THE IP COL·LAB·ORATION PROJECT

Educational Toolkit

This initiative is funded by an unrestricted educational grant from Roche Diagnostics.
Educational Toolkit

Resources to help address gaps in healthcare knowledge and performance at the point of care and the point of need.

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Introduction

This Educational Toolkit has been developed by the Association for Professionals in Infection Control and Epidemiology (APIC), and the American Society for Microbiology (ASM), for the IP Collaboration Project. It seeks to build bridges of shared knowledge and experience between professionals in infection prevention and the laboratory.

The purpose of this project was to develop practical resources to share best practices in an on-going manner. We invite you to improve upon any of the entries, leave your name and contact information if you can be a resource on a tool or method, and share stories (both success and challenges) of these methods and tools in use. We can help one another by becoming stewards for this toolkit and by sharing it with our peers.

The main components of this Toolkit are:

- Knowledge – identifying the gaps, and how they can be addressed using multimedia content
- Usage - examples of best practices and guidance that can help you choose tools and methods for your needs.

Our goal is for users of this Toolkit to identify what is relevant to them and share their knowledge with all stakeholders.

We hope that you will find the Educational Toolkit both informative and useful as you pursue opportunities of collaboration to bridge the tactical gaps between laboratory professionals and infection preventionists who are both focused on helping improve patient outcomes across the continuum of care.
Clinical Advisors

Established in partnership with ASM, this team of Clinical Advisors was formed to provide leadership to guide the work of this project.

- Lillian Burns MT, MPH,CIC, lead clinical advisor for APIC
- Lance Peterson, MD, lead clinical advisor for ASM
- Kathy Aureden MS, MT(ASCP), SI, CIC
- Marc-Oliver Wright, MT(ASCP), MS, CIC

Market Research

A joint market research survey was conducted to gain a better understanding of the dynamic relationships of each professional membership group, and to identify what each saw as the key factors affecting current working relationships.

Research findings:

- Both groups shared a common goal – reducing the level of healthcare-associated infections across the continuum of care
- A disparity exists in the involvement of each group in critical cross-cutting issues in handling healthcare-associated infections in the areas of:
  - Quality standards
  - Turn-around time
- Both groups are interested in learning about how other facilities are creating partnerships between infection preventionists and lab professionals.
- The “need for a methodical approach for making things better” – developing a sustainable approach for creating synergies.
Resources

Educational Webinars

Each webinar featured timely topics in best practices and active surveillance, and offer quality continuing education for infection preventionists. These 60-minute streaming presentations were designed and moderated by experienced practitioners and senior healthcare administrators within their areas of expertise.

These webinars were presented during the first half of 2012. They are archived, and available for free to all members of APIC and ASM

**What Infection Preventionists need to know about the lab.**
Content Experts: Ann Maher, MS, M(ASCP), CIC; and Richard A Van Enk, PhD, CIC.

**Laboratory Support of Infection Control Initiatives: Should we be doing more or less?**
Content Expert: Richard Van Enk, PhD, CIC.
[http://labproject.site.apic.org/files/2012/02/Should-we-be-doing-more-or-less.pdf](http://labproject.site.apic.org/files/2012/02/Should-we-be-doing-more-or-less.pdf)

**Best Practices in Clostridium Difficile Infection (CDI).**
Content Expert: L. Clifford McDonald, MD, FACP, FSHEA.

**Active MRSA Surveillance Program.**

**Case Study of an Active MRSA Surveillance Program.**

**Best Practices in MDRO Screening and Control.**
References & Tools

All of the references/tools listed below are free, downloadable, and easy to use:

- Lab IP Collaboration: 20 ideas for infection preventionist-laboratory partnering activities
- Case study: Rapid screening for high risk patient in reducing health-care associated infections
- Extract from *The Infection Preventionist Guide to the Lab*. Chapters 1, 2, 3 and 5. The complete guide can be bought online at [www.apic.org/APICStore/Products](http://www.apic.org/APICStore/Products).
- *Guide to the Elimination of MRSA*
- Journal Articles from:

  **American Journal of Infection Control**
  [www.ajicjournal.org](http://www.ajicjournal.org)
  - *Barriers to implementing infection prevention and control guidelines during crises: Experiences of health care professionals*
  - *Wide variation in adoption of screening and infection control interventions for multidrug-resistant organisms: a national study*
  - *Antimicrobial stewardship: A collaborative partnership between infection preventionists and health care epidemiologists*

  **Journal of Clinical Microbiology**
  [http://jcm.asm.org](http://jcm.asm.org)
  - *The Role of the Clinical Microbiology Laboratory in the Diagnosis of Selected Infectious Processes*
  - *New Technologies in Clinical Microbiology*
  - *Enhancing the Function of Clinical Microbiology Laboratories: Can We Navigate the Road Less Travelled*
Lab IP Collaboration: 20 ideas for IP-Laboratory Partnering Activities

1. Invite lab representative to be on hand hygiene team (and other HAI teams if appropriate)
   a. can help provide before and after hand hygiene cultures
   b. can participate in educational campaigns, sharing knowledge of good and bad bugs
   c. can help with educational environmental cultures done as examples of contamination in healthcare facilities - what’s growing and why is it there
2. Collaborate on a joint IP / Lab “Bug of the month” or Infectious disease quarterly” publication for staff
3. Offer to be on speaker roster for local professional society meetings (APIC, ASCP, ASM, etc)
4. Jointly prepare a collaboration poster to present at local or national professional society meetings
5. Give a joint lab / IP presentation or CME to other healthcare professionals (nursing, RT, coders, etc) on multidrug resistance, TB, antimicrobial stewardship, central line infections, rapid testing innovations, emerging pathogens, and other topics for which both the laboratory and infection prevention can provide expert knowledge
6. Share APIC presentations and infection prevention journal articles with lab professionals (IPs can often obtain a ppt presentation from professional meetings to review with lab)
7. Provide yearly laboratory bloodborne pathogen education in person, customized to your laboratory
8. Participate in CAP (College of American Pathologists) readiness with lab
9. Keep print copies of IP professional journals in the pathology library
10. Become antimicrobial stewardship team colleagues
11. Mentor a microbiologist – provide a shadowing experience in IP
12. Invite a microbiologist to attend an APIC meeting with you
13. Give each lab employee a mini bottle of AHR during Laboratory Week
14. Send thank you notes to lab staff during Laboratory Week signed by IP and the Infection Control Committee
15. Ensure ongoing lab participation on Infection Control Committee (technologist, pathologist), consider a standing agenda item for laboratory
16. Present a case study at a monthly lab meeting that highlights the importance of the laboratory in preventing hospital associated infections
17. Assist the laboratory with the business case for best practice laboratory testing
18. Collaborate on a journal article for professional or trade journals after successful collaboration on an improvement resulting in great patient outcomes regarding HAIs, antimicrobial stewardship, new technology or products, etc.
19. Invite laboratory to participate in Infection Prevention Week
20. Publically praise and appreciate the contribution of your facility’s laboratory’s to infection prevention during meetings and when rounding in patient care units and clinical departments
Extract from *The Infection Preventionist Guide to the Lab*
Chapter 1

Specimen Collection and Transport

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Additional Contributors:
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The diagnostic microbiology laboratory (DML) plays a pivotal role in patient care by providing information on a variety of microorganisms with clinical significance such as bacteria, fungi, viruses, and parasites. The primary goals of the DML are to identify the presence of pathogenic microorganisms in clinical samples, predict response to antimicrobial therapy, and assist the infection prevention department as needed in epidemiological investigation.

A variety of methods can be used to identify microorganisms in clinical specimens. Methods used in the DML in the diagnosis of infection are (1) classical methods (direct smear, culture, antigen detection, serological tests) and (2) molecular methods (hybridization, nucleic acid amplification, real-time amplification).

The DML is an essential component of an effective infection prevention program. Changes in microbiological diagnostic techniques, such as rapid diagnosis and typing methods, have strengthened the role of microbiology laboratory in infection prevention. The partnership between the infection preventionist and the DML medical microbiologist is crucial in combating healthcare-associated infections (HAIs).

The appropriate selection, collection, and transport of specimens to the DML is an essential part in the accurate laboratory identification of microorganisms that cause infections which affect patient care and infection prevention.

Specimen collection guidelines include:

- Use standard precautions for collecting and handling all clinical specimens.
- Utilize appropriate collection device(s).
- Use sterile equipment and aseptic technique to collect specimens.
- Collect specimens during the acute phase of illness (or within 2 to 3 days for viral infections).
- Collect specimens before administration of antibiotics wherever possible.
- Avoid contamination with indigenous flora from surrounding tissues, organs, or secretions.
- Optimize the capture of anaerobic bacteria from specimens by using proper procedures.
- Collect a sufficient volume of specimen to ensure that all tests requested may be performed. Inadequate amounts of specimen may yield false-negative results.
- Label specimens properly with patient’s name and identification number, source, specific site, date, time of collection, and initials of collector.
- Provide clear and specific instructions on proper collection techniques to patients when they must collect their own specimens.
Transportation guidelines include:

- All specimens must be promptly transported to the laboratory, preferably within 2 hours of collection. Delays or exposure to temperature extremes compromises the test results.
- Specimens should be transported in a container designed to ensure survival of suspected agents. Never refrigerate spinal fluid, genital, eye, or internal ear specimens because these samples may contain microorganisms sensitive to temperature extremes.
- Materials for transport must be labeled properly, packaged, and protected during transport. A transport medium can be used to preserve the viability of microorganisms in clinical samples (e.g. Stuart, Amies, and Carey-Blair transport media).
- Use leak-proof specimen containers and transport them in sealable, leak-proof plastic bags.
- Never transport syringes with needles attached to the laboratory.
- Laboratories must have enforceable criteria for rejection of unsuitable specimens.

See Chapter 2 for additional information.
### Table 1-1: Specimen Selection, Collection, and Transport by Body Site

<table>
<thead>
<tr>
<th>Upper Respiratory Tract</th>
<th>General Category</th>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
<th>Specimen Frequency</th>
<th>Test Type</th>
<th>Interpretation</th>
<th>Advantages/Disadvantages</th>
<th>Sample Transport</th>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral cavity</td>
<td>• Gram stain principally • Infrequently cultures</td>
<td>Oral lesions, suspicion of oral yeast infection (“thrush”), necrotizing gingivitis</td>
<td><em>Candida</em> sp., <em>Fusobacterium</em> sp. or other anaerobes or spirochetes in cases of necrotizing gingivitis</td>
<td>• Swab of lesions or purulent material • Bacterial transport media</td>
<td>Once</td>
<td>Swab</td>
<td>• Gram stain reveals yeast • Gram stain reveals fusiform bacilli or spirochetes</td>
<td>Swabs not very sensitive or specific</td>
<td>Swab and transport within 2 hours to laboratory (≤2 h) at room temperature (RT)</td>
<td>Culture rarely indicated</td>
</tr>
<tr>
<td>Nares</td>
<td>Culture or polymerase chain reaction (PCR) for methicillin-resistant <em>Staphylococcus aureus</em> (MRSA)</td>
<td>Epidemiological screening for MRSA</td>
<td>MRSA</td>
<td>• Swab of anterior nares • Bacterial transport media</td>
<td>• Once at assessment • Repeat as needed clinically</td>
<td>Nasal swab</td>
<td>Positive culture or PCR indicates colonization with MRSA</td>
<td>• PCR very sensitive and specific but more costly • Specialized test</td>
<td>Swab and transport ≤2 h at RT</td>
<td>Concurrent cultures of wounds or perianal skin also recommended to compensate for lower sensitivity of nares culture method</td>
</tr>
<tr>
<td>Nasopharyngeal</td>
<td>• Viral cell culture, fluorescent antibody stain, rapid membrane antigen detection, or PCR • Bacterial culture</td>
<td>Viral testing (e.g., influenza), bacterial culture of certain pathogens</td>
<td>Influenza, parainfluenza, respiratory syncytial virus (RSV), other respiratory viruses, <em>Neisseria meningitidis</em>, <em>Bordetella pertussis</em>, <em>Corynebacterium diphtheriae</em>, <em>Streptococcus pneumoniae</em>, <em>Staphylococcus aureus</em>, <em>Hemophilus influenzae</em>, <em>Moraxella catarrhalis</em>, <em>Pseudomonas</em> species, oral anaerobes, occasionally fungi or other pathogens</td>
<td>• Swab placed into viral transport media • Swab placed into bacterial transport media</td>
<td>Once</td>
<td>Nasopharyngeal swab or aspirate</td>
<td>Detection of viral pathogens has high specificity but sensitivity highly variable depending on methods used</td>
<td>PCR for respiratory viruses is very sensitive and rapid if available</td>
<td>Swab and transport ≤2 h at RT</td>
<td>May cause coughing, requiring appropriate personal protective equipment (PPE) for person collecting the specimen</td>
</tr>
</tbody>
</table>
### Table 1-1: Specimen Selection, Collection, and Transport by Body Site (continued)

<table>
<thead>
<tr>
<th>General Category</th>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
<th>Specimen</th>
<th>Frequency</th>
<th>Test Type</th>
<th>Interpretation</th>
<th>Advantages/Disadvantages</th>
<th>Sample Transport</th>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upper Respiratory Tract</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Sinuses | • Bacterial culture  
• Gram stain | Healthcare-associated sinusitis in a critical care setting, especially if on mechanical ventilation | *S. pneumoniae*,  
*S. aureus*,  
*H. influenzae*,  
*M. catarrhalis*,  
*Pseudomonas* species, oral anaerobes, occasionally fungi or other pathogens such as coliforms | • Specimen placed into sterile collection device and delivered to laboratory immediately  
• Swab of nasal mucus NOT an acceptable specimen | Once and possibly repeated if clinically required | Direct maxillary puncture by surgeon or aspiration of sinus cavity under direct visualization | Predominant growth of a pathogen that is also seen in the Gram stain suggests pathogenic role | Aspiration of the maxillary sinus by puncture or direct visualization requires specialist to perform | Swab and transport ≤2 h at RT | |
| Throat | • Tests for MRSA as described for nares  
• Culture for *C. diphtheriae*  
• Culture or PCR for *B. pertussis* | Screening for MRSA,  
*diphtheria*, or pertussis | *MRSA, C. diphtheriae, B. pertussis* | Swab placed into bacterial transport media | • Once at assessment  
• Repeat as needed clinically | Swab of posterior pharyngeal wall and tonsils including exudates or purulent material | • For MRSA, as for nares  
• *C. diphtheriae* requires toxigenic testing to determine its disease-producing potential | • “Cough plates” no longer recommended for pertussis  
• If clinical suspicion high for *diphtheria* or pertussis then appropriate infection prevention and notification of public health authorities required at the time of specimen collection | Swab and transport ≤2 h at RT | • Always speak with microbiology laboratory if diphtheria or pertussis considered because special handling is required  
• Throat swab contraindicated for patients with suspected epiglottitis |
### Table 1-1: Specimen Selection, Collection, and Transport by Body Site (continued)

<table>
<thead>
<tr>
<th>Lower Respiratory Tract</th>
<th>General Category</th>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
<th>Specimen</th>
<th>Frequency</th>
<th>Test Type</th>
<th>Interpretation</th>
<th>Advantages/Disadvantages</th>
<th>Sample Transport</th>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expectorated sputum</td>
<td>Bacterial, fungal cultures</td>
<td>Healthcare-associated pneumonia or tracheobronchitis</td>
<td>S. pneumoniae, H. influenzae, B. catarrhalis, coliforms, S. aureus, Pseudomonas species, other glucose nonfermenters, Legionella species, mycobacteria species</td>
<td>Sputum, aspirates from endotracheal tube or tracheostomy</td>
<td>• As clinically indicated but not normally more than once per week</td>
<td>Expectorated, aspirated specimen</td>
<td>• Very challenging to interpret for bacterial infections</td>
<td>• Due to difficulties in interpretation of sputum samples, consideration should be given to broncho-alveolar lavage (BAL) or protected bronchoscopic brush specimens using quantitative microbiological methods for diagnosis of healthcare-associated pneumonia.</td>
<td>Sterile container, transport ≤2 h at RT</td>
<td>Legionella specimens should not be collected in saline; sterile water is best</td>
<td></td>
</tr>
<tr>
<td>Induced sputum</td>
<td>Viral detection</td>
<td>Healthcare-associated viral respiratory infection</td>
<td>Respiratory viruses such as influenza, RSV</td>
<td>Induced sputum collected in sterile bottle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sterile container, transport ≤2 h at RT</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Key Points**
- Induced sputum collection is challenging due to technical aspects.
- Urine antigen for Legionella pneumophila.
- PCR for L. pneumophila.
Table 1-1: Specimen Selection, Collection, and Transport by Body Site  (continued)

<table>
<thead>
<tr>
<th>General Category</th>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
<th>Specimen</th>
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<th>Test Type</th>
<th>Interpretation</th>
<th>Advantages/ Disadvantages</th>
<th>Sample Transport</th>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Respiratory Tract</td>
<td>- Bronchoalveolar lavage (BAL), endotracheal aspirate</td>
<td>- Bacterial, fungal cultures; direct fluorescent stain or PCR for <em>Pneumocystis jiroveci</em></td>
<td>Healthcare-associated pneumonia or tracheobronchitis, healthcare-associated viral respiratory infection where sputum is not specific enough</td>
<td>- Bronchoalveolar lavage (BAL)</td>
<td>- As clinically indicated but not normally more often than once per week</td>
<td>- Bronchoscopically collected BAL collected in a sterile bottle, or protected specimen brush collected 1.0 mL of sterile saline</td>
<td>- Specimens are cultured using a quantitative method to differentiate pathogens from contaminants</td>
<td>- Exact cut-off values depend on individual laboratory procedures</td>
<td>- In general, where a significant lower respiratory tract infection is considered, BAL is the preferred specimen if it can be safely collected</td>
<td>- Sterile container, transport ≤2 h at RT</td>
</tr>
</tbody>
</table>

- Alternative is protected bronchial brush that is placed into affected lung area through broncho-scope
- As above; better for *P. jiroveci* than sputum specimens
- Use sterile water for *Legionella* species
- These specialized specimens require a bronchoscopy to be performed, which is not always possible in patients with severe respiratory failure
- In general, where a significant lower respiratory tract infection is considered, BAL is the preferred specimen if it can be safely collected
- Immediate transportation to the microbiology laboratory is necessary
- Due to the risks of bronchoscopy in critically ill patients, advanced planning with the medical microbiologist is highly recommended
Table 1-1: Specimen Selection, Collection, and Transport by Body Site (continued)

<table>
<thead>
<tr>
<th>Blood and Intravascular Devices</th>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
<th>Specimen</th>
<th>Frequency</th>
<th>Test Type</th>
<th>Interpretation</th>
<th>Advantages/Disadvantages</th>
<th>Sample Transport</th>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood cultures</td>
<td>Aerobic and anaerobic culture of blood for bacteria and yeast</td>
<td>Clinical suspicion of bacteremia or septic shock</td>
<td>Many: S. aureus, S. pneumoniae, meningococci, enterococci, coliforms, Pseudomonas species, nonfermenting Gram-negative bacilli (Acinetobacter, Stenotrophomonas maltophilia, Burkholderia, Monoxella), yeasts</td>
<td>• Blood from properly cleaned and disinfected vein site</td>
<td>• One venipuncture drawing 20 mL of blood divided evenly between an aerobic and anaerobic bottle (i.e., 10 mL per bottle constituting one set of blood cultures)</td>
<td>• Whole blood aseptically drawn into blood culture bottle</td>
<td>• Typical pathogens such as S. aureus always considered significant</td>
<td>• Single sets of blood cultures of limited value with reduced sensitivity to detect a bacteremia and are to be avoided</td>
<td>Blood culture bottles, transport ≤2 h at RT</td>
<td>• Proper skin preparation with 70% alcohol and chlorhexidine will reduce the risk of contamination to less than 2% of specimens</td>
</tr>
<tr>
<td>Central venous catheter</td>
<td>• Aerobic culture for bacteria and yeast</td>
<td>Clinical suspicion of central venous catheter–related bacteremia</td>
<td>Many: S. aureus, S. pneumoniae, meningococci, enterococci, coliforms, Pseudomonas species, nonfermenting Gram-negative bacilli (Acinetobacter, Stenotrophomonas maltophilia, Burkholderia, Monoxella), yeasts</td>
<td>• Aseptically cut off terminal 5 cm of the catheter and place in sterile tube or bottle</td>
<td>• If endovascular infection considered, then draw a third set 1 or more hours after first two sets taken</td>
<td>• Catheter tip is rolled on bacterial agar</td>
<td>• Concurrent blood cultures also positive for the same pathogen</td>
<td>Sterile screwcap tube or cup, container, ≤15 min at RT</td>
<td>Catheter tips should be sent to the microbiology laboratory only with concurrent blood cultures to establish the presence of a bacteremia</td>
<td></td>
</tr>
</tbody>
</table>

### Notes:
- **Key Points**
  - **Aerobic and anaerobic culture of blood for bacteria and yeast**
    - Clinical suspicion of bacteremia or septic shock
    - Many: S. aureus, S. pneumoniae, meningococci, enterococci, coliforms, Pseudomonas species, nonfermenting Gram-negative bacilli (Acinetobacter, Stenotrophomonas maltophilia, Burkholderia, Monoxella), yeasts
    - **Specimen**
      - Blood from properly cleaned and disinfected vein site
      - Less desirable from central venous catheter due to increased risk of contamination of the specimen
      - On average, 30–40 mL of blood per septic episode in adults taken before administering antimicrobials if at all possible
      - Volume in children based on body weight
    - **Frequency**
      - One venipuncture drawing 20 mL of blood divided evenly between an aerobic and anaerobic bottle (i.e., 10 mL per bottle constituting one set of blood cultures)
      - Repeat at new venipuncture site
      - If endovascular infection considered, then draw a third set 1 or more hours after first two sets taken
    - **Test Type**
      - Whole blood aseptically drawn into blood culture bottle
      - Normally place 10 mL into each bottle for adults and larger children, and take no less than two sets (four bottles) per septic episode to ensure >95% sensitivity
    - **Interpretation**
      - Typical pathogens such as S. aureus always considered significant
    - **Advantages/Disadvantages**
      - Single sets of blood cultures of limited value with reduced sensitivity to detect a bacteremia and are to be avoided
      - Available blood culture systems not generally able to detect filamentous fungi; in such cases, lysis centrifugation tubes may be needed or alternative methods (e.g., serology)
    - **Sample Transport**
      - Blood culture bottles, transport ≤2 h at RT
      - Proper skin preparation with 70% alcohol and chlorhexidine will reduce the risk of contamination to less than 2% of specimens
      - Follow specific protocol of your microbiology laboratory

- **Central venous catheter**
  - • Aerobic culture for bacteria and yeast
    - • Semi-quantitative roll plate or sonication (detects intra-luminal infection) methods
    - • Clinical suspicion of central venous catheter–related bacteremia
    - Many: S. aureus, S. pneumoniae, meningococci, enterococci, coliforms, Pseudomonas species, nonfermenting Gram-negative bacilli (Acinetobacter, Stenotrophomonas maltophilia, Burkholderia, Monoxella), yeasts
    - • Aseptically cut off terminal 5 cm of the catheter and place in sterile tube or bottle
    - • Transport immediately to microbiology laboratory
    - • Take concurrent blood cultures at the same time as described previously
    - • Only if there is a suspicion of central venous catheter causing a bacteremia
    - • Do not routinely send venous catheter tips for culture if there is no suspicion of catheter-related bacteremia
    - • Catheter tip is rolled on bacterial agar
    - • Concurrent blood cultures also positive for the same pathogen
    - **If >15 colonies cultured, considered significant if concurrent blood cultures also positive**
    - **Careful attention to aseptic technique in cutting off the catheter segment required**
    - **Sample Transport**
      - Sterile screwcap tube or cup, container, ≤15 min at RT
      - Catheter tips should be sent to the microbiology laboratory only with concurrent blood cultures to establish the presence of a bacteremia
### Table 1-1: Specimen Selection, Collection, and Transport by Body Site (continued)

#### Sterile Body Sites and Fluids

<table>
<thead>
<tr>
<th>General Category</th>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
<th>Specimen Frequency</th>
<th>Test Type</th>
<th>Interpretation</th>
<th>Advantages/Disadvantages</th>
<th>Sample Transport</th>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abdominal abscess, biliary fluid</strong></td>
<td>• Aerobic and anaerobic bacterial culture</td>
<td>Suspicion of intra-abdominal, pelvic, or hepatic abscesses</td>
<td>S. aureus, enterococci, coliforms, <em>Pseudomonas</em> species, <em>Bacteroides</em> species, <em>Clostridium</em> species, other anaerobes, and <em>Candida</em> species or other yeasts</td>
<td>• Aseptically collected abscess fluid at time of surgery or by direct percutaneous aspiration</td>
<td>Aerobic and anaerobic bacterial cultures on multiple media to identify all potential pathogens</td>
<td>• Correlation with Gram stain and culture results essential</td>
<td>• Early acquisition of the specimen in the course of the infection is ideal</td>
<td>• Anaerobic transport system, sterile tube or blood culture bottle ≤15 min at RT</td>
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<td></td>
<td>• Yeast culture</td>
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<td></td>
<td>• Specimen should be placed into anaerobic collection tube for optimal recovery of all pathogens</td>
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<td></td>
<td>• Results more difficult to interpret in face of prior antibiotic therapy</td>
<td>• Rapid delivery to laboratory is essential</td>
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<td></td>
<td>Once at time of surgery or by direct percutaneous aspiration</td>
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<td>• Anaerobic transport system, sterile tube or blood culture bottle ≤15 min at RT</td>
<td>• Do not take specimen from preexisting drainage collection device as this has an unacceptable risk of significant contamination</td>
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<td>• Do not take specimen from preexisting drainage collection device as this has an unacceptable risk of significant contamination</td>
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<td>• Swabs not adequate, collect liquid specimen</td>
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</table>

| **Ascites** | • Aerobic and anaerobic bacterial culture | Suspicion of primary (spontaneous) or secondary peritonitis | • S. aureus, enterococci, coliforms, *Pseudomonas* species, *Bacteroides* species, *Clostridium* species, other anaerobes, and *Candida* species or other yeasts | • Aseptically aspirate ascites fluid | Aerobic and anaerobic bacterial cultures on multiple media to identify all potential pathogens | • Correlation with Gram stain and culture results essential | • Anaerobic transport system, sterile tube or blood culture bottle ≤15 min at RT | • Do not take specimen from preexisting drainage collection device as this has an unacceptable risk of significant contamination |
| | • Yeast culture | | | Place into anaerobic collection tube or sterile bottle | | | • Results more difficult to interpret in face of prior antibiotic therapy | • Rapid delivery to laboratory is essential |
| | • Cell count and differential count of fluid | • Spontaneous bacterial peritonitis can also be caused by S. pneumoniae | | Additional 10 mL should be placed into aerobic blood culture bottle to increase yield of bacterial pathogens | | | • Anaerobic transport system, sterile tube or blood culture bottle ≤15 min at RT | • Do not take specimen from preexisting drainage collection device as this has an unacceptable risk of significant contamination |
| | | | | • Cell count and differential count on fluid | | | | • Swabs not adequate, collect liquid specimen |
| | | | | • Once at time of suspicion of peritonitis | | | • Early acquisition of the specimen in the course of the infection is ideal | • Do not take specimen from preexisting drainage collection device as this has an unacceptable risk of significant contamination |
| | | | | May be repeated during therapy if there is no response to treatment | | | • Results more difficult to interpret in face of prior antibiotic therapy | • Swabs not adequate, collect liquid specimen |
| | | | | • Cell count and differential count on fluid | | | • Rapid delivery to laboratory is essential | |
Table 1-1: Specimen Selection, Collection, and Transport by Body Site (continued)

