Christie P, Stari T, et al. Nasal swab screening for methicillin-resistant *Staphylococcus aureus*—how well does it perform? a cross-sectional study. *Infect Control Hosp Epidemiol* 2012;33:803–808.
  160. Eveillard M, de Lassence A, Lancien E, Barnaud G, Ricard JD, Joly-Guillou ML. Evaluation of a strategy of screening multiple anatomical sites for methicillin-resistant *Staphylococcus aureus* at admission to a teaching hospital. *Infect Control Hosp Epidemiol* 2006;27:181–184.
  161. Popovich KJ, Hota B, Aroutcheva A, et al. Community-associated methicillin-resistant *Staphylococcus aureus* colonization burden in HIV-infected patients. *Clin Infect Dis* 2013;56:1067–1074.
  162. Gerber SI, Jones RC, Scott MV, et al. Management of outbreaks of methicillin-resistant *Staphylococcus aureus* infection in the neonatal intensive care unit: a consensus statement. *Infect Control Hosp Epidemiol* 2006;27:139–145.
  163. Rosenthal A, White D, Churilla S, Brodie S, Katz KC. Optimal surveillance culture sites for detection of methicillin-resistant *Staphylococcus aureus* in newborns. *J Clin Microbiol* 2006;44: 4234–4236.
  164. Bishop EJ, Grabsch EA, Ballard SA, et al. Concurrent analysis of nose and groin swab specimens by the IDI-MRSA PCR assay is comparable to analysis by individual-specimen PCR and routine culture assays for detection of colonization by methicillin-resistant *Staphylococcus aureus*. *J Clin Microbiol* 2006;44:2904–2908.
  165. Diederer B, van Duijn I, van Belkum A, Willemse P, van Keulen P, Kluytmans J. Performance of CHROMagar MRSA medium for detection of methicillin-resistant *Staphylococcus aureus*. *J Clin Microbiol* 2005;43:1925–1927.
  166. Diederer BM, van Leest ML, van Duijn I, Willemse P, van Keulen PH, Kluytmans JA. Performance of MRSA ID, a new chromogenic medium for detection of methicillin-resistant *Staphylococcus aureus*. *J Clin Microbiol* 2006;44:586–588.
  167. Flayhart D, Hindler JF, Bruckner DA, et al. Multicenter evaluation of BBL CHROMagar MRSA medium for direct detection of methicillin-resistant *Staphylococcus aureus* from surveillance cultures of the anterior nares. *J Clin Microbiol* 2005;43:5536–5540.
  168. Stoakes L, Reyes R, Daniel J, et al. Prospective comparison of a new chromogenic medium, MRSAselect, to CHROMagar MRSA and mannitol-salt medium supplemented with oxacillin or cefoxitin for detection of methicillin-resistant *Staphylococcus aureus*. *J Clin Microbiol* 2006;44:637–639.
  169. Han Z, Lautenbach E, Fishman N, Nachamkin I. Evaluation of mannitol salt agar, CHROMagar Staph aureus and CHROMagar MRSA for detection of methicillin-resistant *Staph-*

- Staphylococcus aureus* from nasal swab specimens. *J Clin Microbiol* 2007;56:43–46.
170. Wassenberg MW, Kluytmans JA, Box AT, et al. Rapid screening of methicillin-resistant *Staphylococcus aureus* using PCR and chromogenic agar: a prospective study to evaluate costs and effects. *Clin Micro Infect* 2010;16:1754–1761.
  171. Denys GA, Renzi PB, Koch KM, Wissel CM. Three-way comparison of BBL CHROMagar MRSAII, MRSAselect, and Spectra MRSA for detection of methicillin-resistant *Staphylococcus aureus* isolates in nasal surveillance cultures. *J Clin Microbiol* 2013;51:202–205.
  172. Safdar N, Narans L, Gordon B, Maki DG. Comparison of culture screening methods for detection of nasal carriage of methicillin-resistant *Staphylococcus aureus*: a prospective study comparing 32 methods. *J Clin Microbiol* 2003;41:3163–3166.
  173. Wolk DM, Marx JL, Dominguez L, Driscoll D, Schifman RB. Comparison of MRSASelect agar, CHROMagar methicillin-resistant *Staphylococcus aureus* (MRSA) medium, and Xpert MRSA PCR for detection of MRSA in nares: diagnostic accuracy for surveillance samples with various bacterial densities. *J Clin Microbiol* 2009;47:3933–3936.