<table>
<thead>
<tr>
<th>Sterile Body Sites and Fluids</th>
<th>General Category</th>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
<th>Specimen</th>
<th>Frequency</th>
<th>Test Type</th>
<th>Interpretation</th>
<th>Advantages/Disadvantages</th>
<th>Sample Transport</th>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peritoneal dialysis fluid</td>
<td>• Aerobic and anaerobic bacterial culture • Yeast culture • Cell count and differential count of fluid</td>
<td>Suspicion of peritoneal dialysis catheter-related peritonitis</td>
<td>• Aseptically collected peritoneal dialysis fluid through the catheter into anaerobic collection tube or sterile bottle • Additional 10 mL should be placed into aerobic blood culture bottles to increase yield of bacterial pathogens • Cell count in appropriate container for hematology laboratory</td>
<td>• Staphylococcus epidermidis, S. aureus, Candida species, Pseudomonas aeruginosa, or S. maltophilia • Rare cases of mycobacterial infection</td>
<td>• Once at time of clinical suspicion of peritoneal dialysis catheter-related peritonitis • May be repeated during therapy if response incomplete (see above)</td>
<td>• Aerobic and anaerobic bacterial cultures on multiple media to identify all potential pathogens • Cell count and differential count on fluid</td>
<td>• ≥250 polymorphonuclear neutrophils (PMN) per mL compatible with spontaneous bacterial peritonitis, higher counts seen in secondary bacterial peritonitis • Elevated PMNs with positive cultures prove diagnosis of peritonitis</td>
<td>• Placing some but not all of the ascites fluid in a blood culture bottle at the patient's bedside improved yield of the cultures • It is still important to send fluid in sterile containers for Gram stain, cell counts, and bacterial culture onto agar media as well</td>
<td>• Anaerobic transport system, sterile tube or blood culture bottle ≤15 min at RT</td>
<td>• Culture of the peritoneal dialysis catheter tip is not appropriate</td>
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</tr>
<tr>
<td>Amniotic fluid</td>
<td>• Aerobic and anaerobic bacterial culture • Yeast culture</td>
<td>Suspicion of intra-abdominal, pelvic, or hepatic abscesses</td>
<td>S. aureus, enterococci, coliforms, Pseudomonas species, Bacteroides species, Clostridium species, other anaerobes, and Candida species or other yeasts</td>
<td>• Aseptically collected abscess fluid at time of surgery or by direct percutaneous aspiration • Specimen should be placed into anaerobic collection tube for optimal recovery of all pathogens</td>
<td>Once at time of surgery or by direct percutaneous aspiration</td>
<td>Aerobic and anaerobic bacterial cultures on multiple media to identify all potential pathogens</td>
<td>• Correlation with Gram stain and culture results essential • Classical pathogens easy to interpret • When patient has been on prolonged antibiotic therapy, coagulase negative staphylococcus species, enterococci, and yeasts may be the only pathogens discovered</td>
<td>• Fluid collected through a vaginal swab not an acceptable specimen due to contamination with vaginal flora • Collect by percutaneous aspiration, at surgery, or by aseptically placed intruterine catheter</td>
<td>• Anaerobic transport system, sterile tube or blood culture bottle ≤15 min at RT • Rapid delivery to laboratory is essential</td>
<td>Swabs of placenta not an appropriate specimen due to contamination by vaginal flora</td>
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<tr>
<td>General Category</td>
<td>Laboratory Test</td>
<td>Indications</td>
<td>Specific Microbes</td>
<td>Specimen</td>
<td>Frequency</td>
<td>Test Type</td>
<td>Interpretation</td>
<td>Advantages/Disadvantages</td>
<td>Sample Transport</td>
<td>Key Points</td>
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<tr>
<td>Synovial fluid</td>
<td>• Aerobic and anaerobic bacterial culture • Yeast culture • Cell count and differential count of fluid • Phase contrast microscopy for crystals</td>
<td>Clinical suspicion of septic arthritis of joint</td>
<td>S. aureus, S. epidermidis, enterococcus species, coliforms, <em>Pseudomonas</em> species, rarely yeast, fungi, mycobacteria, or nocardia</td>
<td>• Aseptic aspiration of joint or surgical exploration by arthroscopy with collection of joint fluid in anaerobic collection tube and into sterile bottle appropriate for cell count and microscopy for crystals • Collection should be before initiation of antimicrobial therapy if at all possible</td>
<td>Initially and repeated at time of second joint therapeutic lavage</td>
<td>• Aerobic and anaerobic bacterial cultures on multiple media to identify all potential pathogens • Cell count and differential count on fluid</td>
<td>For prosthetic joint infections very desirable to have specimens obtained at time of surgery as this facilitates interpretation of <em>S. epidermidis</em> and other low virulence pathogens</td>
<td>• Cultures by swabbing a chronic draining sinus lack sensitivity for the true pathogen in the joint space • Important to have proper aseptic aspiration or surgical samples</td>
<td>Anaerobic transport system, sterile tube or blood culture bottle ≤15 min at RT • Rapid delivery to laboratory is essential</td>
<td>• Cell count and differential count as well as microscopy for crystals important</td>
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<tr>
<td>Pericardial fluid</td>
<td>• Aerobic and anaerobic bacterial culture • Yeast culture • Viral detection • Cell count and differential count of fluid</td>
<td>Clinical suspicion of pericarditis</td>
<td>S. aureus, S. pneumoniae, H. influenzae, <em>Pseudomonas</em> species, anaerobic bacteria, enterovirus, influenza, <em>Candida</em> species, <em>Histoplasmosis capsulatum, Aspergillus</em> species, mycobacteria</td>
<td>Aseptic aspiration of pericardial space or surgical exploration by pericardiotomy with collection of pericardial fluid in anaerobic collection tube, aerobic transport media, viral transport media, and into sterile bottle appropriate for cell count</td>
<td>• Once at time of clinical suspicion of pericarditis</td>
<td>• Aerobic and anaerobic bacterial, fungal, and mycobacterial cultures on multiple media to identify all potential pathogens • Viral culture and/or PCR • Cell count and differential count on fluid</td>
<td>• Any growth of a pathogen of significance • Most healthcare-associated cases occur after cardiac surgery due to <em>S. aureus</em>; may be associated with sternal osteomyelitis</td>
<td>Some cases require pericardial window to drain the fluid</td>
<td>Anaerobic transport system, sterile tube or blood culture bottle ≤13 min at RT • Rapid delivery to laboratory is essential</td>
<td>Although uncommon, tuberculosis is still an important cause of pericarditis • Many cases undiagnosed due to viral etiology</td>
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</tbody>
</table>
Table 1-1: Specimen Selection, Collection, and Transport by Body Site (continued)

<table>
<thead>
<tr>
<th>Sterile Body Sites and Fluids</th>
<th>General Category</th>
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<th>Indications</th>
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<th>Test Type</th>
<th>Interpretation</th>
<th>Advantages/Disadvantages</th>
<th>Sample Transport</th>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pleural fluid</td>
<td>Sterile Body Sites and Fluids</td>
<td>Pleural fluid</td>
<td>• Aerobic and anaerobic bacterial culture • Yeast culture • Mycobacterial and fungal cultures • Cell count and differential count of fluid • Lactate dehydrogenase (LDH), protein, pH to biochemistry laboratory also</td>
<td>Pleural fluid • Aerobic and anaerobic bacterial culture • Yeast culture • Mycobacterial and fungal cultures • Cell count and differential count of fluid • Lactate dehydrogenase (LDH), protein, pH to biochemistry laboratory also</td>
<td>• Aseptically collected pleural fluid at time of surgery or by direct percutaneous aspiration • Specimen should be placed into anaerobic collection tube for optimal recovery of all pathogens • Rapid delivery to microbiology laboratory essential</td>
<td>Initially and repeated during therapy if response is incomplete</td>
<td>• Aerobic and anaerobic bacterial, fungal, and mycobacterial cultures on multiple media to identify all potential pathogens • Cell count and differential count, LDH, protein, pH on fluid</td>
<td>• Accurate diagnosis with biochemical characteristics with elevated LDH, protein, and pH &lt;7.0 essential as is culture • Biochemical characteristics and positive cultures of a pathogen confirms the diagnosis of empyema</td>
<td>Empyema occurs in 1%–2% of pneumonias and is therefore uncommon</td>
<td>• Anaerobic transport system, sterile tube or blood culture bottle ≤15 min at RT • Rapid delivery to laboratory is essential</td>
<td>Empyemas require tube drainage or surgical drainage/decortication</td>
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<tr>
<th>Eye</th>
<th>General Category</th>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
<th>Specimen</th>
<th>Frequency</th>
<th>Test Type</th>
<th>Interpretation</th>
<th>Advantages/Disadvantages</th>
<th>Sample Transport</th>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conjunctiva</td>
<td>Conjunctival scraping for bacterial cultures, viral culture, fluorescent stain or PCR, chlamydia fluorescent stain or culture</td>
<td>Conjunctival scraping for bacterial cultures, viral culture, fluorescent stain or PCR, chlamydia fluorescent stain or culture</td>
<td>Suspicion of conjunctivitis with purulent secretions</td>
<td>H. influenzae, Neisseria gonorrhoeae, Chlamydia trachomatis, S. aureus, herpes simplex virus (HSV), adenovirus</td>
<td>• Scrapings of conjunctiva or swabs of purulent material • Submit in bacterial, viral, and chlamydia transport media</td>
<td>Once and possibly repeated if clinically required</td>
<td>• Bacterial cultures • Viral cultures • Fluorescent antibody stain or PCR • Chlamydia fluorescent stain or culture</td>
<td>Positive results for a pathogen indicate a significant finding</td>
<td>Direct culture inoculation or swab transport ≤2 h</td>
<td>• Acute hemorrhagic conjunctivitis can occur in epidemics due to picornavirus • Epidemic keratoconjunctivitis due to adenovirus also occurs and is severe</td>
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<tr>
<td>General Category</td>
<td>Laboratory Test</td>
<td>Indications</td>
<td>Specific Microbes</td>
<td>Specimen</td>
<td>Frequency</td>
<td>Test Type</td>
<td>Interpretation</td>
<td>Advantages/ Disadvantages</td>
<td>Sample Transport</td>
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<tr>
<td><strong>Cornea</strong></td>
<td>Corneal scraping for bacterial cultures, viral culture, fluorescent stain or PCR, <em>Acanthamoeba</em> fluorescent stain</td>
<td>Suspicion of corneal infection (keratitis) with pain, photophobia, increased secretions, and red eye</td>
<td>• <em>S. pneumoniae</em>, <em>S. aureus</em>, <em>P. aeruginosa</em>, <em>H. influenzae</em>, <em>M. catarrhalis</em>, <em>HSV</em>, varicella zoster virus • <em>Acanthamoeba</em> species (a protozoan)</td>
<td>• Corneal scrapings by qualified ophthalmologist with anesthesia • Multiple specimens recommended • Submit in bacterial transport media, viral transport media, and as freshly prepared smear onto glass slides for immediate staining with Giemsa stain and calcofluor white and viewed with fluorescent microscope</td>
<td>Once and possibly repeated if clinically required</td>
<td>• Bacterial cultures • Viral cultures • Fluorescent antibody stain or PCR • Giemsa stain and calcofluor fluorescent stain on scrapings</td>
<td>• Positive results for a pathogen indicate a significant finding • Positive Gram stain in 75% of bacterial cases • If diagnosis still not made, ophthalmologist may consider keratoplasty for diagnosis and treatment</td>
<td><em>Acanthamoeba</em> seen in users of long wear contact lenses requires special communication with the microbiology laboratory</td>
<td>≤15 min at RT</td>
<td>Infection of the cornea requires urgent assessment and treatment by an ophthalmologist</td>
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<tr>
<td><strong>Vitreous fluid</strong></td>
<td>Vitreous fluid for bacterial cultures, fungal cultures</td>
<td>Suspicion of endophthalmitis with pain, loss of vision, increased secretions, and red eye</td>
<td><em>S. aureus</em>, <em>S. epidermidis</em>, <em>P. aeruginosa</em>, viridans group streptococci, <em>H. influenzae</em>, <em>Bacillus</em> species, <em>Candida</em> species, fungi</td>
<td>Aspiration of vitreous fluid obtained at bedside or during surgical vitrectomy</td>
<td>Once and possibly repeated if clinically required</td>
<td>• Bacterial cultures • Fungal cultures</td>
<td>Positive results for a pathogen indicate a significant finding</td>
<td>Vitreal samples must be collected by an ophthalmologist and must be processed immediately in the microbiology laboratory</td>
<td>≤15 min at RT</td>
<td>Possible endophthalmitis requires urgent assessment and treatment by an ophthalmologist</td>
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</tbody>
</table>
Table 1-1: Specimen Selection, Collection, and Transport by Body Site (continued)

<table>
<thead>
<tr>
<th>Gastrointestinal Samples</th>
<th>General Category</th>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
<th>Specimen</th>
<th>Frequency</th>
<th>Test Type</th>
<th>Interpretation</th>
<th>Advantages/Disadvantages</th>
<th>Sample Transport</th>
<th>Key Points</th>
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</thead>
<tbody>
<tr>
<td>Feces, rectal swab</td>
<td>Microscopy</td>
<td>Stool culture</td>
<td>Diarrhea, food poisoning</td>
<td>Bacterial pathogens: Shigella spp., Salmonella spp., Vibrio cholerae, Escherichia coli, Campylobacter spp. toxins of Clostridium difficile, S. aureus, Bacillus cereus, Clostridium perfringens, Yersinia enterocolitica, Plesiomonas shigelloides</td>
<td>1 g of stool</td>
<td>Three consecutive specimens</td>
<td>Culture, microscopy for ova and parasites, toxin test for C. difficile</td>
<td>Fecal leukocyte examination recommended for differentiation between inflammatory and secretory diarrhea</td>
<td>Swabs not sensitive (recommended only for infants)</td>
<td>Clean wide-mouthed container, unpreserved within 1 h, at RT</td>
<td>History of travel, specific food consumption</td>
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<td>Toxin test</td>
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<td>At least 5 mL of diarrheal stool</td>
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<td>Antigen detection by enzyme immunoassay (EIA) for Giardia and Cryptosporidium</td>
<td>Fecal cultures are not performed for patients who stayed &gt;3 days in hospital; test C. difficile in those patients</td>
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<td>If viruses are suspected, take 2–4 g of stool</td>
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<td>PCR for norovirus and other viruses</td>
<td>Method is used with children younger than 3 years</td>
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<td></td>
<td>PCR for C. difficile is now available and much more sensitive than EIA for toxins</td>
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<td></td>
<td>Report all findings of culture and microscopy</td>
<td>This method is used when sputum is unavailable</td>
<td>Sterile container, ≤15 min, at RT</td>
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<td></td>
<td>介绍了50 mL chilled, sterile water through nasogastric tube</td>
<td>Method is used with children younger than 3 years</td>
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<tr>
<td>Gastric content</td>
<td>Gastric lavage</td>
<td></td>
<td>Tuberculosis in children</td>
<td>Mycobacterium tuberculosis</td>
<td>Introduce 50 mL chilled, sterile water through nasogastric tube</td>
<td>Once, in the morning</td>
<td>Acid-fast bacillus (AFB) smear, culture</td>
<td>Report all findings of culture and microscopy</td>
<td>This method is used when sputum is unavailable</td>
<td>Sterile container, ≤15 min, at RT</td>
<td>Method is used with children younger than 3 years</td>
</tr>
</tbody>
</table>
Table 1-1: Specimen Selection, Collection, and Transport by Body Site (continued)

<table>
<thead>
<tr>
<th>Nervous System</th>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
<th>Specimen</th>
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<th>Test Type</th>
<th>Interpretation</th>
<th>Advantages/Disadvantages</th>
<th>Sample Transport</th>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cerebrospinal fluid (CSF)</td>
<td>• Microscopy</td>
<td>Meningitis and encephalitis</td>
<td>• <em>N. meningitidis</em>, <em>S. pneumoniae</em>, <em>S. agalactiae</em>, <em>L. monocytogenes</em>, <em>Enterobacteria</em>, <em>Leptospira</em> spp., <em>H. influenzae</em>, <em>S. aureus</em>, <em>M. tuberculosis</em> • Coxsackievirus, echovirus, poliovirus, HSV1 and HSV2, varicella zoster virus, flaviviruses, mumps virus, Bunyaviruses, Rubeola, lymphocytic choriomeningitis virus, adenoviruses • <em>Cryptocococcus neoformans</em>, <em>Histoplasma capsulatum</em>, <em>Coccidioides immitis</em>, <em>Candida</em> spp., <em>Naegleria fowleri</em>, <em>Acanthamoeba</em> spp., <em>Angiostromyelis cantonensis</em></td>
<td>Disinfect the skin with Povidine, iodine, or chlorhexidine gluconate and take 1–2 mL fluid into three tubes by lumbar puncture, or from ventricular shunt fluid</td>
<td>As clinically indicated</td>
<td>• Microscopy, culture, antigen detection, virus isolation • PCR for <em>N. meningitidis</em> and <em>S. pneumoniae</em> available in some labs and useful where culture fails • PCR for HSV and enteroviruses very sensitive</td>
<td>All findings from CSF are significant and should be reported immediately to clinician</td>
<td>Antigen tests are expensive and have low sensitivity</td>
<td>Sterile screw-capped tube, ≤15 min, at RT</td>
<td>• Obtain blood culture also • Collect sample before antimicrobial therapy • Patient age is important clue for possible agent</td>
</tr>
</tbody>
</table>
Table 1-1: Specimen Selection, Collection, and Transport by Body Site (continued)

<table>
<thead>
<tr>
<th>Nervous System</th>
<th>General Category</th>
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<th>Sample Transport</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Cerebral tissue</td>
<td>Culture</td>
<td>Brain abscess</td>
<td>Staphylococci spp., Peptostreptococci spp., Propionibacterium spp., Enterobacteriaceae, Burkholderia cepacia, S. pneumoniae, N. meningitidis, H. influenzae, Listeria monocytogenes, Haemophilus aphrophilus, Actinomyces spp., Nocardia spp., Zygomycetes, Actinomyces spp., (primary meningoencephalitis), Acanthamoeba spp., Balamuthia mandrillaris (granulomatous encephalitis)</td>
<td>As clinically indicated</td>
<td>• Brain biopsy specimen • Intraoperative specimen</td>
<td>• Culture, computed tomography • Specimen should be homogenized in sterile saline before plating</td>
<td>Brain abscess may rupture into subarachnoid space, producing severe meningitis</td>
<td>Swabs are not the optimum specimen to obtain purulent exudate</td>
<td>Transport under anaerobic conditions</td>
<td>Mainly occur as the result of direct extension from infections in surrounding areas</td>
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<table>
<thead>
<tr>
<th>Urogenital Tract</th>
<th>General Category</th>
<th>Laboratory Test</th>
<th>Indications</th>
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<th>Specimen</th>
<th>Frequency</th>
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<th>Advantages/Disadvantages</th>
<th>Sample Transport</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Urine</td>
<td>Urine culture</td>
<td>Urinary tract infections</td>
<td>E. coli, Staphylococcus saprophyticus, Proteus spp., Klebsiella spp., Enterococcus spp., Pseudomonas spp., Candida spp.</td>
<td>One early morning specimen for symptomatic patients and two consecutive samples for asymptomatic patients</td>
<td>• Microscopy • Culture</td>
<td>Presence of single microbial isolate at &gt;100,000 colony-forming unit (CFU)/mL is considered significant for all nosocomial infections (lower number applies to sexually active, symptomatic young women)</td>
<td>Do not culture indwelling Foley catheter tip or from indwelling catheter bags</td>
<td>Sterile container, ≤2 h, at RT</td>
<td>• Indicate whether or not the patient is symptomatic; pyuria is important consideration • Beware of asymptomatic bacteriuria in the elderly; in this case, pyuria also has very low specificity</td>
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<tr>
<td>General Category</td>
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<td>Specific Microbes</td>
<td>Specimen</td>
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<tr>
<td>Genital, female</td>
<td>Culture</td>
<td>Chorioamnionitis, premature rupture of membranes &gt;24 h</td>
<td><em>Ureaplasma urealyticum</em>, <em>Mycoplasma hominis</em>, <em>Bacteroides</em> spp., <em>Gardnerella vaginalis</em>, <em>Streptococcus agalactiae</em>, <em>Peptostreptococcus</em> spp., <em>E. coli</em>, <em>Enterococcus</em> spp., <em>Fusobacterium</em> spp.</td>
<td>Amniotic fluid</td>
<td>Once</td>
<td>• Microscopy • Culture</td>
<td>Other analysis of amniotic fluid can reveal many aspects of the baby’s genetic health</td>
<td>Swabbing of vaginal membranes is not acceptable</td>
<td>Anaerobic sterile tube, ≤2 h, at RT</td>
<td>Aspirate fluid via amniocentesis, or collect during Cesarean delivery</td>
<td></td>
</tr>
<tr>
<td>Genital, female</td>
<td>Microscopy • Culture</td>
<td>Vaginitis, vulvovaginitis, vaginosis</td>
<td>• <em>Trichomonas vaginalis</em>, <em>Candida</em> spp., <em>Bacteroides</em> spp., <em>Prevotella bivia</em>, <em>Prevotella disiens</em>, <em>Prevotella</em> spp., <em>Actinomyces</em> spp., <em>Peptostreptococcus</em> spp. • <em>Gardnerella vaginalis</em>, <em>Mycoplasma hominis</em></td>
<td>Bartholin gland secretions • Vaginal discharge</td>
<td>As clinically indicated</td>
<td>• Microscopy • Culture</td>
<td>• High number of commensal flora makes vaginal specimens difficult to interpret • Bacterial vaginosis is diagnosed by microscopy</td>
<td>Pus from Bartholin gland can be collected with digital palpation, otherwise take by aspiration</td>
<td>Anaerobic transport system, ≤2 h, at RT</td>
<td>Do not process vaginal specimens for anaerobes because of the potential for contamination with commensal vaginal flora</td>
<td></td>
</tr>
<tr>
<td>Genital, female</td>
<td>Culture</td>
<td>Endometritis, cervicitis, pelvic inflammatory disease</td>
<td><em>N. gonorrhoeae</em>, <em>C. trachomatis</em>, <em>S. agalactiae</em>, <em>Mycoplasma hominis</em>, <em>HSV</em>, <em>Bacteroides</em> spp.</td>
<td>Endometrial tissue and secretions • Product of conception/ fetal tissue • Placenta • Membranes • Cervical secretions</td>
<td>As clinically indicated</td>
<td>• Swab • Culture</td>
<td>Gram stain can’t be used effectively to detect <em>N. gonorrhoeae</em> in vaginal or cervical specimen</td>
<td>Likelihood for external contamination is high for cultures obtained through vagina</td>
<td>Anaerobic transport system, more than 1 mL, ≤2 h, at RT; cervical secretions in swab transport, ≤2 h, at RT</td>
<td>Visualize cervix with speculum and without lubricant; don’t process lochia</td>
<td></td>
</tr>
</tbody>
</table>
### Table 1-1: Specimen Selection, Collection, and Transport by Body Site (continued)

#### Urogenital Tract

<table>
<thead>
<tr>
<th>General Category</th>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
<th>Specimen</th>
<th>Frequency</th>
<th>Test Type</th>
<th>Interpretation</th>
<th>Advantages/Disadvantages</th>
<th>Sample Transport</th>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genital, male</td>
<td>• Gram stain • Cultures • Molecular probes</td>
<td>Urethritis, prostatitis, epididymitis</td>
<td>N. gonorrhoeae, C. trachomatis, Ureaplasma urealyticum, E. coli, other Enterobacteriaceae, Pseudomonas spp., S. aureus, S saprophyticus, Enterococcus spp., Trichomonas vaginalis</td>
<td>Insert a small swab 2–4 cm into urethral lumen, rotate 360 degrees, and leave it for 2 seconds • Prostate: cleanse meatus, massage prostate through rectum, collect fluid expressed from urethra on a sterile swab, or collect post prostate massage urine sample</td>
<td>As clinically indicated</td>
<td>• Urethral swabs • Immunologic tests • Culture</td>
<td>Positive stained smear diagnostic in a man with gonorrhea</td>
<td>Many specimens contaminated with normal skin or mucous membrane flora</td>
<td>Swab transport or sterile tube for more than 1 mL of specimen, ≤2 h, at RT</td>
<td>• The choice of swab is critical • Pathogens may be identified by quantitative culture of urine before and after massage</td>
</tr>
</tbody>
</table>

#### Hair, Nails, Skin

<table>
<thead>
<tr>
<th>General Category</th>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
<th>Specimen</th>
<th>Frequency</th>
<th>Test Type</th>
<th>Interpretation</th>
<th>Advantages/Disadvantages</th>
<th>Sample Transport</th>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hair, nails</td>
<td>• Microscopy • Culture</td>
<td>Dermatophytosis</td>
<td>Trichophyton spp., Epidermophyton spp., Microsporum spp., Candida spp., Trichosporon spp.</td>
<td>Collect 10–12 hairs • Scrape infected nail area, or clp infected nail. • Collect hairs with intact shaft</td>
<td>As clinically indicated</td>
<td>• Hair • Scrapings</td>
<td>• Direct examination with potassium hydroxide, methylene blue, etc. • Report all findings from Saburo plate</td>
<td>Humidity in a closed system may cause the sample to be overgrown by bacteria</td>
<td>Clean container, ≤24 h, at RT</td>
<td>Culture for fungi may take several weeks</td>
</tr>
<tr>
<td>Skin</td>
<td>• Gram stain • Culture</td>
<td>Impetigo, erysipelas ecchyma, folliculitis, furunculus, and carbuncles; erythema migrans</td>
<td>Streptococcus pyogenes (Group A strep), S. aureus, Borrelia burgdorferi, Trichophyton spp., Epidermophyton spp., Microsporum spp., Candida spp., Malassezia spp., Sporothrix schenckii</td>
<td>Skin sample</td>
<td>• Once • Repeat as needed</td>
<td>Swabs, biopsy, or aspirate aseptically collected</td>
<td>Presence of leukocytes represents appropriate specimen</td>
<td>High likelihood of contamination</td>
<td>Clean container, ≤2 h, at RT</td>
<td>The skin surface should be disinfected with 70% alcohol</td>
</tr>
</tbody>
</table>
### Table 1-1: Specimen Selection, Collection, and Transport by Body Site (continued)

<table>
<thead>
<tr>
<th>General Category</th>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
<th>Specimen</th>
<th>Frequency</th>
<th>Test Type</th>
<th>Interpretation</th>
<th>Advantages/Disadvantages</th>
<th>Sample Transport</th>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin, wounds</td>
<td>• Microscopy, • Culture</td>
<td>Acute wound infections, chronic wound infections, cellulitis, necrotizing fasciitis, Fournier’s gangrene</td>
<td>Aerobic and facultative microorganism: Coagulase-negative staphylococci, <em>S. aureus</em>, beta-hemolytic streptococci, Enterococcus spp., Streptococcus viridans group, Corynebacterium spp., <em>Bacillus ceno</em>, <em>E. coli</em>, <em>Serratia</em> spp., <em>Klebsiella</em> spp., <em>Enterobacter</em> spp., <em>Citrobacter</em> spp., <em>Morganella morganii</em>, <em>Providencia stuartii</em>, Proteus spp., <em>Pseudomonas aeruginosa</em>, <em>Acinetobacter baumannii</em>, <em>S. maltophilia</em>, Anaerobic bacteria: <em>Peptostreptococcus</em> spp., <em>Clostridium</em> spp., <em>Bacteroides</em> fragilis group, <em>Prevotella</em> spp., etc.</td>
<td>• Cutaneous abscesses, postsurgical wounds, bites, decubitus ulcer, skin abscess, burns, soft tissues</td>
<td>• Once</td>
<td>• Aspirate</td>
<td>Gram stain should assess the quality of the sample</td>
<td>• Tissue or aspirate is always superior to swab specimen</td>
<td>Swab transport system or anaerobic transport system, ≤2 h, at RT</td>
<td>Attention to skin decontamination is critical</td>
</tr>
</tbody>
</table>

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**Key Points**

- Sample Transport:
  - Swab transport system or anaerobic transport system, ≤2 h, at RT
  - Attention to skin decontamination is critical
References


Clinical and surveillance specimens are submitted to the clinical laboratory for quick and accurate detection of significant microbes that may be involved in an infectious disease process. Laboratory specialties for detection of clinically important and disease-causing microbes (pathogens) include microbiology, virology, parasitology, mycology (fungi), mycobacteriology, surgical pathology, and molecular diagnostics.

This chapter reviews laboratory tests utilizing microscopy (routine and special staining procedures) and microbiological cultures (see Table 2-2). It is very important to select the appropriate specimen to be submitted, ensure appropriate timing of collection, and utilize the correct method of collection to maximize recovery of potential pathogen(s) for diagnosis of an infectious process. Please refer to Chapter 1, Specimen Collection and Transport, for more information regarding these factors.

No single laboratory test is available that permits isolation of all possible pathogens. Clinical information, such as tentative diagnosis and suspected type of infection, aids in the selection of the proper media and incubation conditions for the isolation of the suspected pathogens. The specimen type will determine other culture requirements for the suspected pathogen(s) as outlined in the facility’s laboratory protocol. For example, a stool sent for bacterial culture is appropriate when bacterial gastroenteritis (e.g., shigellosis, Campylobacter infection, typhoid fever) is suspected. A stool specimen order for ova and parasites is submitted for the detection of amebiasis, giardiasis, or intestinal parasitic “worms.” An order for norovirus polymerase chain reaction (PCR) is indicated when the presence of this specific virus in a stool specimen is clinically relevant.

Important considerations regarding specimens and types of cultures

- Specimens for bacterial and fungal culture must be collected prior to initiation of antimicrobial therapy. This will ensure that organisms present in the specimen are viable for growth in culture.
- A culture result can only accurately depict the infectious process if the specimen is adequate. Laboratory collection manuals provide specific specimen collection directions to ensure an optimal specimen.
- A sufficient quantity of specimen must be submitted to ensure that all of the requested tests can be performed.
- The process of “splitting” a specimen for multiple tests must be done in a way that does not contaminate or compromise the specimen prior to setting up cultures.

Surveillance cultures require specimens from patient sites, and occasionally from environmental sites, that are known to be implicated as an ongoing source of the organism in question, as may be the case for methicillin-resistant Staphylococcus aureus (MRSA), vancomycin-resistant enterococci (VRE), Acinetobacter, and other organisms. When doing surveillance cultures of patients, knowledge of the usual sites of colonization or infection will determine specimen type. Environmental surveillance cultures require knowledge about preferred sites in which the organism persists. Surveillance cultures may be considered necessary based on an outbreak analysis or may be indicated by the facility’s ongoing infection prevention risk assessment. In either case, the infection prevention-
The Infection Preventionist's Guide to the Lab

The infection preventionist must define a surveillance plan and a standardized process consistent with evidence-based, expert guidance from the Centers for Disease Control and Prevention (CDC) and other recognized professional organizations when implementing a surveillance culture intervention or program. The reader is referred to the Healthcare Infection Control Practices Advisory Committee's 2006 Management of Multidrug-resistant Organisms in Healthcare Settings guideline for evidence-based guidance on this topic.

**Microscopy Defined and Described**

Microscopy is the science of observing images of objects (e.g., cells, microbes) that cannot be seen by the unaided eye. The most common type of microscopy performed in the microbiology lab is bright-field microscopy, in which visible light is used to illuminate a magnified image of an object. In order for the object to be best observed, as well as provide information about the structural and physiologic makeup of the cell, chemicals with well-known characteristics in staining (coloring) cells are used.

The most widely used stain in the microbiology laboratory is the Gram stain, which is used to make visible and, in certain well-defined ways, to differentiate kinds of bacteria and cells (e.g., white blood cells). The Gram stain includes four chemicals, each providing a crucial step in the process that distinguishes a Gram-positive (purple staining) cell from a Gram-negative (pink/red staining) cell (see Figure 2-1). A Gram stain of a specimen, when appropriate, can provide immediate information about an infectious process. Organisms isolated from culture are Gram stained to determine which additional tests must be done to quickly and accurately identify the organism and provide a culture result.

**Figure 2-1: Gram stain**

1. Add crystal violet dye to thin smear of specimen or bacterial cell mixture dried onto a microscope slide to stain cells purple.
2. Add Gram's iodine solution (mordant) to form a large complex between the crystal violet and iodine.
3. Add decolorizer (ethyl alcohol/acetone)—the crystal violet iodine complex is trapped in a Gram-positive cell but can escape from a Gram-negative cell (related to makeup of the cell outer membrane).
4. Add counterstain (safranin), which stains a decolorized Gram-negative cell red but does not affect the purple color of the Gram-positive cells that were not decolonized in previous step.

Note: Gram stain results always give the staining characteristic plus the morphologic shape of the microbe.

- Gram-negative bacillus (bacilli = plural), AKA Gram-negative rod, refers to pink, cylindrically-shaped microbes.
- Gram-positive bacillus (bacilli = plural), AKA Gram-positive rod, refers to purple, cylindrically-shaped microbes.
- Gram-negative coccus (cocci = plural) refers to pink, spherically-shaped microbes.
- Gram-positive coccus (cocci = plural) refers to purple, spherically-shaped microbes.

Other stains and microscopy techniques are used by laboratory professionals to characterize specific organisms or tissues that may contain pathogens, including wet preps, direct and indirect immunofluorescence, dark field microscopy, acid fast stains, and electron microscopy. Table 2-1 provides an overview of Gram stain terminology and results.

**Microbial Cultures Defined and Described**

A microbiologic culture is a laboratory technique used to grow (cultivate) bacteria and yeast. A culture of a clinical specimen can yield polymicrobial growth (more than one type of bacteria cultivated in culture), pure culture (single bacterial strain cultivated in culture), or no growth (no bacteria recovered from clinical specimen).

Identification of the bacteria or yeast grown in culture results in a genus and species designation written in italics (e.g., *S. aureus*—genus first, species second). On occasion, if sufficiently significant for identification purposes, microbes are identified by genus only (e.g., *Staphylococcus* sp., where sp. stands for species, plural spp.) signifying that the isolate is a member of the group referred to as staphylococci; or genus plus a laboratory distinguishing characteristic (e.g., coagulase negative *Staphylococcus*).
When clinically significant, the growth on cultures may be quantified or semiquantified. An example of a quantified culture result is typical in urine cultures (e.g., 50,000 colony-forming units [CFU] *Escherichia coli*). An example of a semiquantitative result is typical in throat culture (e.g., heavy growth *Group A Streptococcus pyogenes*). Some cultures do not require a quantitative result (e.g., blood culture positive for *Streptococcus pneumoniae*).

**Microbiology Techniques**

Laboratory professionals perform many tests to identify the microbes isolated in cultures and to determine the antimicrobial susceptibilities for clinically significant microbes. It is outside the scope of this chapter to review these techniques in depth, so a brief synopsis of bacterial culture techniques and aids are provided here.

Growth media, broth (liquid), or agar (solid or semisolid) that provide nutrients microbes required for growth

- Basic media: nonselective, most organisms will grow (e.g., blood agar, BHI broth, chocolate agar), colony morphology is part of the identifying workup for bacteria grown on solid media (agar)
- Selective media: incorporates antibiotics or inhibitory chemicals to inhibit growth of unwanted type of bacteria and/or preferentially encourage growth of significant bacteria
- Different media: incorporates dyes or chemicals (usually carbohydrates) that provide preliminary organism identification
- Indicator (e.g., chromagenic) media: incorporates indicator(s) that permits identification of certain significant bacteria based on uptake of a dye or development of a color

Optimal incubation parameters are provided as required by different bacteria

- Temperature requirements
- Nutrient requirements
- Incubation atmosphere (O$_2$, CO$_2$, etc.) requirements
- Time required for sufficient growth and further testing; 24 to 48 hours for indigenous flora and many microbial pathogens, 4 to 6 weeks for *Mycobacterium tuberculosis*, etc.
- Additional time required for susceptibility testing of isolates recovered from culture (24 to 48 hours)

**Differential Testing**

- Tests of biochemical responses and carbohydrate fermentation for organism identification
- Tests for microbe specific enzymes, and toxins (e.g., coagulase test, catalase test)
- Motility tests
- Germ tube test (yeast)
- Direct fluorescent antibody tests for specific bacteria
- Latex agglutination (e.g., determining streptococci groups; group A = *Streptococcus pyogenes*, group B = *Streptococcus agalactiae*, etc.)

**Special Methods**

Molecular testing methodologies have greatly enhanced the speed, specificity, and sensitivity of tests for clinically significant microbes. Examples of molecular testing methods are PCR, pulse field gel electrophoresis, Western blot assay, enzyme linked immunoassays, and molecular genotypic assays.

**Final Note**

Infection preventionists and clinical providers rely greatly on the microbiology laboratory for information crucial to infection prevention interventions and for clinical decision making. The work of the microbiology laboratory is instrumental in surveillance programs for detecting emerging significant and multidrug resistant pathogens, public health or facility outbreaks, and potential bioterrorism events. A strong, ongoing partnership between microbiology laboratory professionals and infection preventionists should remain a top priority in all infection prevention programs to ensure maximum patient safety and positive patient outcomes.
### Table 2-1: Gram Stain Terminology and Results

<table>
<thead>
<tr>
<th>Stain Type and Prep Time</th>
<th>Organism Morphology and Staining Characteristics</th>
<th>Specific Microbe Examples (not all-inclusive)</th>
<th>Key Points and Clarifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bright Field Microscopy</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Gram stain: 3 minutes | Gram-positive cocci “in chains” | Group A, B, C, G *Staphylococcus* spp., *Enterococcus*, *Peptostreptococcus*, etc. | • Coccus (plural, cocci) is spherical shape  
• Clusters of cocci of staphylococci can be referred to as “grape-like” (note: staphyle from Greek for “cluster of grapes”) |
| | Gram-positive cocci “in pairs” (diplococci) | *Streptococcus pneumoniae*, *Enterococcus* (pairs, or chains), *Micrococcus* (tetrad) | “Bacillus” is from Latin baculum meaning rod (e.g., Gram-negative bacillus AKA Gram-negative rod) |
| | Gram-positive cocci “in clusters” | *Staphylococcus* spp. (MRSA, MSSA, *S. epidermidis*, other staphylococci), diphtheroids (*Corynebacteria* spp.) | • Gram-positive = purple  
• Gram-negative = pink |
| | Gram-positive rods with or without endospores | *Clostridium* spp., *Bacillus* spp., *Listeria*, pleomorphic, coryneform bacteria (e.g., diphtheroids) | Gram variable organisms may appear as variably purple or partly pink (not uniformly stained) |
| | Gram variable rods | *Bacillus* spp., *Lactobacillus* spp. |  |
| | Gram-negative cocci | *Neisseria* (pairs “diplococci”), *Kingella* | Cocccobacillary means rounded rod shaped (e.g., *Acinetobacter* has cocccobacillus shape) |
| | Gram-negative rods | Enterobacteriaceae (E. coli, *Enterobacter*, *Klebsiella*, etc.), environmental Gram-negative rods (*Pseudomonas*, *Acinetobacter*, etc.), anaerobic Gram-negative rods (*Bacteroides*, *Fusobacteria*, *Prevotella*), others | • Diplo = one pair  
• Tetrad = two pairs in a square  
• Pleomorphic means nonuniform shape  
• Bipolar “safety pin” stain (consider *Yersinia* or *Burkholderia*) |
| | Spirochetes | *Treponema*, *Borrelia*, *Leptospira* |  |
| | Yeast and fungi | *Candida* spp., *Cryptococcus*, *Aspergillus*, *Blastomyces*, *Coccidioides* | • Special stains may be used (Gram stain not always effective)  
• Larger than bacteria, budding yeast and/or branching hyphae may be described |
| **Acid fast stain: ≤ 2 hours** | Detects “acid fast” and “partially acid fast” bacteria | *Mycobacteria*, *Nocardia*, *Cryptosporidium* | • Used for organisms that cannot be stained using Gram stain  
• Longer staining process  
• Methods: Ziehl-Neelsen, Kinyoun techniques |
| **Wet mount: 1 minute** | No stain used, check for fungi or parasites; check for motile organisms | *Trichomonas*, fungal hyphae, or yeast | Useful in vaginal specimens to detect trichomons, clue cells typical of *Gardnerella vaginalis* (vaginal epithelial cells with many adherent bacteria) |
| **Potassium hydroxide (KOH) prep: 5–10 minutes** | Direct exam for fungi | *Trichophyton*, *Microsporum* (ringworm, tinea, etc.) | Useful in skin and nail scrapings, body fluids |
| **Wright-Giemsa stain: 10–60 minutes** | Detect parasites in blood smear | *Plasmodium* spp. (malaria), *Babesia*, *Leishmania*, *Trypanosoma*, some fungi in tissue specimen | Malarial forms detected on this stain may be diagnostic (may be able to determine species type) |
| **Periodic acid-Schiff (PAS): 60 minutes** | Fungal yeast and hyphal forms in tissue specimen | Most fungi are stained by this method |  |
Table 2-1: Gram Stain Terminology and Results (continued)

<table>
<thead>
<tr>
<th>Stain Type and Prep Time</th>
<th>Organism Morphology and Staining Characteristics</th>
<th>Specific Microbe Examples (not all-inclusive)</th>
<th>Key Points and Clarifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>India ink</td>
<td>Encapsulated yeast</td>
<td><em>Cryptococcus</em> spp.</td>
<td>• “Halo effect” around organism&lt;br&gt;• Useful test on spinal fluid, other body fluids</td>
</tr>
<tr>
<td>Trichrome</td>
<td>Parasites in stool</td>
<td><em>Giardia, Entamoeba, Endolimax</em></td>
<td>• Detects protozoan cysts, eggs, trophozoites</td>
</tr>
</tbody>
</table>

**Microscopy—Other**

<table>
<thead>
<tr>
<th>Microscopy Type</th>
<th>Organism Morphology and Staining Characteristics</th>
<th>Specific Microbe Examples (not all-inclusive)</th>
<th>Key Points and Clarifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Darkfield microscopy</td>
<td>Motile forms of bacteria and other cells</td>
<td><em>Spirochetes, sperm, protozoa</em></td>
<td>• Special microscope lens and filter system&lt;br&gt;• Bright organisms seen against a black background</td>
</tr>
<tr>
<td>fluorescent microscopy</td>
<td>fluorescent dye linked to antibody specific to organism of interest</td>
<td>Direct antibody tests and indirect antibody tests (technique specific) to detect antigen of organism, cell, etc.</td>
<td>• Special microscope lens and filter system&lt;br&gt;• Fluorescing organisms seen against a black background&lt;br&gt;• Color is specific to fluorescent dye used (often fluorescent green or red)</td>
</tr>
<tr>
<td>General Category</td>
<td>Laboratory Test</td>
<td>Indications</td>
<td>Specific Microbes</td>
</tr>
<tr>
<td>------------------------------------------------------</td>
<td>-----------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Microbiology: Culture and sensitivity for clinical</td>
<td>Blood culture</td>
<td>Clinical sepsis, fever of unknown origin, pneumonia, suspected catheter-related</td>
<td>Aerobic and anaerobic Gram-positive cocci (e.g., <em>Staphylococcus</em>, <em>Streptococcus</em>), Gram-positive</td>
</tr>
<tr>
<td>management of patient condition</td>
<td></td>
<td>bloodstream infection, subacute or acute bacterial endocarditis, urosepsis,</td>
<td>rods (<em>Bacillus</em>), Gram-negative cocci (e.g., <em>Neisseria</em>), mycobacteria, yeast, other fungi, others</td>
</tr>
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</table>
### Table 2-2: Overview of Cultures and Gram Stains (continued)

<table>
<thead>
<tr>
<th>General Category</th>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
<th>Specimen</th>
<th>Frequency</th>
<th>Test Type</th>
<th>Interpretation</th>
<th>Advantages/ Disadvantages</th>
<th>Key Points</th>
</tr>
</thead>
</table>
| Microbiology: Culture and sensitivity for clinical management of patient condition (continued) | CSF cell count and chemistry; additional laboratory tests | Meningitis, encephalitis, post-procedures accessing epidural space or spinal canal, neonatal sepsis | *Streptococcus pneumoniae*, *Neisseria meningitidis*, *Haemophilus influenzae*, Group B *Streptococcus*, especially in neonates, S. aureus, *Cryptococcus* fungi, mycobacteria, viral pathogens such as West Nile virus (WNV), Eastern equine encephalitis virus (EEE), varicella, herpes, prions | • CSF  
• Note that if prion disease is a consideration, special handling of used equipment and follow-up of unanticipated exposures is necessary | Acute illness onset; chronic condition (e.g., prion disease or multiple sclerosis) | • Hematology  
• Chemistry | • Gram stain: presence of >5 white blood cells (WBCs) in non-bloody specimen  
• Predominant neutrophils (segs) common in bacterial disease  
• Predominant lymphocytes common in viral disease  
• Eosinophils (>10/mm³) in parasitic meningitis (e.g., *Angiostrongylus*) and fungal meningitis (e.g., *Coccidioides*) | • In addition to CSF culture: presence of WBCs (neutrophils or lymphocytes), increase in protein and decrease in glucose may be associated with bacterial meningitis  
• Neutrophils (segs) and normal glucose may be associated with early viral (enterovirus, WNV, EEE, St. Louis encephalitis)  
• Lymphocytes present with low glucose may be associated with tuberculosis (TB), fungal, tumor |
| Body fluid culture | Fluid aspirated from joint or organ space | Acute illness onset; chronic condition complication | Aerobic and anaerobic bacteria, fungi, mycobacteria, and other acid-fast bacilli (AFB) | • Knee, hip, or other joint fluid  
• Pleural fluid  
• Pericardial fluid  
• Peritoneal (ascites) | Acute illness onset; chronic condition complication | • Acrobic and anaerobic culture  
• Fungal culture  
• AFB culture | Gram stain positive for WBCs, bacteria, yeast can be significant for infection; WBCs may only indicate noninfectious inflammation | Quick aid to treatment if Gram stain is positive for bacteria  
• If bacterial, identification and antibiotic susceptibility typically resulted within 3–5 days | If organisms that cannot be cultured are suspected, order organism-specific tests; additional laboratory tests include body fluid protein, glucose, other stains |
### Table 2-2: Overview of Cultures and Gram Stains (continued)

<table>
<thead>
<tr>
<th>General Category</th>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
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<th>Advantages/ Disadvantages</th>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbiology: Culture and sensitivity for clinical management of patient condition (continued)</td>
<td>Lower respiratory culture</td>
<td>Lower respiratory infection (LRI): tracheobronchitis, pneumonia, empyema, opportunistic infections of the lower respiratory tract in immunosuppressed patients</td>
<td>Aerobic and anaerobic bacteria including <em>Streptococcus pneumoniae</em>, <em>Klebsiella pneumoniae</em>, <em>Staphylococcus aureus</em>, <em>Mycobacterium tuberculosis</em> and other AFB, <em>Nocardia</em> and <em>Actinomyces</em>, <em>Histoplasma</em>, * Blastomyces*, <em>Coccidioides</em>, <em>Mycoplasma</em>, viral pathogens, <em>Pneumocystis</em>, others</td>
<td>• Sputum • Induced sputum • Bronchoscopy (lavage, brush biopsy, etc.)</td>
<td>Acute illness (bacterial, viral); chronic illness (some fungal, opportunistic, mycobacterial, and parasitic etiologies)</td>
<td>• Gram stain • Routine culture • Susceptibility • Blood culture • Fungal culture • AFB/mycobacterial stain and culture • Viral culture • PCR testing for specific pathogen</td>
<td>• Organism cultured from blood can be significant in pneumonia • Bronchoscopy specimen is preferred over sputum as upper respiratory normal flora in culture can confound assessment of clinical picture • Some lower respiratory pathogens have very specific culture requirements often only available at reference labs • Environmental organisms isolated from specimens in patients on ventilator may be clinically significant</td>
<td>• If organisms that cannot be cultured are suspected, order organism-specific tests • Additional stains may be appropriate (e.g., AFB, PAS, others) • Bacteria aspirated from throat (normal flora) may cause pneumonia or LRI but may also be contaminants from nonsterile specimen collection via upper respiratory tract</td>
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<tr>
<td>Upper respiratory culture</td>
<td>Throat infection, nasal colonization, or abscess</td>
<td>Group A <em>Streptococcus</em> (Streptococcus pyogenes), <em>Staphylococcus aureus</em>, influenza, <em>Candida</em>, <em>Haemophilus influenzae</em> (children), <em>Neisseria meningitidis</em> carriers, others</td>
<td>• Throat swab • Anterior nares swab • Nasopharyngeal aspirate</td>
<td>Acute upper respiratory illness, sinusitis, infection prevention surveillance</td>
<td>Culture or rapid point of care (POC) test for Group A strep and influenza</td>
<td>• Known respiratory pathogens identified in culture or by POC test is clinically significant • &quot;Normal throat flora&quot; is resulted as such in culture • Gram stain is generally not helpful due to presence of normal flora</td>
<td>• Specimen easy to obtain • POC test results available quickly • POC test (waived test) often done in satellite labs or doctor's offices</td>
<td>• POC tests for Group A strep and influenza are often less sensitive • Negative result may be followed up by culture or other confirmatory test</td>
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<tr>
<td>General Category</td>
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<td>Specific Microbes</td>
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<td><strong>Microbiology:</strong> Culture and sensitivity for clinical management of patient condition (continued)</td>
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<td>Other tests for upper respiratory infection</td>
<td></td>
<td>Whooping cough, sore throat, parotitis, coughing, illness</td>
<td>Bordetella pertussis, mumps, respiratory syncytial virus (RSV), influenza, other bacterial and viral agents</td>
<td>Nasopharyngeal collection (swab or aspirate)</td>
<td>Acute illness</td>
<td>• POC test&lt;br&gt;• PCR&lt;br&gt;• Direct fluorescent antibody (DFA)&lt;br&gt;• Viral culture</td>
<td>Negative POC test result may be followed up by confirmatory test</td>
<td>• Nasopharyngeal collection more invasive&lt;br&gt;• Special transport media based on microbe suspected may be required</td>
<td>Specimen collection technique critical to recovery of organisms—ensure nasopharyngeal technique used (See Chapter 8 for antibody tests)</td>
</tr>
<tr>
<td>Urinary tract culture</td>
<td>UTI including bladder or kidney infection; kidney stones in urinary tract are sometimes associated with bacteriuria (bacteria in urine) with or without symptoms of infection</td>
<td>E. coli, Enterobacter, Klebsiella, Morganella, Citrobacter, Proteus, Pseudomonas, Serratia, Enterococcus spp., Staphylococcus spp., Candida spp., others</td>
<td>Specimen obtained by “clean catch” or aseptic collection of urinary catheter</td>
<td>Acute illness, urologic condition</td>
<td>Quantitative culture and susceptibility</td>
<td>• Symptomatic UTI colony count &gt;100,000 CFU/mL with no more than 2 species is clinically significant&lt;br&gt;• Or 1000 – 100,000 CFU with pyuria per NHSN criteria&lt;br&gt;• Urinalysis frequently of additional help (See Chapter 9)</td>
<td>Clinical assessment differentiates symptomatic UTI from asymptomatic bacteriuria</td>
<td>Specimen collection technique and prompt delivery to microbiology to ensure specimen integrity&lt;br&gt;• Do not routinely order culture in patients with urinary catheter unless UTI is suspected by clinician&lt;br&gt;• DO NOT culture urinary catheter tips</td>
<td></td>
</tr>
<tr>
<td>Wounds and abscess culture</td>
<td>Skin and soft tissue infections, cellulitis, necrotizing fasciitis</td>
<td>Staphylococci, Streptococcus spp., Gram-negative bacteria, yeast, and fungi</td>
<td>• Aseptically obtained abscess aspiration or tissue&lt;br&gt;• Swab of advancing margin of base of wound after cleansing outer portion of wound</td>
<td>Acute infection</td>
<td>• Culture and Gram stain&lt;br&gt;• Other culture types per clinical request</td>
<td>Presence of organisms correlated with symptoms and clinical status</td>
<td>Gram stain of specimen aseptically obtained from wound bed can direct empiric treatment before culture results</td>
<td>• Specimen collection technique important for actual organism recovery&lt;br&gt;• Skin flora contamination possible</td>
<td></td>
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<tr>
<td>Surgical site infection (SSI) cultures</td>
<td>SSI symptoms associated with skin incision, deep tissue, or organ space surgical site</td>
<td>Surgical site pathogens may include normal skin, respiratory or intestinal flora, environmental microbes, fungus, mycobacteria, Nocardia, Actinomyces, anaerobic microbes, others</td>
<td>• Aseptically obtained abscess aspiration or tissue&lt;br&gt;• Swab of advancing margin of base of wound after cleansing outer portion of wound&lt;br&gt;• Computed tomography (CT)-guided specimen collection, surgical debridement specimen</td>
<td>Acute illness or acute symptoms</td>
<td>Routine culture and Gram stain</td>
<td>Presence of organisms is correlated with symptoms and clinical status</td>
<td>Gram stain of specimen aseptically obtained from surgical site can direct empiric treatment before culture results</td>
<td>See CDC and NHSN surveillance criteria for additional information regarding SSI criteria and designations</td>
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<tr>
<td>General Category</td>
<td>Laboratory Test</td>
<td>Indications</td>
<td>Specific Microbes</td>
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</table>
| Microbiology: Gastrointestinal (GI) tract infections | GI symptoms per infectious etiology | *Salmonella*, *Shigella*, *Campylobacter*, *Giardia*, *Vibrio*, *Yersinia*, *Clostridium difficile* or its toxins, *norovirus*, *rotavirus*, *Entamoeba*, *Giardia*, *Cryptosporidium*, *ovum* from parasitic “worms,” *tapeworm* (whole or segments), nematodes, *trematodes* (flatworms), yeast, alterations in normal flora, others | • Stool, colonic washings  
• Occasionally emesis specimen, blood, or urine | Acute illness, when diarrheal specimen can be obtained | • Routine culture  
• Ova and parasite test  
• PCR tests  
• Gross exam for intestinal worms (including worm segments) | Presence of pathogens, ova and/or parasites, toxins correlated with GI symptoms | • Ova and parasite test  
• PCR and toxin tests may be available same day  
• Culture results often available within 48 hours | • Diarrheal stool specimen indicates active condition and is required when testing for *C. difficile* toxin  
• Urine and blood may also be positive for *Salmonella* or *Shigella*  
• Copious stool flora requires selective and enhanced media for isolation of pathogens |
| Genital infections | Symptoms of genital infection | *Candida* spp. (“yeast”), *Gardnerella vaginalis* (bacterial vaginosis), *Trichomonas* | • Culture  
• PCR  
• Gram stain  
• Wet mount | • Motile flagellar protozoan, size of a WBC = *Trichomonas*  
• Budding cells smaller than an RBC = yeast +/- pseudohyphae  
• Clue cells = epithelial cells with adherent bacteria | • Candida can be detected in culture or wet prep  
• *Trichomonas* is detected in wet prep  
• *Gardnerella vaginalis* can be detected in wet prep or Gram stain (clue cells) |
| Sexually transmitted disease testing per clinical assessment | *Neisseria gonorrhoeae*, *Trichomonas*, *Chlamydia trachomatis* | *Gram-negative diplococci* suggests *N. gonorrhoeae* | PCR test is used for *Chlamydia trachomatis* (Gram-negative intracellular parasite and not readily grown in culture)  
PCR or culture can detect *N. gonorrhoeae* | Motile spirochete that may be detected in a specimen using darkfield microscopy; however, is generally tested for by serologies (immune response) including RPR (nonspecific) and FTA, TPA, etc. (specific) |
### Table 2-2: Overview of Cultures and Gram Stains (continued)