  174. Nonhoff C, Denis O, Brenner A, et al. Comparison of three chromogenic media and enrichment broth media for the detection of methicillin-resistant *Staphylococcus aureus* from mucocutaneous screening specimens: comparison of MRSA chromogenic media. *Eur J Clin Microbiol Infect Dis* 2009;28:363–369.
  175. Huletsky A, Lebel P, Picard FJ, et al. Identification of methicillin-resistant *Staphylococcus aureus* carriage in less than 1 hour during a hospital surveillance program. *Clin Infect Dis* 2005; 40:976–981.
  176. Warren DK, Liao RS, Merz LR, Eveland M, Dunne WM Jr. Detection of methicillin-resistant *Staphylococcus aureus* directly from nasal swab specimens by a real-time PCR assay. *J Clin Microbiol* 2004;42:5578–5581.
  177. Drews SJ, Willey BM, Kreiswirth N, et al. Verification of the IDI-MRSA assay for detecting methicillin-resistant *Staphylococcus aureus* in diverse specimen types in a core clinical laboratory setting. *J Clin Microbiol* 2006;44:3794–3796.
  178. Wong H, Louie L, Lo RY, Simor AE. Characterization of *Staphylococcus aureus* isolates with a partial or complete absence of staphylococcal cassette chromosome elements. *J Clin Microbiol* 2010;48:3525–3531.
  179. Blanc DS, Basset P, Nahimana-Tessema I, Jaton K, Greub G, Zanetti G. High proportion of wrongly identified methicillin-resistant *Staphylococcus aureus* carriers by use of a rapid commercial PCR assay due to presence of staphylococcal cassette chromosome element lacking the *mecA* gene. *J Clin Microbiol* 2011;49:722–724.
  180. Bartels MD, Boye K, Rohde SM, et al. A common variant of staphylococcal cassette chromosome *mec* type IVa in isolates from Copenhagen, Denmark, is not detected by the BD GeneOhm methicillin-resistant *Staphylococcus aureus* assay. *J Clin Microbiol* 2009;47:1524–1527.
  181. Laurent C, Bogaerts P, Schoevaerdt D, et al. Evaluation of the Xpert MRSA assay for rapid detection of methicillin-resistant *Staphylococcus aureus* from nares swabs of geriatric hospitalized patients and failure to detect a specific SCC*mec* type IV variant. *Eur J Clin Microbiol Infect Dis* 2010;29:995–1002.
  182. Cunningham R, Jenks P, Northwood J, Wallis M, Ferguson

- S, Hunt S. Effect on MRSA transmission of rapid PCR testing of patients admitted to critical care. *J Hosp Infect* 2007;65: 24–28.
183. Bootsma MC, Diekmann O, Bonten MJ. Controlling methicillin-resistant *Staphylococcus aureus*: quantifying the effects of interventions and rapid diagnostic testing. *Proc Natl Acad Sci USA* 2006;103:5620–5625.
184. Olchanski N, Mathews C, Fufeld L, Jarvis W. Assessment of the influence of test characteristics on the clinical and cost impacts of methicillin-resistant *Staphylococcus aureus* screening programs in US hospitals. *Infect Control Hosp Epidemiol* 2011; 32:250–257.
185. Li J, Ulvin K, Biboh H, Kristiansen IS. Cost-effectiveness of supplementing a broth-enriched culture test with the Xpert methicillin-resistant *Staphylococcus aureus* (MRSA) assay for screening inpatients at high risk of MRSA. *J Hosp Infect* 2012; 82:227–233.
186. Jeyaratnam D, Whitty CJ, Phillips K, et al. Impact of rapid screening tests on acquisition of methicillin resistant *Staphylococcus aureus*: cluster randomised crossover trial. *BMJ* 2008; 336:927–930.
187. Safdar N, Marx J, Meyer NA, Maki DG. Effectiveness of preemptive barrier precautions in controlling nosocomial colonization and infection by methicillin-resistant *Staphylococcus aureus* in a burn unit. *Am J Infect Control* 2006;34:476–483.
188. Guyatt GH, Oxman AD, Vist GE, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ* 2008;336(7650):924–926.
189. GRADE. Canadian Task Force on Preventive Health Care website. <http://canadiantaskforce.ca/methods/grade/>. Accessed December 31, 2013.
- 190.