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<tr>
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<td>Group B <em>Streptococcus</em> (GBS)</td>
<td>For GBS, lower vaginal and/or rectal swab</td>
<td>Obtain 1 specimen at 35–37 weeks</td>
<td>Culture or PCR</td>
<td>Presence of GBS—clinicians follow CDC guidelines</td>
<td>Timing during pregnancy is important</td>
<td>PCR is faster than culture when test is ordered STAT in a laboring woman with no prior testing; GBS in urine can be a marker for vaginal GBS colonization</td>
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<td>Maternal surveillance cultures for clinical management</td>
<td>Pregnancy, maternal issues</td>
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<td>Blood test</td>
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<td>Serologic test for immune status and/or active infection</td>
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<td>Microbiology: Culture for infection prevention and control purposes</td>
<td>MRSA surveillance cultures; other surveillance cultures per infection prevention (IP) policies or during outbreak situations</td>
<td>Annual, ongoing surveillance per infection prevention risk assessment, other surveillance cultures per IP policies</td>
<td>MRSA, VISA/VRSA (vancomycin-intermediate or resistant <em>S.aureus</em>); other organisms per IP risk assessment, may include multidrug-resistant <em>Acinetobacter, Pseudomonas, Stenotrophomonas, VRE, ESBL</em> Gram-negative rods, carbapenemase-resistant Gram-negative rods (including KPC, CBE, NDM-1), drug resistant <em>Streptococcus pneumoniae, Neisseria gonorhoeae</em>, other emerging pathogens</td>
<td>MRSA surveillance via nasal swab at minimum, other sites as appropriate for organism of interest</td>
<td>Surveillance for colonization; per IP policy</td>
<td>Routine culture</td>
<td><em>Surveillance cultures ordered for IP purposes (e.g., transmission based precautions, patient risk groups, outbreaks, etc.)</em></td>
<td>Surveillance cultures not routinely done for clinical management of patient unless medically indicated; Surveillance cultures are used for patient placement purposes and for decisions on discontinuing precautions; Note: surveillance cultures for staff colonization not routinely indicated unless staff are implicated in cluster/outbreak</td>
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</table>
| Microbiology: Culture for infection prevention and control purposes (continued) | Other surveillance situations | Outbreak or increased incidence in population, unit, or facility; surveillance as indicated per IP risk assessment | Emerging pathogens, significant pathogen cluster, outbreak investigation, possible bioterrorism event | Specimen determined by normal colonization site of organism of interest and presence of patient tubes or lines | Per IP policy for surveillance cultures | • Routine culture  
• Chromogenic or other specialty agars  
• PCR  
• Sensitivity if indicated for microbe identification  
• Genotypic testing if indicated in outbreak investigation | Presence of organism indicates colonization unless symptoms of upper respiratory infection are present and/or infection is suspected | • Surveillance cultures ordered for infection prevention purposes per infection prevention risk assessment  
• Cultures not done for medical management of patient | • Outbreak surveillance cultures aids in characterization and control of outbreak  
• Annual infection prevention risk assessment determines routine surveillance culture criteria  
• Bioterrorism events—special considerations and laboratory requirements, obtain guidance from public health department and CDC |
References


Hospitalizations for sepsis have more than doubled in the United States between the years 2000 and 2008 according to a recent report released by the CDC’s National Center for Health Statistics. Data from the National Hospital Discharge Survey, 2008 shows a dramatic increase in the number of sepsis cases from 326,000 in 2000 to 727,000 in 2008. As the U.S. population has aged, increased use of invasive devices, extended device dwell time, increased antimicrobial use, and emerging antimicrobial resistance have all contributed to rising numbers of sepsis cases. Due to the high morbidity and mortality associated with septicemia, prompt and accurate diagnosis is essential. The laboratory test that is used to detect the presence of microorganisms in the blood is the blood culture.

**Bacteremia types**

According to the *Manual for Clinical Microbiology*, there are several types of bacteremia, depending on the source from which bacteria enters the bloodstream. Primary bacteremia refers to the presence of bacteria in the blood in the absence of an identifiable source or as the result of “silent” subclinical passage of bacteria from normally colonized sites in the body. This commonly occurs after dental procedures with no clinically significant sequelae. Secondary bacteremia refers to bacteria that enter the bloodstream from a primary site such as the lungs or a remote wound infection. Intermittent bacteremia occurs when bacteria are present in the blood for periods of time followed by nonbacteremic episodes. Continuous bacteremia occurs when patients with intravascular sites of infection such as endocarditis experience continuous seeding of the blood from a remote site. Many of these patients have very low quantities of bacteria in their blood, in spite of severe clinical symptoms.

Primary and secondary bacteremia can result in sepsis, septic shock, or severe sepsis. Symptoms such as fever, chills, and tachycardia indicate sepsis, and the presence of hypotension along with sepsis indicates septic shock. Acute organ dysfunction, secondary to severe sepsis, has a 20 to 40 percent mortality rate. Because of the high morbidity and mortality associated with any type of sepsis, blood cultures have become the focal point of the sepsis workup and are critical to prompt diagnosis and treatment.

The *Manual for Clinical Microbiology* defines infective endocarditis (IE) as “an infection of the lining of the heart chambers and valves. IE occurs when bacteremia or fungemia delivers infectious organisms to the surface of one or more heart valves where they adhere and eventually invade the valvular leaflets.” As with sepsis, blood culture results are vital to the diagnosis and management of patients with IE. Current culture techniques allow positive blood cultures to be obtained in more than 90 percent of infective endocarditis cases. Continuous bacteremia is often the result of IE and, because of this, the timing of specimen collection for blood cultures is less important. Clinical and Laboratory Standards Institute recommends that blood cultures be collected 30 minutes prior to starting empiric antimicrobial therapy.

**The role of blood cultures in infection prevention and surveillance**

With the advent of public reporting of healthcare-associated infections (HAIs) in many states and the recent CMS reporting requirements linked to Medicare reimbursement, there is significant interest in the collection and interpretation of blood cultures for confirmation of central venous catheter (often called central lines) infection.
Central Line–Related Blood Stream Infection (CRBSI) versus Central Line–Associated Blood Stream Infection (CLABSI)

CRBSI and CLABSI are often used interchangeably to describe bloodstream infections linked to intravascular catheters. However, it is important that clinicians and infection preventionists understand differences between the definitions of CRBSI and CLABSI to avoid misclassification.

**CRBSI**

CRBSI is a rigorous clinical definition that requires specific laboratory testing to identify a catheter as the source of the BSI. The CRBSI definition is not used for surveillance, but rather for clinical research or determining diagnosis and treatment.

To determine that an infection is directly related to the presence of the vascular access catheter, specific diagnostic criteria must be met. These criteria include one the following diagnostic tests:

- A positive semiquantitative (>15 colony-forming units [CFU/segment]) or quantitative (>10³ CFU/segment) cultures in which the same organism (species and antibiogram) is isolated from the catheter segment and peripheral blood. Semiquantitative testing is the most commonly performed test due to its lower cost and simple technique. However, it does not detect organisms on the intraluminal surface of the catheter and may lead to a false-negative result, because bacterial biofilms may be present on both the exterior and/or interior surfaces of the device.

- Simultaneous quantitative blood cultures with a ≥5:1 ratio central venous catheter (CVC) versus peripheral. This is the most reliable method but may not be available in all laboratories.

- Differential time-to-positivity between two blood cultures. If the blood culture obtained from the device is positive at least two hours before the percutaneously obtained culture, the infection is then related to the catheter.

A drawback in CRBSI testing is that the catheter must be removed. This can be problematic for the patient who requires venous access and increases the costs of care. Furthermore, the advantages and disadvantages of CRBSI remain controversial—large randomized controlled studies have not been conducted. As a result, the impact of prior antimicrobial therapy, the use of antimicrobial impregnated or coated catheters, the presence of multilumen catheters, and questions regarding the appropriate threshold for positive results complicate CRBSI analysis.

**CLABSI**

CLABSI is a less scientifically rigorous definition and is only used for surveillance purposes. National Healthcare Safety Network (NHSN) defines CLABSI as a bloodstream infection that develops within 48 hours of insertion of a central venous or umbilical catheter. In the NHSN system, the infection must be described as primary or secondary during the reporting process. A primary CLABSI is (a) laboratory confirmed infection and (b) not an HAI meeting CDC/NHSN criteria for another body site.

Only lumened devices that terminate at or adjacent to the heart are included in CLABSI reporting. Pacemaker wires, extracorporeal membrane oxygenation (ECMO), intraaortic balloon pumps (IABPs), and femoral arterial catheters are not included as central catheters. However, peripherally inserted central catheters (PICCs) are part of CLABSI reporting in NHSN.

NHSN requires that, in addition to patient identification and demographic information, the following elements are reported:

- If the CLABSI has been detected after any procedure, and if so, when and what type
- If the CLABSI is part of the organization's in-plan MDRO/CDI reporting
• Risk factors identified
• Event details describing patient signs and symptoms
• Event details by laboratory findings (recognized pathogen from one of more cultures or common commensals from at least two or more cultures)
• Identified pathogens and their sensitivities

The culture of the catheter tip or any segment of the catheter is not a criterion for CLABSI.7

As value-based purchasing (VBP) becomes the norm in healthcare, the differences in CRBSI and CLABSI definitions, as well as their correct application, will become increasingly important. Currently, CMS requires that the CDC NHSN definition of CLABSI be used when reporting catheter-associated bloodstream infections for Medicare reimbursement. It is important to note that these surveillance definitions were not intended to be used for reimbursement purposes. The initial and ongoing intent of the CDC has been to develop a baseline reporting tool capable of producing comparable data across institutions and settings.

Blood Culture Tests

The accuracy of a blood culture can be impacted by a wide variety of factors, many of which pertain to skin antisepsis and/or specimen collection techniques.

Skin Antisepsis: In order to minimize the risk of contamination of the blood specimen with common commensals, the venipuncture site should be cleaned with an antiseptic. The most common antiseptics used are rubbing alcohol, tincture of iodine, povidone-iodine, iodophors, and chlorhexidine gluconate (CHG).

• Studies suggest that tincture of iodine and CHG are superior to povidone-iodine.
• It is important to follow the manufacturer’s guidelines regarding the amount of time required for the antiseptic product to dry. If venipuncture is performed before the product has been in place long enough to achieve its full bactericidal effect, the integrity of the blood specimen may be jeopardized.
• CHG products are increasingly used as they are effective, require only 30 seconds to dry, and are not commonly associated with allergic reactions. CHG products do not need to removed or rinsed from the skin following venipuncture.
• Special considerations in pediatrics: CHG products are not approved for use with infants younger than 2 months of age. In addition, iodine-containing compounds should not be used with neonates due to the potential of developing subclinical hypothyroidism. For patients younger than 2 months of age, 70 percent isopropyl alcohol is an acceptable alternative.8

Specimen Collection: In order to assure the integrity of the specimen and the accuracy of testing, the following general guidelines for specimen collection must be followed:

• The volume of blood obtained for culture is a critical variable in detecting bacteremia or fungemia.
• Specimen collection from the central catheter is not recommended due to the possibility of intraluminal bacterial contamination of the device. Percutaneous venipuncture from two separate sites is preferred. Inguinal blood vessels (groin) should be avoided when other venipuncture sites are available.
• Follow institutional policy regarding any amount to be discarded when blood is sampled from indwelling vascular access devices.
• Blood specimens are only obtained from peripheral vascular access catheters at the time of insertion. If a patient has a peripheral catheter in place, the sample must be obtained percutaneously.
• It is critical that blood cultures be drawn prior to initiation of antibiotic therapy. Blood may not become sterile immediately following antimicrobial therapy. If empiric antibiotic therapy is initiated on an emergency basis, cultures should be obtained as soon as possible following the first dose.
• Single blood cultures should never be drawn from adult patients, as these results can be misleading.
Only designated blood culture bottles are used for specimen collection. If blood is drawn into tubes, sodium polyanetholesulfonate (SPS) anticoagulant can inhibit microbial growth.

The accidental contamination of blood culture bottles is unfortunately a common problem. It is essential that the tops, into which the blood specimen is transferred, remain sterile until the transfer is completed.

For neonates and pediatric patients the volume of blood should be no more than 1 percent of the patient’s total blood volume.

Blood culture bottles must be labeled following laboratory policy and should indicate not only the patient’s name and other required identification information, but also the date, time, and location of specimen collection. If blood is obtained from a multilumen catheter, the specific lumen sampled should be described.

Follow institutional policy regarding the removal of needleless connectors attached to the end of a central catheter. Although some products are labeled for blood sampling, many institutions require their removal to eliminate the risk of contamination by biofilm that can accumulate in the interior components of these devices. The previously used connector is then discarded and a new, sterile connector is attached after the blood specimen is obtained.

See Table 3-1 for general guidelines for the collection of blood culture specimens.
### Table 3-1: General Guidelines for Blood Culture Specimen Collection

<table>
<thead>
<tr>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
<th>Specimen Collection</th>
<th>Media</th>
<th>Time to Results</th>
<th>Test Type</th>
<th>Common Skin Contaminants</th>
<th>Interpretation</th>
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</thead>
</table>
| **Routine blood cultures**       | Acute febrile episode        | Aerobic and anaerobic Gram-positive cocci (e.g., *Streptococcus*, *Staphylococcus*), Gram-positive rods (*Bacillus*), Gram-negative rods (e.g., *Escherichia coli*, *Pseudomonas*), Gram-negative cocci (e.g., *Neisseria*) | • Collect two to three sets in a 24-hour period                                      | • Broth media is commonly used                                      | Incubated for 3 days | • Continuous monitoring systems incubate, agitate, and continuously monitor blood culture bottles for organism growth  
• The most common systems rely on increased CO₂ production by actively metabolizing organisms in the blood culture (BLC) bottles  
• A sensor at the bottom of the bottle will undergo acidification and either a colorimetric, fluorometric, or pressure change will occur that is detected by the system  
• Bottles are monitored every 10 minutes for changes in sensor; agitation is continuous to increase yields and improve time to recovery of organisms  
• Staphylococcus epidermidis, *Bacillus* spp., *Propionibacterium*, *Streptococcus viridans*  
• In general, single cultures positive for these bacteria represent contamination  
• Multiple, separate cultures drawn from different sites growing one of these organisms are considered positive  
• Contamination rates of less than 3 percent are desired | • One positive bottle out of two bottles drawn is a positive result  
• BLC results are typically reported according to the organism’s Gram stain reaction (positive or negative) and morphology seen on the slide (e.g., *staphylococci* are reported as Gram-positive cocci in clusters, entero- cocci are reported as Gram-positive cocci in chains and pairs, *E. coli* is Gram-negative and appears in rods) |
| **Pediatric blood cultures**     | Suspected sepsis             | As for adult patients; that is, aerobic and anaerobic Gram-positive cocci (e.g., *Streptococcus*, *Staphylococcus*), Gram-positive rods (*Bacillus*), Gram-negative rods (e.g., *Escherichia coli*, *Pseudomonas*), Gram-negative cocci (e.g., *Neisseria*) | • Collect two to three sets in a 24-hour period                                      | Routine aerobic broth media                                          | Five days           | • As for adult patients; that is, *S. epidermidis*, *Bacillus* spp., *Propionibacterium*, *S. viridans*  
• In general, single cultures positive for these bacteria represent contamination  
• Multiple, separate cultures drawn from different sites growing one of these organisms are considered positive  
• Contamination rates of less than 3 percent are desired | • As for adult patients; that is, one positive bottle out of two bottles drawn is a positive result  
• BLC results are typically reported according to the organism’s Gram stain reaction (positive or negative) and morphology seen on the slide (e.g., *staphylococci* are reported as Gram-positive cocci in clusters, entero- cocci are reported as Gram-positive cocci in chains and pairs, *E. coli* is Gram-negative and appears in rods) |
<table>
<thead>
<tr>
<th>Laboratory Test</th>
<th>Indications</th>
<th>Specific Microbes</th>
<th>Specimen Collection</th>
<th>Media</th>
<th>Time to Results</th>
<th>Test Type</th>
<th>Common Skin Contaminants</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood cultures for rare and fastidious pathogens</td>
<td>Fever of unknown origin (FUO), IE, subacute endocarditis (SBE)</td>
<td>HACEK group (Haemophilus spp., Actinobacillus spp., Cardiobacterium spp., Eikenella spp., Kingella spp., Abiotrophia spp., Bartonella spp., Brucella spp., Campylobacter spp., Francisella spp., Helicobacter spp., Legionella spp., Leptospira spp., Mycoplasma spp.)</td>
<td>• Collect two to three sets in a 24-hour period; • Collect 20 mL per set divided into aerobic and anaerobic bottles</td>
<td>No special media needed</td>
<td>Hold for 21 days if negative at 5 days</td>
<td>Continuous monitoring systems have demonstrated acceptable recovery of these organisms</td>
<td>• As for routine blood cultures; that is, S. epidermidis, Bacillus spp., Propionibacterium, S. viridans</td>
<td>• A phenomenon sometimes associated with these organisms is that of signal-positive (analyzer detects a positive signal from blood culture bottle)/Gram stain negative cultures; these organisms may have atypical morphology or unusually small size; • In these cases clinical correlation should be attempted; culture may be held for 21 days</td>
</tr>
<tr>
<td>Mycobacterial blood cultures: Lysis centrifugation</td>
<td>When mycobacterial infections are suspected; not generally part of a sepsis workup</td>
<td>Growth of Mycobacterium tuberculosis as well as the nontuberculous mycobacteria</td>
<td>Consult laboratory</td>
<td>Optimal recovery requires supplementation of broth cultures with fatty acids (e.g., oleic acid), albumin, and carbon dioxide</td>
<td>Due to slow generation time, incubate minimum of 4 weeks</td>
<td>Automated broth-based media has shown superior recovery rates</td>
<td>As for routine blood cultures (see above)</td>
<td>Mycobacteria grow on solid or in broth media from the lysed material</td>
</tr>
<tr>
<td>Fungal blood cultures</td>
<td>When fungal infections are suspected</td>
<td>Generally yeast forms such as Candida and Cryptococcus</td>
<td>Consult laboratory</td>
<td>Recovery of yeasts is best in aerobic broth formulations; Special media is not necessary</td>
<td>Five days for recovery of yeast</td>
<td>Continuous monitoring systems have demonstrated acceptable recovery rates of yeast</td>
<td>As for routine blood cultures (see above)</td>
<td>Yeast has a distinctive morphology on Gram stain and is reported as such</td>
</tr>
<tr>
<td>Laboratory Test</td>
<td>Indications</td>
<td>Specific Microbes</td>
<td>Specimen Collection</td>
<td>Media</td>
<td>Time to Results</td>
<td>Test Type</td>
<td>Common Skin Contaminants</td>
<td>Interpretation</td>
</tr>
<tr>
<td>-----------------</td>
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</tr>
<tr>
<td>Manual fungal blood culture systems</td>
<td>When fungal infections are suspected</td>
<td>Generally yeast forms such as <em>Candida</em> and <em>Cryptococcus</em></td>
<td>Consult laboratory</td>
<td>Nutrient broth</td>
<td>Five days</td>
<td>Manual fungal blood culture—nutrient broth</td>
<td>• As for routine blood cultures; that is, <em>S. epidermidis</em>, <em>Bacillus</em> spp., <em>Propionibacterium</em>, <em>S. viridans</em>&lt;br&gt;• In general, single cultures positive for these bacteria represent contamination&lt;br&gt;• Multiple, separate cultures drawn from different sites growing one of these organisms are considered positive&lt;br&gt;• Contamination rates of less than three percent are desired</td>
<td>Yeast has a distinctive morphology on Gram stain and is reported as such</td>
</tr>
<tr>
<td>When fungal infections are suspected</td>
<td>Generally dimorphic forms such as <em>Histoplasma capsulatum</em> and filamentous fungi</td>
<td>Consult laboratory</td>
<td>Biphasic bottles (agar plus broth)</td>
<td>Four weeks' incubation required for reliable detection of dimorphic fungi</td>
<td>Biphasic fungal blood culture</td>
<td>As for routine blood cultures (see above)</td>
<td>Blood cultures for dimorphic fungi can only be grown by this method to recover both the yeast and the filamentous (&quot;fuzzy&quot;) phases</td>
<td></td>
</tr>
<tr>
<td>When fungal infections are suspected</td>
<td>Generally dimorphic forms such as <em>H. capsulatum</em> and filamentous fungi</td>
<td>Consult laboratory</td>
<td>• Fungal blood culture for dimorphic fungi&lt;br&gt;• Yeast on one medium, &quot;fuzzy,&quot; or filamentous on another medium at room temperature</td>
<td>Four weeks' incubation required for reliable detection of dimorphic fungi</td>
<td>Lysis centrifugation fungal blood culture</td>
<td>As for routine blood cultures (see above)</td>
<td>Blood cultures for dimorphic fungi can only be grown by this method to recover both the yeast and the filamentous (&quot;fuzzy&quot;) phases</td>
<td></td>
</tr>
<tr>
<td>Laboratory Test</td>
<td>Indications</td>
<td>Specific Microbes</td>
<td>Specimen Collection</td>
<td>Media</td>
<td>Time to Results</td>
<td>Test Type</td>
<td>Common Skin Contaminants</td>
<td>Interpretation</td>
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</tr>
<tr>
<td>Parasite blood cultures</td>
<td>When parasitic blood infections are suspected</td>
<td>Only a few parasites can be cultured: <em>Entamoeba histolytica</em>, <em>Naegleria fowleri</em>, <em>Acanthamoeba spp.</em>, <em>Trichomonas vaginalis</em>, <em>Trypanosoma cruzi</em>, and <em>Leishmania</em></td>
<td>Consult laboratory</td>
<td>Consult laboratory</td>
<td>Consult laboratory</td>
<td>Blood culture—rule out parasites</td>
<td>• As for routine blood cultures; that is, <em>S. epidermidis</em>, <em>Bacillus</em> spp., <em>Propionibacterium</em>, <em>S. viridans</em></td>
<td>• In general, single cultures positive for these bacteria represent contamination</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Multiple, separate cultures drawn from different sites growing one of these organisms are considered positive</td>
<td>• Contamination rates of less than three percent are desired</td>
</tr>
<tr>
<td>Viral blood cultures</td>
<td>Suspected acute phase of a viral infection</td>
<td>Adenovirus, cytomegalovirus, herpes simplex, influenza, varicella-zoster</td>
<td>Laboratory specific; consult with laboratory</td>
<td>Growth on monolayer cell cultures</td>
<td>Consult laboratory</td>
<td>As for routine blood cultures (see above)</td>
<td>• Continuous monitoring systems cannot identify the presence of virus particles in blood</td>
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<td></td>
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<td></td>
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<td></td>
<td>• Use viral polymerase chain reaction (PCR) testing in the blood</td>
<td></td>
</tr>
<tr>
<td>Viral blood culture: Nucleic acid testing</td>
<td>Suspected acute phase of a viral infection</td>
<td>Common viruses such as HIV, enteroviruses, hepatitis C, human papillomaviruses, varicella-zoster viruses</td>
<td>Consult with laboratory</td>
<td>By PCR testing</td>
<td>Consult laboratory</td>
<td>Viral PCR blood test</td>
<td>As for routine blood cultures (see above)</td>
<td>Test detects viral DNA or rRNA present in the sample</td>
</tr>
</tbody>
</table>
References


Chapter 5

Antimicrobial Testing

Carol Sykora, MT(ASCP), MEd, CIC

Clinical microbiology laboratories analyze organisms suspected of causing infectious processes in the patient. Once an infectious organism is identified, the lab performs susceptibility testing, using a variety of testing methods. Only if the organism is capable of exhibiting resistance to commonly used antimicrobials, or if its susceptibility cannot be predicted from its identity, is susceptibility testing performed. Not all identified organisms warrant susceptibility testing.

The American National Standards Institute (ANSI) has accredited the Clinical and Laboratory Standards Institute (CLSI), a voluntary, international, nonprofit organization, to develop standards and guidelines and provide interpretative education to the healthcare community in the United States.

The CLSI Subcommittee on Antimicrobial Susceptibility Testing establishes the test methods, interpretive criteria, and quality control parameters used in antimicrobial susceptibility testing. The CLSI interpretive susceptibility breakpoints are based on generic reference testing methods. Commercial devices commonly used for susceptibility testing (e.g., Phoenix, Vitek, Microscan, Aris) are regulated by the U.S. Food and Drug Administration (FDA) in the United States. Per the CLSI, “In the US, laboratories that use FDA-approved susceptibility testing devices are allowed to use the FDA interpretive breakpoints. Either FDA or CLSI susceptibility interpretive breakpoints are acceptable to clinical laboratory accrediting bodies. Policies in other countries may vary.”

Table 5-1 lists the various methods of antimicrobial testing performed on nonfastidious aerobic organisms. In addition to the methods listed, there are confirmatory tests (e.g., D-test, modified Hodge test, etc.) that can be performed to detect resistance mechanisms of the organisms. Need for these confirmatory tests vary per the testing methodology and antibiotic breakpoints, and will not be described in this chapter.

Standardized methods for susceptibility testing are only available for a limited subset of organisms. For many organisms, there are no interpretive criteria available. Additional susceptibility testing can be performed on these isolated organisms, per physician request, but the results are not interpretable using known susceptibility criteria and therefore this testing is discouraged.

Clinical microbiologists use the Gram stain to help them identify bacteria. The Gram stain separates organisms into two groups known as Gram positives and Gram negatives according to their cell structure. Differences in the structures of these two groups account for the differences in their susceptibility to various antimicrobial agents.

Antimicrobial agents impact the growth of bacteria either by killing them (bactericidal) or impairing their ability to grow or multiply (bacteriostatic). These agents impact their bacterial targets through specific modes of action. They may:

- Interfere with cell wall synthesis
- Inhibit protein synthesis
- Interfere with nucleic acid synthesis
- Inhibit a metabolic pathway
Antimicrobial agents within the same class typically have the same modes of action.

Table 5-2 lists the classes of antimicrobial agents and their antibiotic activity.

In response to the antimicrobial agents used to kill or impair bacteria, bacteria have developed a number of ways to resist these agents and survive. Their resistance mechanisms include:

- Producing enzymes to destroy the antimicrobial agent before it reaches its target
- Modifying the agent so that it no longer interacts with its target
- Altering their cell wall makeup, making them impermeable to the antimicrobial agent
- Altering the bacterial cell target site so that the antimicrobial agent no longer binds to it
- Using an efflux pump that expels the antimicrobial agent from the bacteria before it can impact the bacteria
- Developing alternative metabolic pathways that bypass the reaction inhibited by the antimicrobial agent

Bacteria that have developed resistance to several classes of antimicrobial agents are categorized as multidrug-resistant organisms (MDRO). MDROs are increasingly isolated in more and more species of organisms. Infection preventionists (IPs) began recognizing the significance of MDROs with the development of resistant Gram-positive organisms, such as oxacillin-resistant *Staphylococcus aureus* and vancomycin-resistant *Enterococcus faecium* and *faecalis*. IPs were aware of the increasing resistance developing in the community-acquired infections due to infectious organisms such as *Neisseria gonorrhoea* and *Mycobacterium tuberculosis*. We learned of resistance developing in strains of viral organisms, too, such as the human immunodeficiency virus (HIV). Most recently the microbiology community has been alerting IPs to the multidrug-resistance identified in Gram-negative organisms such as *Escherichia coli* and *Klebsiella pneumoniae*.

Microbiology departments track the changing sensitivity patterns of their most frequently isolated organisms in a periodic (e.g., quarterly, annually) antibiogram report. The antibiogram report summarizes the sensitivity results of organisms isolated for the first time per year per patient.

Table 5-3 provides an example of an annual antibiogram report. Please note that the antibiogram report results vary according to the organisms and antimicrobials routinely prescribed at a specific hospital. Table 5-3 is an example only and is not necessarily representative of the “typical sensitivity pattern” of the organisms identified at every hospital in the United States.

The antibiogram report is useful in several ways:

1. Clinicians can use the information to guide them in choosing appropriate empirical antimicrobial therapy.
2. The pharmacy department can use the sensitivity results to determine which antimicrobials are effective and should be readily available for the physicians to prescribe through the hospital formulary of medications.
3. The microbiology department, working with the pharmacy, can determine if the selection of antimicrobials per class that are tested should be altered to better reflect the antimicrobials recommended for use.
4. The antimicrobial stewardship committee can use the information to evaluate the effectiveness of their efforts in reducing the overall incidence of resistant organisms isolated from patients. Comparing the current report with previous reports demonstrates the change in sensitivity patterns for the most frequently isolated organisms. If organisms are decreasing in sensitivity to the antimicrobials most frequently prescribed, a change in prescribing practices may help to relieve the antimicrobial selection pressure and reduce the risk of MDROs.
### Table 5-1: Antimicrobial Testing

<table>
<thead>
<tr>
<th>Laboratory Test</th>
<th>Process</th>
<th>Results</th>
<th>Measurement</th>
<th>Interpretation</th>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Disk Diffusion (Kirby-Bauer)</strong></td>
<td>• Use a Mueller-Hinton solid agar plate</td>
<td>Measure the zone of inhibition (a cleared circle of “no growth” around the antimicrobial disk)</td>
<td>Measure the diameter of area where there is no growth of the organism (zone size) in millimeters (mm)</td>
<td>Interpret zone sizes, using CLSI-defined criteria, as: S – Sensitive I – Intermediate R – Resistant</td>
<td>Routine testing</td>
</tr>
<tr>
<td></td>
<td>• Inoculate the organism onto the agar plate (organism is diluted to a specified turbidity and spread over the surface of the solid agar plate in all directions to ensure total coverage of the plate's surface)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>• Place an antimicrobial-impregnated paper disk onto the inoculated plate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Labor: Manual</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Antimicrobial Gradient Diffusion (E-test)</strong></td>
<td>Use a plate of Mueller-Hinton solid agar</td>
<td>Measure the zone of inhibition</td>
<td>Read and record the lowest concentration of antimicrobial (µg/mL) that inhibits the growth of the organism around the strip on the agar plate</td>
<td>Interpret the minimum inhibitory concentration (MIC) and record as: S – Sensitive I – Intermediate R – Resistant</td>
<td>Routine testing</td>
</tr>
<tr>
<td></td>
<td>• Inoculate organism onto the agar plate (organism is diluted to a specified turbidity and spread over the surface of the solid agar plate in all directions to ensure total coverage of the plate's surface)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>• Place an antibiotic-impregnated strip with a gradient concentration of antimicrobial agent onto the inoculated plate</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>• Labor: Manual</td>
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<td></td>
</tr>
<tr>
<td><strong>Minimum Inhibitory Concentrations (MIC)</strong></td>
<td>Serial dilutions (e.g., 1/2, 1/4, 1/8) of the antimicrobial agent are inoculated with a liquid suspension of the organism</td>
<td>Inhibition of visible growth — there is no turbidity seen in the dilution wells</td>
<td>The well with the lowest (minimum) concentration of the antimicrobial (µg/mL) that inhibits growth is reported</td>
<td>MICs are interpreted according to CLSI or FDA guidelines as: S – Sensitive I – Intermediate R – Resistant</td>
<td>Routine testing</td>
</tr>
<tr>
<td></td>
<td>• Labor: Semi-automated or manual broth method</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Minimum Bactericidal Concentration (MBC)</strong></td>
<td>Serial dilutions of antimicrobial agent against actively growing (log-phase) inoculum of the organism</td>
<td>Endpoint of growth (calculated from the number of colonies isolated upon subculture of serial dilution tubes above the MIC)</td>
<td>Lowest concentration of antimicrobial (µg/mL) capable of reducing &gt;99.9% of organisms in inoculum upon subculture</td>
<td>MBC is interpreted as: Lowest concentration of antimicrobial that is bactericidal</td>
<td>This test is rarely performed due to the complexity of the testing</td>
</tr>
<tr>
<td></td>
<td>• Labor: Manual</td>
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</tr>
<tr>
<td><strong>Serum Bactericidal Titer (SBT)</strong></td>
<td>Serial patient serum dilutions against actively growing (log phase) inoculum of organism</td>
<td>Endpoint of growth (calculated from the number of colonies isolated upon subculture of serial dilution tubes of the patient's serum that prevented visible growth)</td>
<td>Lowest concentration of serum (µg/mL) capable of reducing &gt;99.9% of organisms in inoculum upon subculture</td>
<td>SBT is interpreted as: Lowest concentration of serum (titer) that is bactericidal to the pathogen</td>
<td>This test is rarely performed due to the complexity of the testing</td>
</tr>
<tr>
<td></td>
<td>• Labor: Manual</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
### Table 5-2: Antibiotic Class and Activity

#### Penicillins

<table>
<thead>
<tr>
<th>Action: able to inhibit bacterial enzymes; able to trigger autolytic enzymes that destroy the cell wall; may inhibit RNA synthesis in some bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penicillin</td>
</tr>
<tr>
<td>Action: bind to penicillin-binding proteins (PBP), interfering with cell wall synthesis; may trigger autolytic enzymes in the cell</td>
</tr>
<tr>
<td>Cephalexin</td>
</tr>
<tr>
<td>Cefaclor</td>
</tr>
<tr>
<td>Cefprozil</td>
</tr>
<tr>
<td>Cefuroxime (axetil)</td>
</tr>
<tr>
<td>Carbacephem</td>
</tr>
</tbody>
</table>

#### β-Lactams

<table>
<thead>
<tr>
<th>Class</th>
<th>Subclass</th>
<th>Generic Name</th>
<th>Antibiotic Activity Against</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penicillins</td>
<td>Penicillin</td>
<td>Penicillin</td>
<td>Non-β-lactamase-producing aerobic Gram positives, some fastidious aerobic Gram negatives, some anaerobes</td>
</tr>
<tr>
<td>Aminopenicillin</td>
<td>Amoxicillin</td>
<td></td>
<td>Additional Gram negatives, including some Enterobacteriaceae</td>
</tr>
<tr>
<td>Ureidopenicillin</td>
<td>Piperacillin</td>
<td></td>
<td>Expanded list of Gram negatives</td>
</tr>
<tr>
<td>Penicillinase-stable penicillins</td>
<td>Dicloxacillin</td>
<td></td>
<td>Penicillinase-producing Staphylococcus spp.</td>
</tr>
<tr>
<td>β-lactam/β-lactamase inhibitor combinations</td>
<td>Amoxicillin-clavulanic acid</td>
<td></td>
<td>Most Gram positives and Gram negatives</td>
</tr>
<tr>
<td>Cephems (parenteral)</td>
<td>Cefadroxil</td>
<td></td>
<td>Good Gram-positive and modest Gram-negative activity (e.g., S. pneumoniae, S. pyogenes, some Enterobacteriaceae, including many strains of E. coli, Klebsiella spp., and Proteus mirabilis)</td>
</tr>
<tr>
<td>Cephems (oral)</td>
<td>Cefotetan</td>
<td></td>
<td>Marked activity against anaerobes (e.g., members of the B. fragilis group)</td>
</tr>
</tbody>
</table>

---

**Note:** The table provides a summary of antibiotic classes and their activities against specific pathogens, highlighting the action mechanisms and the target enzymes relevant to each class.
### Table 5-2: Antibiotic Class and Activity (continued)

<table>
<thead>
<tr>
<th>Class</th>
<th>Subclass</th>
<th>Generic Name</th>
<th>Antibiotic Activity Against</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>β-lactams</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Monobactams</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Action: binds to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>penicillin-binding protein of Gram-negative aerobes, disrupting cell wall synthesis</td>
<td></td>
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</tr>
<tr>
<td>Aztreonam</td>
<td></td>
<td></td>
<td>Activity only against aerobic Gram negatives; effective against most <em>Enterobacteriaceae</em>, including <em>Enterobacter</em> spp., <em>Serratia marcescens</em></td>
</tr>
<tr>
<td>Penems</td>
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</tr>
<tr>
<td>Action: bind to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>penicillin-binding proteins of Gram-negative and Gram-positive organisms, causing elongation and lysis</td>
<td></td>
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</tr>
<tr>
<td>Carbapenem</td>
<td></td>
<td>Doripenem</td>
<td>Broad-spectrum against non-carbapenemase-producing aerobic and anaerobic Gram positives and Gram negatives; including many <em>Staphylococci</em> (not MRSA), <em>Streptococci</em>, most <em>Enterobacteriaceae</em>, and various anaerobic Gram-positive cocci, <em>Clostridium</em>, <em>B. fragilis</em> group, <em>Fusobacterium</em>, and <em>Prevotella</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ertapenem</td>
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<tr>
<td></td>
<td></td>
<td>Imipenem</td>
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<tr>
<td></td>
<td></td>
<td>Meropenem</td>
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</tr>
<tr>
<td>Non-β-lactams</td>
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<tr>
<td>Aminoglycosides</td>
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</tr>
<tr>
<td>Action: inhibit bacterial protein synthesis by binding irreversibly with the 30S and, in some cases, 50S ribosomal subunit; can be used in synergy with cell-wall active agents against Gram positives</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amikacin</td>
<td></td>
<td>Gentamicin</td>
<td>Aerobic Gram negatives and can be used in synergy at high dose levels with cell-wall active agents against Gram positives</td>
</tr>
<tr>
<td>Kanamycin</td>
<td></td>
<td>Netilmicin</td>
<td></td>
</tr>
<tr>
<td>Streptomycin</td>
<td></td>
<td>Tobramycin</td>
<td></td>
</tr>
<tr>
<td>Ansamycin</td>
<td></td>
<td>Rifampin</td>
<td>Aerobic and anaerobic Gram-positive, Gram-negative, and acid-fast organisms when used in combination therapy</td>
</tr>
<tr>
<td>Action: interferes with nucleic acid synthesis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quinolones</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Action: targets DNA-gyrase, leading to termination of chromosomal replication and interference with cell division and gene expression</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluoroquinolone</td>
<td></td>
<td>Ciprofloxacin</td>
<td>Many Gram positive and Gram negatives</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gatifloxacin</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gemifloxacin</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Levofloxacin</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moxifloxacin</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ofloxacin</td>
<td></td>
</tr>
<tr>
<td>Folate pathway inhibitors</td>
<td></td>
<td></td>
<td>Some Gram positives and negatives</td>
</tr>
<tr>
<td>Action: inhibit sequential steps in the bacterial folate pathway</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trimethoprim</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trimethoprim-sulfamethoxazole</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fosfomycins</td>
<td></td>
<td>Fosfomycin</td>
<td>Most Gram positives and Gram negatives found in lower urinary tract infections</td>
</tr>
<tr>
<td>Action: inhibits a bacterial cytoplasm enzyme</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 5-2: Antibiotic Class and Activity (continued)

<table>
<thead>
<tr>
<th>Class</th>
<th>Subclass</th>
<th>Generic Name</th>
<th>Antibiotic Activity Against</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lipopeptides</td>
<td>Polymyxins</td>
<td>Daptomycin</td>
<td>Gram positives (daptomycin), aerobic Gram negatives (colistin and polymyxin B)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Colistin (polymyxin E)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Polymyxin B</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Macrolides</td>
<td>Azithromycin</td>
<td>Fastidious Gram negatives and Gram positives</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clarithromycin</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Erythromycin</td>
<td></td>
</tr>
<tr>
<td>Nitrofurans</td>
<td>Nitrofurantoin</td>
<td></td>
<td>Gram positives and Gram negatives causing urinary tract infections, including S. saprophyticus and E. faecalis, Corynebacterium spp., 90% of E. coli</td>
</tr>
<tr>
<td>Nitromidazoles</td>
<td>Metronidazole</td>
<td></td>
<td>Various anaerobic bacteria; including B. fragilis group, Fusobacterium and Clostridium, including C. difficile; also against protozoa such as Trichomonas vaginalis, Giardia lamblia, and Entamoeba histolytica</td>
</tr>
<tr>
<td>Glycopeptides</td>
<td>Glycopeptide</td>
<td>Vancomycin</td>
<td>Aerobic Gram positives</td>
</tr>
<tr>
<td>Lincosamides</td>
<td>Lipoglycopeptide</td>
<td>Teicoplanin</td>
<td>aerobic Gram-positive cocci and anaerobes</td>
</tr>
<tr>
<td>Oxazolidinones</td>
<td>Linezolid</td>
<td></td>
<td>Gram positives and mycobacteria</td>
</tr>
<tr>
<td>Phenicols</td>
<td>Chloramphenicol</td>
<td></td>
<td>Gram positives and Gram negatives</td>
</tr>
<tr>
<td>Streptogramins</td>
<td>Quinupristin-dalfopristin</td>
<td></td>
<td>Gram positives</td>
</tr>
</tbody>
</table>
### Table 5-2: Antibiotic Class and Activity (continued)

<table>
<thead>
<tr>
<th>Class</th>
<th>Subclass</th>
<th>Generic Name</th>
<th>Antibiotic Activity Against</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetracyclines</td>
<td>Action: inhibit protein synthesis</td>
<td>Doxycycline, Minocycline, Tetracycline</td>
<td>Gram positives and Gram negatives by inhibiting protein synthesis at the ribosomal level</td>
</tr>
<tr>
<td>Glycylcyclines</td>
<td>Action: inhibit protein synthesis</td>
<td>Tigecycline</td>
<td>Gram positives and Gram negatives that are resistant to tetracyclines</td>
</tr>
</tbody>
</table>
### Table 5-3: Example of an Antibiogram

**Annual Antimicrobial Susceptibility Report for 201X. (Data analysis based on first isolate per patient per year.)**

<table>
<thead>
<tr>
<th>Gram positive</th>
<th>Number of Isolates Tested</th>
<th>Percent Susceptible</th>
<th>Urine</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. aureus—oxacillin resistant</td>
<td>1149/1926 (59%)</td>
<td>0 5 66 100 98</td>
<td>99</td>
</tr>
<tr>
<td>S. aureus—oxacillin sensitive</td>
<td>777/1926 (41%)</td>
<td>100 60 85 100 99</td>
<td>99</td>
</tr>
<tr>
<td>Coagulase negative staph (CNS)</td>
<td>192</td>
<td>31 22 47 100 64</td>
<td>99</td>
</tr>
<tr>
<td>Enterococcus faecium</td>
<td>29</td>
<td>28 14 100</td>
<td>54</td>
</tr>
<tr>
<td>Enterococcus faecalis</td>
<td>95</td>
<td>79 93</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gram negative</th>
<th>Number of Isolates Tested</th>
<th>Percent Susceptible</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Enterobacter spp.—nonurine</td>
<td>150</td>
<td>91 35 95 81 95 87 82 77 81</td>
<td></td>
</tr>
<tr>
<td>Enterobacter spp.—urine</td>
<td>197</td>
<td>82</td>
<td></td>
</tr>
<tr>
<td>Klebsiella spp.—nonurine</td>
<td>193</td>
<td>88 63 72 95 81 95 87 82 77 96 80 83 79 71 89 85 89</td>
<td></td>
</tr>
<tr>
<td>Klebsiella spp.—urine</td>
<td>682</td>
<td>89 78 96 94 98 90 83 85 100</td>
<td></td>
</tr>
<tr>
<td>Escherichia coli—nonurine</td>
<td>301</td>
<td>83 54 58 87 99 95 93 94 81 96 98 90 100</td>
<td></td>
</tr>
<tr>
<td>Escherichia coli—urine</td>
<td>3359</td>
<td>83 60 94 100 99 95 88</td>
<td></td>
</tr>
</tbody>
</table>
References


Guide to the Elimination of MRSA
An APIC Guide
2010

Guide to the Elimination of Methicillin-Resistant Staphylococcus aureus (MRSA) Transmission in Hospital Settings, 2nd Edition

About APIC
APIC’s mission is to improve health and patient safety by reducing risks of infection and other adverse outcomes. The Association’s more than 13,000 members have primary responsibility for infection prevention, control, and hospital epidemiology in healthcare settings around the globe. APIC’s members are nurses, epidemiologists, physicians, microbiologists, clinical pathologists, laboratory technologists, and public health professionals. APIC advances its mission through education, research, consultation, collaboration, public policy, practice guidance, and credentialing.

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On the Cover:
*Highly magnified electron micrograph depicting numbers of Staphylococcus aureus bacteria, found on the luminal surface of an indwelling catheter.* (2005). Courtesy of CDC/ Rodney M. Donlan, Ph.D.; Janice Carr

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Foreword

The 2009 – 2010 update of the Guide to the Elimination of MRSA Transmission in Hospital Settings provides updates and enhancements to the original APIC guide published in March 2007. Additional references and resources, review of current research findings, and updated “level of evidence” guidance are integrated into the best practice recommendations for MRSA surveillance, risk assessment, and the effective hospital MRSA management program. Recent research on the role of environmental cleaning and disinfection provided additional focus on the importance of MRSA environmental decontamination section. Updates to the antimicrobial stewardship and laboratory components of effective an MRSA program are included to supply information on antibiogram development and laboratory testing methodologies. The role of MRSA decolonization in infection prevention and control strategy for eliminating reservoir of the organism continues to be investigated, and a review of recommendations in certain settings or patient populations (in critical care, for some surgical populations, during outbreaks), based on MRSA risk assessment is included. The section on cultural transformation has been expanded to develop more fully the importance of cultural change theory strategies to enhance MRSA prevention programs. A section on education plan for staff, other healthcare professionals, patients and visitors is a new section in the update of the MRSA guide.
MRSA Epidemiology and the Impact on Hospitals

Purpose
The purpose of this document is to provide evidence-based practice guidance for the elimination of methicillin-resistant Staphylococcus aureus (MRSA) transmission in hospital settings.

Key Concepts
- Effective efforts to eliminate MRSA transmission are guided by the epidemiology of MRSA as defined by the comprehensive, facility-specific risk assessment which describes current state and characteristics of the MRSA burden for the facility or setting.
- Knowledge obtained from the risk assessment drives the development of interventions that result in enhanced compliance with existing facility practices, or in implementation of appropriate additional interventions as described in this guidance document. Some facilities may find no additional interventions are needed, thus indicating the importance of doing a careful risk assessment.

Background
The CDC Campaign to Prevent Antimicrobial Resistance in Healthcare Settings has provided the estimate that more than 70% of all hospital-associated infections are caused by organisms exhibiting multidrug-resistance. These infections contribute to significant patient morbidity and mortality and result in limited antimicrobial treatment options as compared to infections caused by non-resistant organisms.

CDC Campaign to Prevent Antimicrobial Resistance in Healthcare Settings
http://www.cdc.gov/drugresistance/healthcare/problem.htm

Drug-resistant pathogens are a growing threat to all people, especially in healthcare settings.
- Each year nearly two million patients in the United States get an infection in a hospital.
- Of those patients, about 90,000 die as a result of their infection.
- More than 70% of the bacteria that cause hospital-associated infections are resistant to at least one of the drugs most commonly used to treat them.
- Persons infected with drug-resistant organisms are more likely to have longer hospital stays and require treatment with second or third-choice drugs that may be less effective, more toxic and/or more expensive.

Increasing Prevalence of Multidrug Resistance
MRSA refers to Staphylococcus aureus isolates that are resistant to all currently available B-lactam antibiotics (penicillins, cephalosporins and carbapenems). For decades, MRSA has been the most commonly identified multidrug-resistant pathogen in Europe, Asia, Africa, the Middle East and the Americas. Increasing incidence of MRSA is a well-documented healthcare and community phenomenon of tremendous concern to medical, public
health and lay communities around the world. In the early 1990s, MRSA was reported to account for 20 – 25 % of *Staphylococcus aureus* isolates in hospitalized patients in the U.S. By the middle of the current decade, many hospitals experienced MRSA percentages in the range of 50–70% of total *Staphylococcus aureus* isolates from clinical cultures. Similarly, National Nosocomial Infections Surveillance System (NNIS) data analysis for 1992 to 2003 showed that the percentage of *Staphylococcus aureus* isolates that were methicillin–resistant increased from 35.9 % in 1992 to 64.4 % in 2003 in participating adult and pediatric ICUs. In the Agency for Healthcare Research and Quality (AHRQ) report of July 2007, data from the Healthcare Cost and Utilization Project (HCUP) showed that the number of hospitalizations involving MRSA infection more than tripled between 2000 and 2005, which included a 30% increase seen between 2004 and 2005. In addition, it was noted that the costs and the lengths of stay for patients with MRSA infections were more than double in relation to all other hospital stays.

**MRSA Epidemiology and Transmission**

The normal bacterial flora of humans often includes *S. aureus*. It has been estimated that nasal colonization in the general adult population is 20% to 40% and that carriage will be intermittent in 30% and prolonged in 50% of the nasal carriers. A study of colonization stratified by multidrug resistance in a nationally representative survey conducted from 2001 through 2004 as part of the National Health and Nutrition Examination Survey found that the prevalence of colonization with *S. aureus* decreased from 32.4% in 2001-2002 to 28.6% in 2003-2004 however the prevalence of colonization with MRSA increased from 0.8% to 1.5%. In this study, colonization with MRSA was independently associated with healthcare exposure in males, age > or =60 years, diabetes, and poverty in females. In a subset of colonized people in 2003-2004, a total of 19.7% of MRSA-colonized persons carried a PFGE type associated with community transmission.

*S. aureus* from a nasal colonization can be transferred to skin and other body areas. When an infection occurs after a breach of the body’s defenses of the skin, the pathogen is often endogenous (“from the body”). Therefore the presence of endogenous *S. aureus*, especially MRSA, is a risk factor for infection, which has been well characterized in bloodstream infections.

Colonization with MRSA often precedes infection by MRSA. The connection between transmission of MRSA from an exogenous (outside of the body) source via hands, equipment, and the hospital environment and subsequent endogenous carriage of MRSA is the primary infection prevention and control consideration for the elimination of MRSA transmission in hospital setting.

**Changing Epidemiology of MRSA: Community-associated MRSA**

MRSA has a history of being frequently associated with healthcare, and conventional wisdom had categorized MRSA as a hospital problem until the late 1990s. But during that decade, data from the Canadian MRSA surveillance system showed that 5–7% of reported MRSA infections occurred in individuals with no known healthcare-associated risk factors for acquisition. Concurrently, reports were being received by the CDC regarding MRSA infections in athletes, children, prisoners, military personnel and full-term newborn infants that were both phenotypically and genotypically characterized as community-associated strains. Research from the veterinary community on MRSA infection and colonization of animals and pets has identified yet another reservoir of MRSA that is transmissible to humans. Amplification of community reservoirs of MRSA provides another incentive for aggressive action to eliminate transmission of MRSA in healthcare settings.

In most community acquired MRSA (CA-MRSA) strains in the United States, methicillin resistance is encoded in a novel genetic elements, staphylococcal cassette chromosome *mec* type IV. Many of these strains have been resistant only to B-lactams and macrolides (eg. erythromycin) and retain susceptibility to many non-B-lactam antimicrobial agents such as lincomycins (eg. clindamycin), fluoroquinolones, rifampin, trimethoprim-
sulfamethoxazole, aminoglycosides and tetracyclines. CA-MRSA also produces several toxins not commonly found in healthcare associated strains, notably Panton-Valentine leukocidin, which causes leukocyte destruction and tissue necrosis. The predominant molecular genotypes that cause CA-MRSA infections are USA300 and USA400. The USA300 clone has emerged as the predominant cause of staphylococcal skin and soft tissue infections. In the majority of healthcare associated MRSA (HA-MRSA) strains in the United States, methicillin resistance is encoded in staphylococcal cassette chromosome mec type II. HA-MRSA are frequently resistant to many other classes of antibiotics and the Panton-Valentine leukocidin is rarely found. The predominant molecular genotypes that cause HA-MRSA infection are USA100 and USA200.\textsuperscript{19,20,21}

**Cost Impact of Hospital MRSA Infections**

In a systematic audit of published hospital-associated infections reports, and interventions conducted by infection control professionals from 1990-2000, the mean cost attributable to an MRSA infection was $35,367.\textsuperscript{22} A recent extensive literature search presented at the spring 2005 meeting of the International Society for Pharmacoeconomics and Outcomes Research (ISPOR) estimated the annual cost to treat MRSA in hospitalized patients in the U.S. to be between $3.2 billion to $4.2 billion. These costs were associated with the prolonged hospital stays (up to 10 days longer than patients who had methicillin-sensitive \textit{Staphylococcus aureus} infections) and to the cost of critical care stays associated with these complications.\textsuperscript{23}

**Human Impact of Hospital MRSA Infections**

The human impact of healthcare-associated MRSA infections makes efforts to eliminate MRSA transmission in healthcare settings compelling and necessary. Patient safety initiatives in hospital settings may be facility derived or imported from national venues (Joint Commission National Patient Safety Goals, IHI's 5 Million Lives Campaign, etc.). These patient safety initiatives are unanimous in promoting the use of science-based best practices to prevent hospital-associated infections.

**Consumer and Legislative Responses**

In response to the huge human impact of hospital infections, actions are being taken in non-clinical arenas as well. Various consumer groups have developed education and web-based information for patients and their families about the risks of hospital infections and about the risk-reduction steps that they should expect and demand from their healthcare providers (AARP, StopHospitalInfection.org, etc.).

Legislation related to hospital infections has been passed in many states and some bills filed are specific to MRSA. Several states now mandate either a MRSA control program, which may include reporting to the department of health or active surveillance testing for MRSA, regardless of the facility’s risk assessment. For the most current legislation related to MRSA you may want to refer to the “MRSA map” located on the APIC website at: http://www.apic.org/am/images/maps/mrsa_map.gif.

Payers, including CMS and private insurers, are implementing non-reimbursement strategies in relation to hospital-associated infections, since several HAIs are considered a category of “hospital-acquired conditions. MRSA is expected to figure more specifically in future reimbursement policies.

**Role of Hospital Leadership**

Support from hospital leadership is essential in any initiative to reduce the impact of multidrug resistant organisms in the hospital setting. Without strong leadership support, to reach the goal of eliminating the transmission of MRSA will be difficult, if not impossible, to achieve. Leadership must support and facilitate the acquisition of supply and personnel resources. Essential support related to infection prevention and control staff, laboratory
resources, information systems upgrades including data mining capability, nursing support, decision support, and access to public relations will be needed. Effective leadership will also facilitate the development of teams and communication pathways, physician and staff buy-in, board of directors’ involvement and community outreach.

Scope:
The main components of the APIC Guide on the Elimination of MRSA Transmission in Hospital Settings are:

- MRSA risk assessment
- MRSA surveillance programs
- compliance with basic infection prevention and control strategies: hand hygiene
- compliance with basic infection prevention and control strategies: contact precautions
- compliance with basic infection prevention strategies: prevention of device-related hospital associated infections (e.g. CLABSI, VAP, UTI) via processes that ensure use and duration based on medical necessity, as part of best practice bundles or empowered teams24,25
- compliance with basic infection prevention and control strategies: thorough environmental and equipment cleaning and decontamination
- enhanced infection prevention and control strategies (e.g., active surveillance testing, etc.) when MRSA transmission rates are not decreasing
- education of healthcare workers, patients, families, and the public
- cultural transformation and change management
- antimicrobial stewardship
- MRSA decolonization strategies

Valuable resources have been accessed to assist in the development of this guide. Many of the components outlined in this document are also found in the following guidelines and can be readily accessed as needed in facility-specific program development.

The Healthcare Infection Control Practices Advisory Committee (HICPAC) guideline “Management of Multidrug-Resistant Organisms in Healthcare Settings, 2006,” has outlined a comprehensive, two-tiered approach with a built-in flexibility designed to accommodate the variety of settings and situations in which healthcare professionals coordinate infection prevention and control programs. It outlines an approach to determine when an “active surveillance protocol” may be applied.

“Guideline for isolation precautions: preventing transmission of infectious agents in healthcare settings, 2007” provides the guidance on patient placement and isolation considerations for multidrug resistant organisms and communicable diseases.

“Strategies to prevent transmission of methicillin-resistant Staphylococcus aureus in acute care hospitals” is one of the HAI compendium guides published in October 2008. This compendium of practice recommendations was sponsored and authored by the Society for Healthcare Epidemiology of America (SHEA) and the Infectious Diseases Society of America (IDSA). Partners in this work were the Association for Professionals in Infection Control and Epidemiology (APIC), the Joint Commission, and the American Hospital Association (AHA)
http://www.journals.uchicago.edu/doi/full/10.1086/591061
In 2003, the Society for Healthcare Epidemiology of America (SHEA) introduced the “SHEA Guideline for Preventing Nosocomial Transmission of Multidrug-Resistant Strains of Staphylococcus aureus and Enterococcus.” One component of this 2003 guideline was the recommendation for active surveillance cultures, in addition to contact isolation, in order to reduce the transmission of MRSA and VRE. While not all experts in the healthcare community were in agreement regarding the role of universal active surveillance, this recommendation has been instrumental in generating research in this controversial arena and has been used by some hospitals in successful MRSA elimination programs.

http://www.shea-online.org/Assets/files/position_papers/SHEA_MRSA_VRE.pdf

The Institute for Healthcare Improvement’s (IHI) “5 Million Lives” Campaign includes a “Getting Started Kit: Reduce Methicillin-Resistant Staphylococcus aureus (MRSA) Infection How-to Guide.” The five components of care in this guide are hand hygiene, decontamination of the environment and equipment, active surveillance, contact precautions and device bundles. This 2006 guide recommends the Plan-Do-Study-Act strategy of action for key interventions and gives useful examples of changes that can be made to result in improvements.

http://www.ihi.org/ihi

Although components of this guide provide the “how-to” when applying “active surveillance” protocols, it is crucial to acknowledge there are multiple ways to eliminate MRSA and other sensitive and resistant organisms. The two-tiered CDC MDRO guidelines should be reviewed for their systematic approach to determining when to apply an “active surveillance” protocol as noted earlier for MRSA or other targeted resistance organisms. A statewide initiative, the Michigan Hospital Association’s Keystone Center program, has focused on elimination of infections, citing “no infection, no resistance.” The success of the approach using “bundling” of evidence-based practices to reach zero infections has been demonstrated in healthcare improvement initiatives.20,21

Cited References


**Resources and References**


MRSA Risk Assessment

Purpose
Performance of a hospital-specific MRSA risk assessment will result in the baseline description of hospital MRSA incidence, prevalence and transmission, and will identify patient populations that are more likely to be colonized and/or infected with MRSA. The purpose of the MRSA assessment is to guide development of a surveillance, prevention and control program plan that is based on facility data and conditions.

Key Concepts
- Past and current hospital surveillance data is the core of the MRSA risk assessment.
- MRSA surveillance data includes demographic, geographic, and published MRSA data on risk populations.
- MRSA risk assessment is developed annually, whenever there is a change based on continuing surveillance, and when change of populations or services occurs.
- Information from the MRSA risk assessment drives improvement processes.

Background
Initiatives to prevent MRSA transmission include consideration of expert guidance and practice standards, and require local resources such as laboratory capabilities, administrative support, infection prevention and control department staffing, public health support, other support elements, current infection prevention and control interventions (e.g., hand hygiene, contact precautions, etc.) and the measurement parameters for the current interventions.

The CDC guideline “Management of Multidrug Resistant Organisms (MDRO) in Healthcare Settings, 2006” recommends monitoring trends in the incidence* of a target MDRO.

V.A.4.e. Monitor trends in the incidence* of target MDROs in the facility over time using appropriate statistical methods to determine whether MDRO rates are decreasing and whether additional interventions are needed. Category IA

*number of new MDROs divided by the size of the population under consideration.

In addition, the CDC MDRO guideline recommends intensified interventions to prevent MDRO transmission when incidence or prevalence of MDROs are not decreasing despite implementation of and correct adherence to the routine control measures (recommendation V.B.).1 The MRSA assessment provides the information needed to identify whether MRSA is increasing, decreasing or staying the same in patient populations, patient care units or service lines being surveyed.2 The goal of eliminating MRSA transmission in hospital settings requires ongoing monitoring and enhanced interventions when appropriate.

Past and current hospital surveillance data is at the core of the MRSA assessment. Relevant MRSA surveillance data available from local public health departments and published MRSA data from facilities of similar
demographic and geographic characteristics may also be helpful in a hospital MRSA assessment. Evaluation of MRSA assessment data identifies patient care units, service lines or groups of individuals likely to be colonized or infected. This information is used to drive the hospital’s surveillance, prevention and control program for the elimination of MRSA transmission. It also aids the infection preventionist in determining when additional interventions may be needed, e.g. if the risk assessment data show that MRSA transmission rates are not decreasing in spite of good compliance with current interventions. Therefore, an important aspect of the plan is identification of endpoints or goals. A clear picture of what will be accomplished through implementation of the plan must be expressed and quantified as appropriate.

Examples of possible outcome measures include “decrease hospital-associated MRSA, central line-related bloodstream infections by X % in the next six months,” and “decrease MRSA transmission by X % in the next three quarters.”

Examples of possible process measures include annual increase in compliance with hand hygiene requirements to the 90 % level as measured by gel and soap use through the “Partners in Your Care Program” or “increase compliance with Contact Precautions to the 95 % level as measured by the quarterly isolation compliance monitor.”

Each of these specifies an element to be measured, how it will be measured and what success will look like.

**MRSA Risk Factors**

General risk factors for MRSA acquisition from hospital and from community settings, are well documented in the literature (see reference list at end of this section). Known risk factors include but are not limited to:

- previous hospital admission in the previous year with at least one underlying chronic illness
- admission to a nursing home in the previous year
- previous receipt of antibiotics during an admission
- diagnosis of skin or soft-tissue infection at admission
- HIV infection
- injection drug use
- previous MRSA infection or colonization
- hemodialysis
- others as defined by the MRSA risk assessment (increasing age, work with animals, incarceration, etc)

**MRSA Risk Assessment Basics**

An assessment of MRSA relies on the availability of test results or a flagging system to identify patients with a laboratory confirmed history of MRSA. Clinical cultures from patients identified with MRSA will be a core component of surveillance in all hospitals. Hospitals that also utilize an active surveillance testing (AST) program will be able to identify patients colonized with MRSA who have no available clinical culture results.

Prevalence surveillance* identifies colonization and infection in high risk units or from high risk populations. This data is used in baseline and follow-up MRSA risk assessments. The ability to track MRSA-positive patients by location, patient population and/or clinical service is essential for MRSA risk assessments. Standardized, consistent processes for capturing the relevant data ensure that statistical evaluation is relevant and comparative over time.

* MRSA prevalence can be defined as the number of patients colonized and infected with MRSA divided by the number of patients in the study population at a particular point in time.
SHEA and HICPAC have issued a joint Position Paper on Recommendations for Metrics for Multidrug-Resistant Organisms in Healthcare Settings. The document defines new terms and the time required from the time a patient is admitted for a MDRO to be considered hospital onset; basic metrics are also discussed.

The MRSA risk assessment must include clear definitions for all measurements. According to the position paper, MRSA is considered to be hospital onset if the organism is isolated after the third calendar day of hospitalization, with the first day being the day of admission (the admission date is determined as the date a patient occupies a room for an overnight stay, not the date of an outpatient and/or emergency department visit.

Note: The National Healthcare Safety Network also uses this definition in the MDRO and Clostridium difficile modules; however this definition cannot be applied to the NHSN device or procedure associated modules because there is not a requirement for time to elapse from the insertion of a device or procedure to the infection outcome occurring.

The variety of suggested metrics are proxy measures and may be an underestimation of the true burden of MRSA. For example, the definition of hospital-onset MRSA does not include community-onset healthcare-associated MRSA (e.g. patient discharged from the hospital, is readmitted within 30 days from discharge and is positive for MRSA on readmission). A program that includes active surveillance testing will increase detection of patients who are colonized; whereas, a program that does not include AST may underestimate the prevalence of MRSA colonization in that facility.

The hospital-specific MRSA assessment requires that the infection preventionist:

- establish baseline incidence and/or prevalence MRSA rates for each surveyed patient care unit, patient population or service line
- identify high risk populations, units or service lines based on incidence rates
- evaluate MRSA transmission data over time in identified populations or units to characterize unit specific MRSA prevalence or transmission rates
- identify clusters in MRSA transmission in patient populations and/or units over a specific time period for analysis to determine if enhanced interventions may be appropriate
- compare MRSA transmission data over time to determine if there are trends within patient populations and/or units
- establish the rate of compliance with hand hygiene and standard precautions
- focus data-driven interventions on specific patient care units or in specific patient populations
- convene planning and improvement teams with enough key players to maximize support and participation (e.g. laboratory, nursing leadership, infectious disease professionals, physician champions, etc.)
- identify gaps in staff knowledge for targeted educational interventions
- finalize a plan in terms of time and interventions, allowing enough time to communicate the plan to staff for maximum participation.

Example 1: Utilizing MRSA surveillance data for the MRSA assessment

During a period of rising MRSA rates, the infection control and prevention department implements a program of surveillance for new cases of MRSA on each inpatient unit. Transmission of MRSA in the hospital setting is assumed if the new case of MRSA meets the hospital’s case definition of hospital-associated MRSA.

A definition is developed to identify an MRSA case as “new”: MRSA isolated from clinical or surveillance culture obtained after the third calendar day of admission to the unit in a patient that had no prior MRSA by culture, molecular test, or by history.
Data is analyzed in order to evaluate MRSA transmission by unit using the formula above. Statistical process control evaluation of the data can be used to identify trends and out-of-control situations that may require intervention. Data is obtained for all months during 2009 on all units.

This type of analysis can be done to determine patient care units or patient populations at high risk. Surveillance is continued during the intervention and post intervention periods. An excellent process for follow-up is available in the IHI “5 Million Lives” campaign which includes a “Getting Started Kit: Reduce Methicillin-Resistant Staphylococcus aureus (MRSA) Infection How-to Guide.” Additional information is also available in the SHEA/IDSA practice recommendation "Strategies to Prevent Transmission of Methicillin-Resistant Staphylococcus aureus in Acute Care Hospitals.”

Example 2: MRSA assessment and intervention (hypothetical scenario)
In this next example, an MRSA assessment reveals that the incidence of MRSA bacteremia in the inpatient renal unit is trending upward over time.
An analysis of data by the infection prevention and control staff confirms that most of the MRSA cases are related to new admissions (culture positive within the first three days of admission with no prior hospitalization in the unit within 30 days). Therefore, the increasing rate is not related to transmission on the unit. The number of MRSA-positive patients admitted to this unit may lead to a future MRSA problem if compliance with hand hygiene, contact precautions, environmental and equipment decontamination is inadequate.

Known risk factors in this population include central lines and peritoneal dialysis, frequent healthcare access, long-term care residence, antibiotic use, diabetes and immunocompromised states. The analysis of data showed a significant trend in admitted dialysis patients on peritoneal dialysis, a known risk factor for dialysis-related infection, and an increase in patients admitted from long-term care facilities.

- The infection prevention and control team communicates their original surveillance findings to the appropriate clinical services.
- The infection prevention and control team determines through observational measurements that compliance with hand hygiene, standard precautions are at expected high levels.
- In collaboration with nursing, laboratory and nephrology, the team institutes an active surveillance testing program (AST) on this unit in order to collect additional data on the magnitude of the MRSA burden for this unit.
- The renal unit staff develops an educational program regarding the importance of equipment cleaning. They implement computer screen saver reminders, as well as enhanced audits for hand hygiene and contact precautions compliance.
- MRSA surveillance data and the results from the audits of hand hygiene and contact precautions compliance are communicated to the unit over the next six months. Based on the analysis of the enhanced MRSA interventions, the renal unit develops an intervention bundle that is hardwired into the contact precautions process for that unit. The success of the bundle leads to its adoption on other patient care units.
• A reduction in MRSA rates to less than 1.0 for three consecutive quarters is achieved. The AST program is discontinued until and if the rates of MRSA bacteremia trend above the new baseline.

• MRSA incidence in the peritoneal dialysis patient population who receive dialysis in two of the three local outpatient dialysis centers is shown to be three times higher than the incidence in the long-term care facility population. Results are presented to nephrology groups (both hospital and outpatient based). The information is used to develop an educational program to facilitate patient acceptance of conversion from peritoneal dialysis to AV shunt access. Infection prevention and control staff communicate results of MRSA surveillance evaluation to both inpatient and outpatient dialysis groups and physicians. Infection prevention and control staff also provide assistance to the nephrology groups regarding implementation of hand hygiene compliance monitors at the outpatient dialysis centers.

What’s next after you have achieved a sustained reduction of MRSA?

A report summarizing data compiled by the National Healthcare Safety Network in 2006-2007 details antimicrobial resistant pathogens associated with healthcare-associated infections. The report states that 8% of the infections reported to NHSN were associated with MRSA, comprising half of the overall percentage (16%) of HAIs associated with a multidrug-resistant pathogen. The article further states, “Nationwide, the majority of units reported no HAIs due to antimicrobial-resistant pathogens.” NHSN went on to report in 2009 that the incidence of MRSA central line–associated BSI has been decreasing in recent years in most ICU types reporting to the CDC, except in pediatric units. Over seven percent (7.4%) of all central line-associated BSIs reported from 1,684 ICUs were MRSA during the period 1997-2007.

However, a report published in 2007 based on 2005 data by the CDC states that 85% of MRSA infections that do occur, were associated with the delivery of healthcare. Two thirds of healthcare-associated MRSA infections were community-onset, whereas one third was determined to be hospital onset. The article concludes that MRSA disease is still predominantly related to exposure to healthcare delivery but no longer confined to hospitals.

The above articles demonstrate that although MRSA continues to be a problem for healthcare facilities in the United States, significant progress has been made in the reduction of central line-associated bloodstream infections associated with MRSA and other HAIs. It is important that a risk assessment be performed at least annually, or more frequently if necessary, including assessment of basic preventive practices such as hand hygiene and standard precautions. If interventions demonstrate a reduction of MRSA the same process of assessing risk can be applied to other MDROs or even sensitive pathogens, which may be problematic.

Cited References


Guide to the Elimination of Methicillin-Resistant *Staphylococcus aureus* (MRSA) Transmission in Hospital Settings, 2nd Edition

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**Resources and References**


MRSA Surveillance Methodology

Purpose
The purpose of surveillance is to identify trends, outbreaks and an increased incidence of MRSA in the patient population. Surveillance activities can identify risk factors for infection and complications among patients.

Key Concepts
• Surveillance methodology is based in sound principles of epidemiology and statistical principles.
• The surveillance program for MRSA provides the definitions, measurements and data analysis needed to evaluate the success of general infection prevention and control programs, and when appropriate, of intensified interventions taken to eliminate the transmission of MRSA in the hospital setting.
• Data from a hospital’s MRSA surveillance is the basis for the MRSA risk assessment.
• The risk assessment based on surveillance data determines the goals, actions/interventions, and evaluation of the surveillance program.
• Surveillance activities should be integrated into the organizations Quality improvement and Safety programs.

MRSA Surveillance Basics
Surveillance is a dynamic, ongoing, essential element of any infection prevention and control program.

Components of Infection Prevention and Control Surveillance Plan

Drug-resistant pathogens are a growing threat to all people, especially in healthcare settings.
• Select the Surveillance Methodology
• Assess and Define the Population(s) to be Studied
• Choose the Indicators (Events) to Monitor
• Determine Time Period for Observation
• Identify Surveillance Criteria
• Identify Data Elements to be Collected
• Determine Methods for Data Analysis
• Determine Methods for Data Collection and Management
• Identify Recipients of the Surveillance Report
• Develop a Written Surveillance Plan

excerpted from: APIC Text of Infection Control and Epidemiology, 3rd Edition; January 2009
MRSA Surveillance Methodology

MRSA surveillance is targeted (focused), and is defined and developed from the MRSA risk assessment.\(^2\)

- The **populations** may reside facility-wide, or may be unit specific. Studies have shown that certain populations such as dialysis patients, residents of long-term care facilities, and patients in the intensive care unit are at-risk populations for MRSA infections and colonization.
- The **indicator** (monitor) is MRSA infection or colonization in the identified populations, and may be further defined by procedure or devices (e.g. MRSA related to central lines).
- The **time period** of surveillance activities is based on the needs of the organization and the scope of activities, but must be long enough to accrue a sufficient number of cases for a valid analysis.

**Population to be Studied**

Surveillance may be focused on a particular patient care unit (intensive care unit, burn unit), on patients undergoing high risk procedures (dialysis, transplant), or on patients with significant medical conditions (elderly, neonates). The surveillance activities should focus on persons at greatest risk of adverse outcome should they become infected. The risk assessment will have identified the high risk patients who receive care in the healthcare facility.

**Indicator Monitors**

The indicator monitor may be broad, for instance “all patients with MRSA infection or colonization” or specific, such as patients with MRSA blood stream infection. The time period of monitoring may vary from a few months to a year, or may be measured over a period of years. The indicators will be based on population served, procedures performed and services provided.

**Surveillance criteria**

Surveillance criteria must be clear, concise and consistent throughout the surveillance period. Changes in definitions affect surveillance analysis, and will result in rates that may not be directly comparable to the historical data. Changes that could affect surveillance include instituting a new active surveillance testing program; introduction of a new patient population or service line; closure or merging of a patient unit; and/or change in the sensitivity or specificity of MRSA testing methods. Evaluation of MRSA surveillance must take into account any changes that have occurred, and in some cases may require discontinuing the old surveillance when the new process is implemented.

*Caution* According to NHSN a positive screening culture at admission does not mean that any subsequent infection with that organism is not a healthcare-associated infection (HAI). Many HAIs are due to organisms from endogenous patient sources. If the patient meets all of the CDC/NHSN criteria for a healthcare associated infection (see [http://www.cdc.gov/nhsn/pdfs/pscmanual/17pscnosinfdef_current.pdf](http://www.cdc.gov/nhsn/pdfs/pscmanual/17pscnosinfdef_current.pdf)), and if that patient had no symptoms of infection present or incubating at the time of admission, then an HAI should be reported. A positive screening culture without evidence of infection represents colonization and does NOT imply or prove incubation.

**Data Elements**

Data elements useful in characterizing MRSA cases should be included in case identification or line listings. Typical elements are patient age and sex, admission date, patient location(s) during admission, prior MRSA history, dates of prior hospitalization, culture date(s), culture source(s), antibiotic susceptibility patterns and presence of known MRSA risk factors as published. Additional information that may be useful include
procedures performed, use of invasive devices, underlying conditions, colonization status, and clinical symptoms of infection. Information related to known or suspected MRSA risk factors in a geographic region or demographic population (e.g., inmates of correctional facilities, veterinary clinic personnel, hemodialysis patients, etc.) should also be collected.

Methods of data collection may be real-time, as in automated surveillance (data mining), ongoing surveillance report review, or rounding. Data collection is often retrospective, but should always be a function of identification of MRSA from clinical culture and active surveillance testing, if utilized.

**Surveillance Data Analysis and Management**

**Methods for Data Analysis**

Before data collection is initiated, the statistical measures that will be used to analyze the data must be determined. If rates or ratios will be calculated, the values corresponding to each numerator and denominator must be defined. Whenever possible, data should be expressed as rates or ratios that are calculated using the same methodology as a nationally validated surveillance system. This allows an organization to compare its rates with another organization or a recognized benchmark. See Figure 1 for an example of a MRSA surveillance rate calculation.

\[
\text{New MRSA case} = \text{MRSA-positive test from patient in SICU for >72 hours with no prior MRSA history}
\]

Calculation requires:
- the number of new MRSA cases in the unit
- the number of patient days in the unit

\[
\text{SICU MRSA rate per 1000 patient days} = \frac{\text{number of new MRSA cases}}{\text{SICU patient days}} \times 1000
\]

**Figure 1:** MRSA Surveillance Performance in a Surgical ICU (SICU)

It is beyond the scope of this guide to cover all of the indications and data tools that may be useful in a MRSA surveillance program. The reader is encouraged to review the SHEA/HICPAC MDRO Metrics position paper for a thorough review of metrics used to determine epidemiology of onset or association, hospital or community; incidence; prevalence; and susceptibility monitoring.

See **Resources** at the end of this section for published surveillance systems from NHSN, SHEA/IDSA HAI compendium, and SHEA/HICPAC MDRO Metrics position paper.

**Written Surveillance Plan**

A written surveillance plan should describe the following: the objectives, the indicators (monitors), the reason for selecting each indicator, the methodology used for case identification, data collection, analysis and the type of reports generated.
Surveillance Program Evaluation

The surveillance program should periodically evaluated, no less frequently than annually, to assess its usefulness and ability to meet the organization's objectives. Revisions should be made at time of annual review, or sooner when indicated by ongoing surveillance results if changes in incidence or outbreaks are identified.

Benchmark and Comparing Data

There are currently no national “benchmarks” for MRSA. Although it is very appealing to compare one's rates externally with others, comparisons should be made only after ensuring that the following conditions are met:

- Standardized case definition used in each comparison group.
- Criteria are consistent.
- The population and time period for study are the same in each comparison group.
- The same surveillance methodology is used in each comparison group.
- Rates and ratios are calculated using the same numerators and denominators.
- The facilities and populations being compared are similar.

Essential Features for Management of MRSA Surveillance Program

1. Consistently applied definitions

Prevalence: number of patients infected/colonized with MRSA divided by the number of patients in the study population in a particular period in time.

Incidence: number of new MRSA cases divided by the number of people being studied in a particular period of time.

MRSA transmission rate: number of new MRSA positive patients divided by the number of patient days times 1,000 or by the number of admissions times 100 in a particular period of time.

2. Consistent and comprehensive system for retrieval of laboratory test results

Automated surveillance technology (data mining) for retrieval of MRSA surveillance data can be implemented to good effect for MRSA surveillance and analysis. The APIC Position Paper on Surveillance Technologies of May 2009 provides a review of the benefits of automated surveillance technology, including to “streamline and facilitate efficient review of relevant data, promoting rapid identification of sentinel events and detection of outbreaks”.

However it is possible, albeit more time intensive, to implement a good MRSA surveillance system with limited technological sophistication. Lab result retrieval, via hard copy or online review of reports, and maintained line listings are sufficient for surveillance as long as the following are achievable:

- access to all MRSA-positive microbiology reports
- access to patient information such as medical record number, date of specimen collection, source of specimen and date of patient admission for MRSA-positive patients
- duplicate isolates easily identified for exclusion from rate calculations
- susceptibility results included or available
3. Collaboration with the microbiology laboratory

MRSA Laboratory Testing

1. Routine culture using blood agar isolation with subsequent testing for oxacillin resistance is used by many hospital laboratories to detect MRSA. However, results by this method have a turnaround time of two to five days.

2. Culture by selective media for MRSA is an alternative to routine culture which can provide positive results in approximately 24 hours with a relatively small cost increase.

3. Polymerase chain reaction (PCR) FDA approved MRSA testing for direct detection from a nasal specimen and from blood culture is available. PCR test results have very short turnaround times when compared to culture, but are more expensive and require additional instrumentation. Laboratories that do offer PCR for MRSA detection usually perform batch testing for most efficient use of resources. Even with batch testing, offering MRSA PCR test turnaround times in the range of two to twenty-four hours has great potential in efforts to eliminate MRSA transmission.\textsuperscript{10,11}

Antibiotic Susceptibility of MRSA Isolates

Susceptibility testing is performed on MRSA isolates to aid the clinician in the medical management of MRSA infection. The “D-test” for inducible clindamycin resistance should be included in the susceptibility test panel. The D-test may be positive on both MRSA and MSSA specimens, therefore it should not be considered a test for methicillin resistance in \textit{S. aureus} strains.

The hospital microbiology laboratory staff should follow the Clinical and Laboratory Standards Institute (formerly NCCLS) guidelines for all susceptibility testing.

Clindamycin Inducible Resistance

Some MRSA isolates that appear erythromycin-resistant and clindamycin-susceptible by routine susceptibility testing exhibit in vitro resistance to clindamycin during therapy and is known as “inducible resistance”. Inducible clindamycin resistance is not detected using standard susceptibility testing and can only be detected through a specialized laboratory test called the D-zone test. Clinical laboratories should test erythromycin resistant isolates for clindamycin inducible resistance. Strains with the inducible resistance phenotype, termed inducible macrolide-lincosamide-streptogramin B resistance (MLSB) may lead to clinical failure of clindamycin therapy.\textsuperscript{12,13}

Clindamycin Inducible Resistance:
“D” shape of the clindamycin zone adjacent to a standard 15-\(\mu\)g erythromycin disk in a conventional disk diffusion test http://wwwn.cdc.gov/nltcn/pdf/2004/2_hindler_d-test.pdf
MRSA Isolate Storage
For purposes of outbreak characterization and management, it is desirable for the laboratory to have a policy for MRSA isolate storage. Storage of isolates for some time period (e.g., minimum of one month and up to six months) ensures that isolates implicated in outbreaks can be retrieved as needed for pulse-field gel electrophoresis (PFGE) or other advanced clonal testing that can help to characterize the epidemiology of an outbreak and manage the outbreak response.

MRSA Results Reporting
The Infection Preventionist should collaborate with the microbiology laboratory regarding the notification process for MRSA test results. Ensure that laboratory reports clearly identify an isolate as “MRSA”, and include a susceptibility report when appropriate. There should be a mechanism in place to ensure that the Infection Preventionist receives a report of MRSA isolates in a timely manner.

The laboratory should notify the patient unit of a MRSA result from clinical culture. It may also be of value for the laboratory to include a comment on the MRSA-positive culture report regarding indications for contact precautions per infection prevention and control policy for hospitalized patients.

Patient with History of MRSA – Admission and Discharge Communications
“Flagging” of MRSA-positive patients is an important component of MRSA surveillance programs. An immediate alert of MRSA history is essential at time of admission to the hospital and at the time of discharge of the patient to another service or another healthcare facility. Some electronic medical record programs can be set up so that an MRSA notice or flag is automatically displayed during the admission process. If electronic flagging is not possible, alternative systems must be arranged so that notification of the receiving unit or facility is made consistently and in a timely manner.

4. Results of MRSA surveillance program – communications to key stakeholders
MRSA surveillance reports are valuable tools in efforts to eliminate MRSA transmission in hospital settings. Share reports and results with patient care units, patient care-related departments, administration, hospital board and medical staff. Tell the story, reward successes, and draw attention to opportunities for improvements. Reports may be discussed at staff meetings, posted on quality improvement bulletin boards, published in infection prevention and control newsletters, developed into grand rounds or CME presentations, and shared at physician meetings. Opportunities to reward and recognize successful units, staff and physicians will result from good compliance with MRSA transmission elimination measures. Certificates, pizza parties, award banners, presentations at meetings, publication of success stories at professional meetings and thank you notes are some of the ways to celebrate good efforts and results.

Cited References


**Resources and References**

- **National Healthcare Safety Network (NHSN)** is a voluntary, secure, internet-based surveillance system. A stated purpose of NHSN is to “assist facilities in developing surveillance and analysis methods that permit timely recognition of patient and healthcare personnel safety problems and prompt intervention with appropriate measures.” Nonparticipating facilities can access the surveillance definitions for Multidrug Resistant Organism infections, select device-associated infections, and procedure associated infections. These definitions can be helpful when developing the facility MRSA surveillance plan. See http://www.cdc.gov/nhsn/index.html for more details.

- **SHEA/IDSA HAI Compendium:** The Society for Healthcare Epidemiology of America (SHEA) and the Infectious Diseases Society of America (IDSA) sponsored and authored a compendium of practice recommendations to prevent healthcare-associated infections in acute care hospitals in partnership with the Association for Professionals in Infection Control and Epidemiology (APIC), the Joint Commission, and the American Hospital Association (AHA). This
compendium offers “Strategies to Prevent Transmission of Methicillin-Resistant *Staphylococcus aureus* in Acute Care Hospitals,” as well as guides related to procedures and devices. The compendium is available for download in the October 2008 Supplement of Infection Control & Hospital Epidemiology (Volume 29, Number S1). [http://www.journals.uchicago.edu/toc/iche/2008/29/s1#SAAPracticeARecommendations7uqwe](http://www.journals.uchicago.edu/toc/iche/2008/29/s1#SAAPracticeARecommendations7uqwe)

MRSA Active Surveillance Testing (AST)

Key Concepts

- MRSA active surveillance tests are useful in epidemiologic studies of the prevalence, incidence and/or transmission of MRSA.
- MRSA active surveillance tests may be done for the purpose of discontinuation of contact precautions.
- Clinical cultures will not identify the majority of MRSA-positive patients, especially in settings with high endemic MRSA rates.
- In addition to MRSA data from clinical culture, if MRSA active surveillance tests are available, the data becomes an element of the ongoing and annual MRSA risk assessment.
- MRSA active surveillance tests may be implemented per MRSA risk assessment, per legislative mandates, and/or when indicated as a component of enhanced control efforts.

Active Surveillance Testing (AST)

The 2006 MDRO guideline\(^1\) recommends a two-tiered approach to the management of MDRO in healthcare settings. The first tier includes routine surveillance activities that can identify evolving MRSA problems (e.g., increased MRSA transmission) and safeguards for managing unidentified MRSA carriers, as well as monitoring adherence to practices known to prevent cross transmission such as adherence to hand hygiene and contact precautions recommendations. The second tier of enhanced control efforts is used when incidence or prevalence is not decreasing despite implementation of and correct adherence to the routine infection control measures.

Active surveillance testing (AST) may be a useful MRSA management intervention in situations requiring enhanced control efforts. The MDRO Guideline recommends the following regarding AST:

\textit{V.B.1.a.} Indications for intensified MDRO control efforts should result in selection and implementation of one or more of the interventions described in VII.B.2 to VII.B.8 below. Individualize the selection of control measures according to local considerations. Category IB

\textit{V.B.5.b.} Develop and implement protocols to obtain active surveillance cultures (ASC) for targeted MDROs from patients in populations at risk (e.g., patients in intensive care, burn, bone marrow/ stem cell transplant and oncology units; patients transferred from facilities known to have high MDRO prevalence rates; roommates of colonized or infected persons; and patients known to have been previously infected or colonized with an MDRO). Category IB

\textit{V.B.5.b.i.} Obtain AST from areas of skin breakdown and draining wounds. In addition, include the following sites according to target MDROs:

\textit{V.B.5.b.i.1.} For MRSA: Sampling the anterior nares is usually sufficient; throat, endotracheal tube aspirate, percutaneous gastrostomy sites and perirectal or perineal cultures may be added to increase the yield. Swabs from several sites may be placed in the same selective broth tube prior to transport. Category IB
MRSA bacteremia is declining in ICU when bacteremia is discussed on page 27. 

**AST Specimens**

Patients who have MRSA infections will be positive for MRSA at the site of their infection and at colonized body sites. After infection has resolved, colonized patients may carry MRSA at one or more sites including the nose, throat, groin, axilla, non-intact skin surfaces, and skin/tube interfaces (including tracheotomy sites and percutaneous feeding tubes).

The colonization site most often cultured to detect MRSA colonization is the anterior nares. Culturing additional sites such as the groin, axilla or throat will increase the sensitivity of AST screens. However, adding alternate site screens may be impractical in terms of cost, time, resources and results.

The minimal specimen requirements for AST are the anterior nares and areas of active skin breakdown or draining wounds.

**Identifying Patients at risk of MRSA colonization for an AST program**

Patients or patient populations eligible for an MRSA AST program will have been identified by the MRSA risk assessment, and may include patients who:

- have a known history of MRSA
- are in high risk groups or populations for healthcare associated MRSA (which may include long-term care residents, patients with recent or frequent hospitalizations, dialysis patients, diabetics injecting insulin, patients in critical care, patients undergoing select surgical procedures, etc.)
- have risk factors for community-associated MRSA infection, (athletes in organized sports, veterinarians and others who have close contact with pets, patients with a history of being in jail or prison settings, patient with history of IV drug use)
- are roommates of MRSA positive patients
- are admitted from a clinical unit or service with high endemic MRSA rates
- are in a population identified by the hospital risk assessment

Patient “flags” for AST:
Identification of patients for AST at time of admission can be problematic. There must be a standardized, consistent process to identify patients and to ensure collection of the AST specimen in the appropriate timeframe. “Flagging” of MRSA-positive patients is an important component of MRSA surveillance programs. An immediate alert of MRSA history is essential at time of admission to the hospital and at the time of discharge of the patient to another service or healthcare facility. Electronic medical record programs can be set up so that an MRSA notice or flag is automatically displayed during the admission process. If electronic flagging is not possible, alternative systems must be arranged so that notification of the receiving unit or facility is made consistently and in a timely manner.

Universal AST:
Some hospitals have implemented a program of universal AST (all admissions) based on risk assessment, availability of resources (supplies and personnel), medical and clinical staff support, and development of a strong business case for the program. One advantage to universal AST is that it eliminates the need for the often complex
process of identifying and promptly obtaining surveillance specimens from patients in populations targeted for AST. A recently published study relates a reduction in MRSA disease after the implementation of universal screening in a three hospital system.²

If such an undertaking is contemplated, careful planning is required. All facets of such planning including management and cost allocation for needed resources are examined by Diekema and Edmond, who conclude that “planning should recognize the following needs: preparing the laboratory and reducing the turnaround time for screening tests, monitoring and optimizing the contact precautions intervention, monitoring and ameliorating the known adverse effects of contact precautions, and measuring important outcomes that can evaluate the effectiveness of a program of active surveillance cultures and contact precautions”.³

**Processes for Collection of AST**

Prior to implementing an AST program, it is necessary to develop a process that has the potential for a high rate of compliance with collection. Use a team approach and include representative members from all departments that play a role.

Develop a monitor, e.g. a line listing, of all patients to be tested for MRSA colonization. Compliance with obtaining surveillance specimens can be compiled weekly and shared for appropriate stakeholders in the process. The compliance monitor should be compiled and evaluated at an appropriate interval. Adjustments to the process can then be made as needed.

<table>
<thead>
<tr>
<th>Patient identifier</th>
<th>Adm date SICU</th>
<th>Adm AST date/results</th>
<th>Discharge /Transfer date from SICU</th>
<th>Discharge AST date/results</th>
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**Figure 1:** Example of a monitor for MRSA surveillance testing patients admitted to SICU

**Figure 2:** Compliance report compiled monthly

Improvement needed on compliance with obtaining discharge surveillance cultures.
Timing of Specimen Collection for AST

A simple AST program would include nasal swab of candidate patients at the time of admission to the hospital or unit and at the time of discharge or transfer from the hospital or unit.

Option 1 - Collect AST specimens
- at the time of admission to the hospital or unit
- at the time of discharge or transfer from the hospital or unit

Option 2 - Collect AST specimens
- at the time of admission to the hospital or unit
- at the time of discharge or transfer from the hospital or unit
- if discharge or transfer is delayed, collect specimen every “X” number of days after admission

This option is problematic unless a system of automatic orders (computer-generated) can be utilized to capture the “every X number of days” culture.

Option 3 - Collect AST specimens (unit specific)
- at the time of admission to the hospital or unit
- at the time of discharge or transfer from the hospital or unit
- collect AST on every patient every Thursday (pick a weekday that works best for the unit)

This captures important data when lengths of stays are extended.

There may be other options that better suit the needs of a given AST program. Timing of specimen collections should be customized to meet surveillance and/or intervention needs.

Communication about AST

Physicians and Healthcare Providers usually view patient testing as a tool in the management of the patient’s clinical condition. Surveillance tests however, are tools used in infection prevention and control efforts. Effective communication and collaboration with medical and clinical staff is crucial to the success of the program. Administrative support for the program must be very visible and clear to the medical staff. The results of MRSA program surveillance and the goal of elimination of MRSA transmission in the hospital should be regularly shared in meetings, on process improvement bulletin boards, infection control newsletters or by other means. Infectious disease physicians are valuable champions and should have up-to-date information so they can effectively support the AST program.

Patients and families should know and understand the reasons for active surveillance testing. A patient letter about surveillance tests, informational scripts for patient caregivers and MRSA fact sheets should be developed prior to the implementation of the AST program. Patient and family satisfaction regarding care can be enhanced when the communication is clear and questions are honestly and correctly answered. The infection preventionist should be able to assure the patient and family that the patient is not being charged for this AST if payment is non-capitated.
MRSA nasal specimen collection procedure

The anterior nares is the routine site of collection of the nasal specimen for MRSA AST. To obtain an adequate specimen, gently rotate the culture swab for 2 – 5 rotations after inserting about \( \frac{3}{4} \) of an inch into the nasal passage (adult).

Follow manufacturer’s instructions specific to the MRSA test methodology for nasal specimen collection.

MRSA Screen Laboratory Testing

Microbiology testing regimens currently available for MRSA nasal screens include:

1. Isolation of MRSA on blood agar and mannitol salt with follow-up confirmatory testing and susceptibility testing. Results are available in 48 hours if negative, but take as long as 3–4 days if staphylococci are present for the confirmatory susceptibility testing to be completed.

2. Selective media for MRSA (e.g., CHROMagar Microbiology, Paris, France) can be used for identification of MRSA nasal colonization in 24–48 hours without requiring any additional tests.

3. Rapid MRSA assays that use FDA-approved, DNA detection-based polymerase chain reaction methodologies (PCR) have the potential for results in two hours if testing is done in real-time. These tests feature relatively simple lab workflow using automated technology. However, they cost more than conventional and selective culture methods.

An important MRSA surveillance consideration when comparing these methodologies is the length of time it takes to get results that will influence infection prevention and control interventions. (See “Contact Precautions” section.)

The most important resource considerations are financial and workload–related. The cost impact to the laboratory is related to the increased volume of AST screens, reagent and instrumentation costs and FTE requirements.

Cited References


Resources and References


Hand Hygiene

Key Concepts

- Hand hygiene plays an integral role in reducing the transmission and occurrence of infection and is the cornerstone of any infection prevention program.
- All healthcare settings must implement a comprehensive hand hygiene program, periodically monitor compliance, and provide feedback to individuals and key stakeholders in the infection prevention program.
- All healthcare settings must maintain gains and facilitate improvements in hand hygiene compliance.

The importance of hand hygiene in the elimination of MRSA transmission cannot be overstated. Guidelines for implementing a hand hygiene program and monitoring compliance have been published by the Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO).\textsuperscript{1,2} Both guidelines recommend the following:

1. Implement a multidisciplinary, multimodal hand hygiene program that includes all levels of healthcare personnel, visitors, patients and patient’s families.
2. Wash hands with soap and water when visibly dirty or visibly soiled with blood and body fluids and after using the toilet.
3. If hands are not visibly soiled, use an alcohol-based hand rub for routinely decontaminating hands in clinical situations.
4. Perform hand hygiene before and after contact with a patient.
5. Perform hand hygiene after contact with the patient’s environment.
6. Wear gloves for all contact with blood, body fluids and moist body surfaces. Remove gloves after caring for patient, when moving from dirty to clean site on same patient, and before care of next patient care.
7. Wash hands or use an alcohol-based hand product after removing gloves.
8. Monitor health care personnel’s adherence to recommended hand hygiene practices and provide them with performance feedback.
9. Provide educational and motivational programs for healthcare personnel.
10. Hold healthcare personnel and administrators accountable for implementing a culture that supports and promotes appropriate hand hygiene practices.

Monitoring hand hygiene practices. There is no standardized method for monitoring hand hygiene compliance; however, there are many good resources for monitoring practices. These include those provided by the WHO,\textsuperscript{2,3} the Institute for Healthcare Improvement,\textsuperscript{4} the Joint Commission,\textsuperscript{5} and the University of Geneva Hospitals in Switzerland.\textsuperscript{6} The Community and Hospital Infection Control Association-Canada provides an extensive list with links to resources posted on its website at http://www.chica.org/links_handhygiene.html.

Strategies to improve and monitor adherence to hand hygiene are important components in an MRSA control and elimination program.\textsuperscript{7} Hand hygiene plays a critical role in standard and contact precautions discussed below.
Cited References


Standard and Contact Precautions to Prevent Transmission of MRSA

Key Concepts

- Transmission of MRSA directly from infected and colonized patients and indirectly via contaminated equipment, supplies, and environmental surfaces in patient rooms has been documented.1-3
- The use of standard precautions for all patients and contact precautions for patients colonized or infected with MRSA is recommended to eliminate transmission of MRSA and other multidrug-resistant organisms (MDROs) in the hospital setting.1-2
- The elements of standard and contact precautions are well-established for hospital settings.1,2,4

Basic Components of Standard and Contact Precautions

Because colonization with MRSA is frequently undetected, consistent use of standard precautions for all patients plays an integral role in interrupting the transmission of MRSA and other MDROs. Contact precautions are recommended in addition to standard precautions for patients colonized or infected with MRSA. The basic components of the Healthcare Infection Control Practices Advisory Committee (HICPAC) recommendations for standard and contact precautions are outlined in the Box 1; for detailed information, the reader is referred to the HICPAC documents.1,2

Standard precautions basic components:1,2

Standard Precautions includes hand hygiene (discussed in the section above), respiratory hygiene, and the following practices:

- **Gloves**: for touching blood, body fluids, secretions, excretions, contaminated items, mucous membranes and non-intact skin
- **Gown**: for procedures and patient-care activities when contact of clothing or exposed skin with blood/body fluids, secretions, and excretions is anticipated
- **Mask, eye protection (goggles), face shield**: during procedures and patient-care activities likely to generate splashes or sprays of blood, body fluids, and secretions, especially wound irrigation, oral suctioning, and endotracheal intubation
- **Soiled patient-care equipment and laundry**: should be handled in a manner that prevents transfer of microorganisms to others and to the environment, including use of gloves for visibly contaminated items
- **Environmental control**: there should be procedures for routine care, cleaning, and disinfection of environmental surfaces, especially frequently touched surfaces in patient-care areas.

Standard Precautions also includes Respiratory Etiquette. As part of respiratory etiquette, the HCW is advised to wear a mask when examining and caring for patients with signs and symptoms of a respiratory infection.
Contact precautions basic components:1,2

- **Patient placement:** Single-patient room preferred. When single-patient room not available, the various risks associated with other patient placement options must be evaluated (e.g., cohorting, keeping the patient with an existing roommate).
- **Gloves and gowns:** recommended for all interactions that may involve contact with the patient or potentially contaminated areas in the patient’s environment. Requiring persons to don gown and gloves upon room entry and discard them before exiting promotes compliance with this recommendation; helps ensure that hands and clothing do not become contaminated; and disrupts transfer of microorganisms to other patients or environments.
- **Patient care equipment:** use of dedicated non-critical patient care equipment is recommended for patients on contact precautions. There should be mechanisms in place to ensure that common equipment that is not dedicated to the patient is adequately cleaned and disinfected before use with another patient.

Note: The use of a mask for MRSA contact precautions remains controversial. Some hospitals require it for all MRSA-related isolation (reduce healthcare worker risk of nasal colonization), while other facilities require it only if the MRSA-positive patient is known to have MRSA infection of the respiratory tract.

**A Note on Strategies to Discontinue Contact Precautions:** There are no definitive criteria that can be cited as specific recommendations for discontinuation of contact precautions for MRSA.1,4 Many hospitals have developed protocols for discontinuing contact precautions when a patient’s infection has resolved and there are several negative surveillance tests in the absence of antibiotics to demonstrate that the patient is no longer colonized with MRSA. Some hospitals choose to consider MRSA-colonized patients to be colonized indefinitely. See *Duration of Contact Precautions* in the HICPAC guideline on multidrug-resistant organisms for further information.1

**Special Considerations: Timing of Contact Precautions if Active Surveillance Testing (AST)**

Active surveillance testing (AST) is done to identify patients that are asymptptomatically colonized with MRSA, as discussed in this guide’s section on AST. Hospitals that conduct AST need a process in place to direct decisions about room placement and use of contact precautions that must be made prior to availability of test results. Decisions and protocols regarding room placement and use of contact precautions should be based on the hospital’s MRSA risk assessment (See section on MRSA Risk Assessment). The following questions should be considered when developing these protocols:

- What is the risk that the patient is colonized with MRSA (e.g., does patient have a skin or soft tissue infection or belong to an identified high risk group)?
- What is the turn-around time for AST results (e.g., less than 24 hours, 24 hours, 48 hours)?
- Are private rooms available for patients identified as high-risk by the MRSA risk assessment?

**Contact Precautions and Room Placement for Patients Screened with AST:**

There is no definitive research regarding how long it takes before the lack of contact isolation precautions leads to significant risk of transmission of MDROs from an infected or colonized patient. Therefore, hospitals must start with a reasonable approach based on MRSA surveillance and risk assessment and adjust the approach if
surveillance demonstrates MRSA transmission is ongoing. Examples of possible options for patient placement on admission for those patients who do not have a history of MRSA and are screened include the following:

**Option 1.** Use private room and implement contact precautions for all patients from identified high risk groups until AST results are known. If AST result is negative, discontinue use of private room and contact precautions.

**Option 2.** Use *routine* room placement assignments per infection control policy (standard precautions or empiric precautions as appropriate for large draining wounds, uncontrolled secretions, MRSA history etc.) until AST results are known. Make reporting of AST results a priority for the laboratory and implement a system to (1) report positive results immediately to the clinical units and (2) implement contact precautions and use of private room as soon as a positive result from AST or clinical culture is reported. If the positive patient has a roommate, obtain specimen for AST from the roommate without delay and again at the time of discharge.

Implementing an AST program will usually increase the use of contact precautions and will affect patients, staffing, and resources. Before implementing new processes related to contact precautions for the purpose of management of MRSA and other MDROs, a hospital should address the following considerations:

**Patient care:** The impact of contact precautions on patient care has been a subject of some controversy and much concern. Contact precautions used preemptively for a patient who ultimately is found not to harbor MRSA will be, at the very least, a dissatisfier for the patient and the patient’s caregivers.

**Staffing:** Staff resources will be impacted if there is an increase in the number of patients on contact precautions and when AST programs are implemented. Personnel from nursing, the laboratory, infection prevention and control, and housekeeping will be most affected.

**Other Resources:** Additional resources related to contact precautions and AST include supplies for contact precautions and specimen collection, laboratory reagents and instrumentation, and written patient/family information regarding AST or contact precautions. If patient rooms in the hospital are not private or single occupancy, lack of bed availability can adversely affect patient placement options.

**Contact Precautions in Settings Outside of In-patient Hospital Units**

This APIC Guide focuses on MRSA infection prevention practices in hospital settings; however, information on the use of contact precautions in out-of-hospital settings can be found in the following publications: the HICPAC guidelines, guidelines for management of MRSA in community settings developed by an expert panel, and recommendations published by Matlow and Morris.

**Strategies for Success**

The following strategies can be used by hospitals to implement standard and contact precautions to prevent the transmission of MRSA and other MDROs and ensure compliance with appropriate infection prevention practices:

- Implement a flag or alert system to identify patients diagnosed with MRSA and other epidemiologically significant organisms so that contact precautions may be initiated immediately on subsequent admissions.
- Develop a system for identifying MRSA-positive patients when they are transported within the hospital so that transport teams and receiving units can implement proper precautions.
- Develop a system for identifying MRSA-positive patients when they are transported outside the hospital so that transport teams and receiving facilities can implement proper precautions.
- Measure adherence to the following and implement corrective actions as indicated:
  - hand hygiene (See the Hand Hygiene section of this guide)
  - standard and contact precautions (See Figure 1, sample monitoring tool)
° environmental sanitation policies
° MRSA active surveillance testing program protocols

- Educate personnel on risks of transmission of MRSA and infection prevention measures at time of orientation and during annual training/competencies.
- Provide training and education when new processes related to elimination of transmission of MRSA are implemented.
- Communicate and re-educate when rates of compliance with processes related to elimination of transmission of MRSA show inadequate results.
- Communicate and re-educate when rates of transmission of MRSA are not decreasing.
- Communicate and celebrate when rates of transmission of MRSA are decreasing.

Cited References


Resources and References


Environmental and Equipment Cleaning and Disinfection

Key Concepts:

- MRSA can survive in the hospital environment and hospital surfaces.
- Patients and healthcare workers can transmit and/or acquire MRSA from contact with contaminated equipment and environmental surfaces.
- Effective environmental cleaning and equipment cleaning/disinfection will reduce the risk of transmission of MRSA.
- All staff must take responsibility for ensuring that the hospital environment is appropriately cleaned and that equipment is cleaned and disinfected between patient use.

Background

Survival of MRSA in the Hospital Environment:

Staphylococci, including MRSA, can survive in the hospital environment. In studies by Neely\(^1\) and Huang\(^2\), staphylococci were recovered for a least one day and up to 56 days after contamination on common hospital materials, and two strains of MRSA survived for nine to 11 days on a plastic patient chart, a laminated tabletop, and a cloth curtain in a hospital. As noted by Dancer, both coagulase negative and positive staphylococci have the ability to survive in the environment regardless of temperature, humidity, and sunlight; and “when mixed with hospital dust, MRSA can still be revived more than 1 year after inoculation”.\(^3\) People colonized continually shed staphylococci into their environment. Since neither the environment nor equipment are self-cleaning, all reusable medical equipment that contacts patients and or their environment have the potential to become a vehicle for transmission of MRSA.

Transmission of MRSA to Patients from the Hospital Environment:

It been proven that MRSA can survive on common hospital surfaces, and some studies have implicated contaminated hospital surfaces in MRSA acquisition. Hardy et al\(^4\) found strong evidence to suggest that three of 26 patients who acquired MRSA while in the intensive care unit acquired the organism from the environment. In addition, MRSA was isolated in every environmental room screening done per study protocol. In a study of MRSA environmental contamination in rooms of MRSA patients, Boyce et al\(^5\) recovered MRSA from the rooms of 73% of infected patients and 69% of colonized patients. The authors of both studies concluded that inanimate surfaces in close proximity to infected or colonized patients commonly become contaminated and may become a source of transmission of MRSA. Healthcare workers, patients and visitors contract MRSA by touching contaminated room surfaces. This has major implications for any effort to eliminate the transmission of MRSA in hospital settings.

There is an increasing body of evidence demonstrating that healthcare workers contaminate hands or gloves by touching inanimate objects in the immediate vicinity of patients who are colonized or infected with organisms that can survive for prolonged time periods in the environment.\(^6\) It is a recognized principle of standard precautions that healthcare-associated pathogens are frequently spread from one patient to another via the transiently contaminated hands of healthcare workers.
Delineate Responsibility for Cleaning

All hospital staff have responsibility for maintaining a clean, safe patient environment. Patient care and ancillary department staff are responsible for disinfection of equipment between each patient use. This aspect of cleaning and disinfection should be built into general protocols and procedures. Hospital-approved disinfectants must be readily available to all staff with cleaning responsibility at all points of use. A system should be in place to ensure that reusable medical equipment is appropriately cleaned per manufacturer instructions, and to ensure that the equipment is cleaned before the next patient use. Cleaning and disinfection protocols can be effective tools for the management of environmental contamination with antimicrobial resistant pathogens such as MRSA. See the HAI compendium supplement “Strategies to Prevent Transmission of Methicillin-Resistant Staphylococcus aureus in Acute Care Hospitals” for a good review of methods to ensure cleaning and disinfection of equipment and the environment. (Reference from HAI compendium and the HICPAC CDC Guidelines for environmental infection control in health-care facilities are located in Resources at the end of this section)

The role of Environmental Services (EVS) staff in patient safety cannot be overstated. The overall maintenance of a clean, safe hospital environment is the responsibility of this department. Initial training on cleaning and disinfection procedures, reinforcement of best practice (checklists, monitors), and annual competency for EVS staff is important to the elimination of MRSA transmission.

Policies and procedures must specify how, by whom, and when environmental surfaces are cleaned. This includes specifying the proper dilution of the standard hospital–approved disinfecting agents and the contact time for germicidal agents. Proper use of cleaning and disinfection products requires that manufacturer’s instructions and contact times are carefully observed. Daily cleaning of occupied patient rooms is an essential component of the facility policy on cleaning. Frequent cleaning of patient care areas, e.g. the emergency department or units experiencing an outbreak, may be targeted for more frequent cleaning. Some facilities have found it beneficial to assign dedicated EVS staff in targeted patient care areas to provide consistency of appropriate cleaning and disinfection procedures. In areas experiencing high endemic MRSA rates, increasing the frequency of cleaning and disinfection for areas with substantial hand contact is warranted.

Monitoring Environmental Cleaning

Carling et al., concluded that “significant improvements in disinfection cleaning can be achieved in most hospitals, without a substantial added fiscal commitment, by the use of a structured approach that incorporates a simple, highly objective surface targeting method, repeated performance feedback to environmental services personnel, and administrative interventions.”

Initial and ongoing training as well as monitors to assess cleaning performance of all staff will ensure consistency. Monitors should include an assessment of the cleaning surfaces nearest to the patient, including bedrails, bedside tables—including under the handles, overbed tray tables, telephones, remote controls, call lights, doorknobs, bedside commodes, faucet handles, chairs, and curtains. The use of an environmental cleaning checklist may increase efficacy of daily and discharge cleaning and may be helpful when monitors show that cleaning is inadequate. There is generally no need for environmental cultures unless there is epidemiologic evidence that an environmental source is associated with ongoing transmission of MRSA. Consider closing a unit for deep cleaning and disinfection if there is evidence of unchecked transmission.

Photographs of patient rooms with high impact areas identified can be a visual aid and cue to housekeeping employees. These photos also ensure consistency in room cleaning.
Example of Basic Cleaning Checklist
(modify to include additional high touch locations as appropriate)


**ENVIRONMENTAL SERVICES CHECK LIST AUDIT**

**DAILY CLEANING OF PATIENT ROOM**

**STEPS**

1. **High Dusting Performed**
   a. Use high duster/mop head: wipe ledges (shoulder high and above)  
      **Yes**___  **No**___
   b. Vents  
      **Yes**___  **No**___
   c. Lights  
      **Yes**___  **No**___
   *Do not high dust OVER the resident*
   d. Dust TV: rotate and dust screen and wires  
      **Yes**___  **No**___
   *Remove dust over cart trash bag gently*
2. **Damp Dust**
   Cloth (rag) and spray bottle of disinfectant – damp wipe:  
   Yes___  No___
   a. Ledges (shoulder high)  
   Yes___  No___
   b. Door handles  
   Yes___  No___

3. **Bedrails and Bedside Table**  
   Yes___  No___

4. **Glass Surfaces**  
   Yes___  No___
   a. Wall spots  
   Yes___  No___  N/A___

5. **Bathroom (Toilet Bowl Mop) All Surfaces**  
   Yes___  No___
   a. Weekly toilet chemical allow to stay  
   Yes___  No___
   b. Ledges in bathroom  
   Yes___  No___
   c. Door handles  
   Yes___  No___
   d. Sink  
   Yes___  No___
   e. Shower stall  
   Yes___  No___
   f. Finish toilet  
   Yes___  No___
   g. Damp wipe toilet seat  
   Yes___  No___
   h. Clean mirrors/chrome  
   Yes___  No___

6. **Empty Waste Basket**  
   Yes___  No___
   a. Disinfect if wet  
   Yes___  No___
   b. Bags – close  
   Yes___  No___

7. **Isolation (Red Bag Waste) Empty**  
   Yes___  No___
   a. Carry to soiled utility room  
   Yes___  No___
   b. Carry to Large Red Hazard trash  
   Yes___  No___

8. **Needle Boxes**  
   a. Check level of Sharps  
   Yes___  No___
   b. Replace if ½ to ¾ full  
   Yes___  No___  N/A___
   c. To soiled Utility Room after securely closing  
   Yes___  No___  N/A___

9. **Floor Disinfection – Sign on Door**  
   Yes___  No___
   a. Wet mop head in disinfectant  
   b. Mop (farthest from door) ½ way room  
   c. Bathroom shower floor  
   d. Bathroom floor  
   e. Flip mop head – do remainder of room
Cited References


Resources and References


Cultural Transformation

Key Concepts

• Healthcare-associated infections are a preventable patient safety concern.
• Infection Prevention is EVERYONE’s business, not just clinicians.
• Strong Leadership and a “call to action” can engage maximum potential from all levels of workers.
• Workers who feel respected and empowered can effect positive change.
• Where compliance with strategies and behaviors known to prevent infection transmission is weak, cultural transformation can effect improvement in compliance and ultimately prevent infections.

Background

Hospital-associated colonization and infection was generally considered a necessary evil until the release in 1999 of the Institute of Medicine (IOM) report To Err is Human: Building a Safer Health System. 1 The report brought new attention to the fact that tens of thousands of people die in American hospitals each year due to preventable causes, including medical errors and healthcare-associated infections. Another IOM report in 2001, Crossing the Quality Chasm 2 described a healthcare system struggling to find a new direction in the aftermath of two decades of economic instability, shifts in governmental regulations and payment practices, and shortages in the workforce. The focus in many healthcare organizations seemed to have shifted from the historical mission of healing the sick to sheer survival.

In “Cultural Transformation in Health Care”, a 2005 white paper authored for the Robert Woods Johnson Foundation, Bobbi Kimball describes the complex nature of organizational culture emerging from twenty years of chaos and change that is facing healthcare leaders and workers. Organization leaders and healthcare workers have described their situations as task-oriented, isolated, routine, and meaningless, and have the feeling of powerlessness to effect change—the epitome of bureaucracy, or “top-down” management style. Recognizing the stagnation, and supported by a growing body of literature suggesting that strong and deliberate Leadership could leverage culture transformation for positive changes in healthcare, some organizations began applying culture change theories from other industries to healthcare. 3

At the time, leading oversight and accreditation bodies prioritized diverse preventable healthcare-associated problems such as medication errors and pressure ulcers. 4 Preventing healthcare-associated infections was a common theme. Even though infection prevention strategies, like hand hygiene and use of barrier isolation practices, were known to work and were recommended by infectious diseases experts, many studies reported inconsistent compliance with those strategies among healthcare workers. 5

In the early 2000s, over half of the Staphylococcus aureus bloodstream isolates from patients in intensive care units reported to the CDC’s National Nosocomial Infection Surveillance (NNIS) were resistant to methicillin. 6 Many healthcare organizations that were dealing with significant numbers of MRSA infections began to institute culture change theories in an effort prevent the spread of MRSA in their facilities. Most of these theories endorse similar common elements, including a leadership-driven effort to engage and empower frontline workers in change from the “bottom up”. 7-13 By 2009, there were cautious reports of success controlling MRSA using a “MRSA Bundle” that included the application of culture change strategies. 14-15
Applying Culture Change Theories to Healthcare

Culture transformation is usually a slow, evolving process, as small successes are recognized and slowly accepted by others, growing in popularity over time, and eventually becoming the status quo. It is important to understand that changing culture is generally not needed due to a deficit of knowledge, but rather because of failure to behave in a certain way—a failure to follow through on known best practices. MRSA has not become the huge healthcare problem because healthcare workers did not know how to stop transmission. It became a problem because, for many and varying reasons, the culture in healthcare organizations did not support behaviors associated with best practices.

When Leadership adopts new ways of doing business that facilitates staff involvement in identifying problems and resolving system barriers to best practices, staff discover ways to implement change. Staff-designed and -driven changes are always culturally appropriate for those staff, and this type of change minimizes the typical rejection and pushback when change is imposed from an external source. The role of Leadership is to invite participation, listen to staff problems and barriers, remove barriers to best practices, and support innovative ideas.

Giving healthcare workers the freedom and the opportunity to create solutions fosters cultural change from within. For example, when staff discover latent behaviors that are routine to coworkers who have managed to accomplish better outcomes with the same resources, they are more likely to implement these successful strategies since they are adopting the change as their own idea. By providing opportunities for staff to discover, identify, and practice those isolated behaviors from each other, the culture of the organization enjoys a huge opportunity to prevent healthcare problems.

Many culture change theories have been described in the literature, among them Six Sigma\(^\text{12}\), Lean Six Sigma\(^\text{16}\), Toyota Production System\(^\text{17}\), and Positive Deviance\(^\text{18}\) and CUSP-Comprehensive Unit-based Safety Program (See Resources). Although they each have succinct and individual detail in their theoretical frameworks, many of them have common themes associated with their application strategies:

- Leadership leads the effort, and engages frontline workers (can be a “kickoff” announcing a “new way of doing business”)
- The problem is clearly defined, so everyone focuses on the same objective, e.g. eliminate healthcare-associated MRSA transmissions and infections
- **All levels** of the organization are actively engaged and contribute to problem identification and potential solutions
- Potential solutions are assessed for feasibility and usefulness
- Action Plans are developed and shared
- Successes and barriers are shared and transparent in the organization
- Outcomes are tracked and processes repeated or reevaluated and new strategies tried

Culture change is not linear. It requires dedication and perseverance to cope with the potential surprises and barriers, and time for the successes to emerge and show positive outcomes. The obstacles and successes will be unique to each organization, which will allow all levels to work together on the problems, developing their own meaning and unique path toward their unique objectives and organizational legacy.
Cited References


Resources and References


• Fraser VJ, Olsen MA. The business of health care epidemiology: Creating a vision for service excellence. Am J Infect Control 2002; 30: 7-85

Resources (CUSP)

• The Patient Safety Group
  https://www.patientsafetygroup.org/program/index.cfm

• AHRQ– Ending Health Care- Associated Infections
  http://www.ahrq.gov/qual/haicusp.htm

• AHRQ Innovations Exchange On the CUSP: Stop Blood Stream Infections – Resources
  http://www.innovations.ahrq.gov/content.aspx?id=2685
MRSA Education Plan

Key Concepts

- Education is a critical component of every infection prevention and control program.
- Education about MRSA should be provided to healthcare personnel, patients and their families, and visitors as appropriate.
- Education activities should be based on a needs assessment of each group targeted for education.
- A MRSA education plan complements and supports Cultural Transformation in that everyone in the healthcare environment, including patients and visitors, has the opportunity to learn about MRSA, improve their own practice, and teach others to practice the strategies that prevent MRSA transmission, and other patient safety objectives.

Education is widely recognized as an important component of any program to eliminate hospital-associated infections and MDRO pathogens. The HICPAC 2006 MDRO guideline recommends routine MDRO education as a primary (Tier 1) control strategy, and recommends that additional education is implemented when indicated by the infection prevention risk assessment.¹ The MRSA guideline of the SHEA/IDSA HAI Compendium recommends that healthcare personnel receive education related to MRSA risk factors, transmission, prevention measures, and outcomes of hospital associated MRSA infections. The education is expected to meet needs of a wide range of personnel (targeted for specific groups) and result personnel behavior changes as appropriate.² The 2010 National Patient Safety Goal on hospital associated infection emphasizes annual staff and licensed independent practitioners education regarding health care–associated infections, multidrug-resistant organisms, and prevention strategies based on facility risk assessment, as well as education provided to patient and families related to MDRO infection and colonization.³

Educational Principles

The following tools and principles should be considered to develop any educational plan and activities.

- Base educational activities and plans on an educational needs assessment
  - Identify deficits in knowledge, attitude, or skills
  - Identify the learning needs and levels of a particular group.
  - Use a tool designed to measure the effectiveness of the education
- Learning occurs on three levels⁴
  - Cognitive learning increases knowledge
  - Affective learning changes attitudes and feelings
  - Psychomotor learning promotes behavior change
- The educator controls the learning experience by
  - Developing goals that clearly communicate the intent and direction of the education.
  - Writing clear, concise learning objectives that describe in measurable terms the knowledge or behavior outcome that is expected from the education program.
  - Using teaching methods that promote the appropriate skill levels identified in the education needs assessment.
• Adult learners prefer experiences that make sense to them and relate to their needs,
• A thorough discussion of these and many other principles of education can be found in the 2009 APIC Text of Infection Control and Epidemiology⁶, Chapter 11, “Education and Training”.

Components of Education Related to MRSA in Hospital Settings

A hospital’s Infection Prevention program should include education for staff, patients and their families, other healthcare professionals, and visitors based on recognized best practice recommendations and regulatory requirements. The HICPAC 2006 MDRO Guideline¹ recommends the following regarding education: “Provide education and training on risks and prevention of MDRO transmission during orientation and periodic educational updates for HCP; include information on organizational experience with MDROs and prevention strategies. (IB)” The Joint Commission’s National Patient Safety Goals⁴, which includes an expectation that MDRO education is provided annually to staff, and to colonized or infected patients and their families as needed.

The annual infection prevention risk assessment should be used to identify educational needs regarding MRSA. The HICPAC 2006 MDRO Guideline¹ recommends intensifying the frequency of educational programs for HCP when MDRO (e.g. MRSA) rates are not decreasing, and provide unit-specific feedback when available.

Based on the MRSA infection prevention intervention being addressed and on the needs of the learners, some or all of the following topics may be included in MRSA education:

• What is an MDRO?
• What is MRSA?
• What is the difference between colonization and infection?
• Why is MRSA a problem?
• How do people get MRSA?
• What can be done to stop the spread of MRSA?
• How do you know if someone has MRSA?
• What are MRSA risk factors?
• What are the outcomes associated with MRSA infection?
• What is Active Surveillance Testing (AST)?
• Why is isolation used when someone is colonized or infected with MRSA?
• What are the components of contact precautions?
• How to don and remove PPE?
• Do people with MRSA have to stay in isolation forever?
• What practices can be done at home to prevent the spread of MRSA to other household members?
• Are there special cleaning products or laundering needs at home when a person has MRSA?
• What about cleaning of hands?
• What about cleaning the environment and “high touch” points?
• Can I get medicine to make MRSA go away?
• What other information about MRSA is important for me to know?
• What is MRSA decolonization and when is it used?
• Are hospital employees tested for MRSA?
• Is MRSA a problem in the community?
• What is done about MRSA in community settings?

Since staff will be responsible for documenting effective teaching of patients and families, a post-education evaluation should be conducted to assure that personnel have accurate comprehension of the topic. It may be helpful to allow time in the delivery of the education for staff to have group discussion and role-play in patient teaching scenarios, so that staff can learn to translate their higher-level information into language that the patient can understand.

Successful MRSA education programs for patients and family must stress the importance of preventing transmission of MRSA while in the hospital by adhering to the hospital’s policy regarding Standard and Contact Precautions, with a major emphasis on hand hygiene. Nursing staff should assist patients and families in understanding the rationale for these prevention strategies and the importance of adherence to them. The role of environmental cleanliness and the concept of “high touch” points should also be emphasized. One example of a patient/family MRSA teaching sheet can be found in the “Patient Guide on MRSA” from the SHEA/IDSA 2008 HAI compendium accessed at: http://www.shea-online.org/Assets/files/patient%20guides/NNL_MRSA.pdf

The fact that MRSA is prevalent in the environment in public places should be stressed, so that patients and families understand that the strategies that prevent transmission of organisms are elements of sound personal hygiene. With the right blend of facts, education, sensitivity, and encouragement, patients and families can transfer hospital-learned safety strategies to make a safer life outside the hospital.

Cited References


Resources and References
Antimicrobial Management and Stewardship

Key Concepts
Antimicrobial misuse and overuse are associated with antimicrobial resistance. Antimicrobial resistance poses an ongoing and increasing challenge to clinical management and treatment of patients in hospitals.

An essential strategy in prevention and control of antimicrobial resistance is a hospital antimicrobial stewardship program. Antimicrobial management and stewardship strategies result in:

- Appropriate evidence based clinical treatment and prophylactic use of antimicrobial agents.
- Treating infections, not colonization.
- Utilization of local antibiogram data and when available, genetic resistance markers, as well as local epidemiology, for empiric and patient specific treatment.
- Reduced antimicrobial resistance.
- Decreased incidence of infections due to and transmission of multidrug resistant (MDRO) strains.
- Reduced preventable adverse events due to inappropriate use of antimicrobial agents.
- Improved clinical outcomes and patient safety.

Antimicrobial management and stewardship integrates current evidence-based guidelines, including those established by the Centers for Disease Control and Prevention (CDC), Infectious Diseases Society of America (IDSA), Centers for Medicare and Medicaid Services (CMS) and associated endorsements by a number of professional associations including American Society for Health-System Pharmacists (ASHP), Society for Healthcare Epidemiology of America (SHEA) and the Joint Commission (TJC). The CDC 12 Step Campaign advocates for antimicrobial resistance prevention.

Background
Antimicrobial use and selection pressures have resulted in the development of methicillin and vancomycin resistance in *Staphylococcus aureus*. Recent publications have reported increasing rates of antimicrobial resistance and multidrug resistant microorganisms (MDRO), including methicillin resistant *Staphylococcus aureus*. Antimicrobial resistance is identified as a contributing factor to infection related morbidity and mortality, increased lengths of stay, and increased expenditures. The misuse, overuse, and underuse of antimicrobials contribute to increased resistance rates [Dellit, Cosgrove, Roberts]. A recent publication by the National Healthcare Safety Network (NHSN) reported on the burden and significance of MDRO’s, including MRSA, in device associated and procedure related healthcare associated infections.

Guidelines on Antimicrobial Stewardship
The CDC/HICPAC “Management of Multidrug-Resistant Organisms in Healthcare Settings, 2006” does not make specific recommendations regarding antimicrobial stewardship. The relative importance of antimicrobial stewardship as a specific control measure for MRSA remains unclear. However, it noted in both Tier 1 and Tier 2 recommendations of this guide that judicious antimicrobial use is crucial to the management of MDRO in hospitals.
Tier 1
In hospitals and LTCFs, ensure that a multi-disciplinary process is in place to review local susceptibility patterns (antibiograms), and antimicrobial agents included in the formulary, to foster appropriate antimicrobial use. (IB)

Implement systems (e.g., CPOE, susceptibility report comment, pharmacy or unit director notification) to prompt clinicians to use the appropriate agent and regimen for the given clinical situation. (IB)

Provide clinicians with antimicrobial susceptibility reports and analysis of current trends, updated at least annually, to guide antimicrobial prescribing practices. (IB)

In settings with limited electronic communication system infrastructures to implement physician prompts, etc., at a minimum implement a process to review antibiotic use. Prepare and distribute reports to providers. (II)

CDC/HICPAC “Management of Multidrug-Resistant Organisms in Healthcare Settings, 2006

Tier 2
Review the role of antimicrobial use in perpetuating the MDRO problem targeted for intensified intervention. Control and improve antimicrobial use as indicated. Antimicrobial agents that may be targeted include vancomycin, third-generation cephalosporins, antianaerobic agents for VRE; third generation cephalosporins forbESBLs; and quinolones and carbapenems. (IB)

CDC/HICPAC “Management of Multidrug-Resistant Organisms in Healthcare Settings, 2006

The 2007 guideline for developing an institutional program to enhance antimicrobial stewardship from the Infectious Diseases Society of America (IDSA) and the Society for Healthcare Epidemiology of America (SHEA) recommends implementation of a comprehensive hospital antimicrobial management program. The core members of a comprehensive hospital antimicrobial management program include infectious diseases physicians, clinical pharmacists with infectious disease training, infection control professionals, hospital epidemiologists, clinical microbiologists, and information system specialists. The reader is encouraged to refer to this guideline for specific measures that may be implemented in a facility wide antimicrobial stewardship program.

Antimicrobial Management Programs
Evidence based antimicrobial management has process and outcomes measures endorsed by the CMS and National Quality Forum Pneumonia and Surgical Care Improvement Project (SCIP) core measures initiatives. Evidence based empiric therapeutic pathways treating infection, not colonization or contaminants reduce the overuse of antimicrobials and avoid treatment of asymptomatic bacteriuria or colonizations. Antimicrobial
stewardship combined with a comprehensive infection and control program, decrease MDRO transmission and resistance rates while improving patient outcomes.\textsuperscript{10} Figures 1 and 2 show examples of tools that can be used for specific antimicrobial management programs. These programs have specific MRSA antimicrobial prophylactic and treatment options.

**Role of Infection Prevention and Control in Antimicrobial Management and Stewardship**

The infection preventionist is a vital member of the multidisciplinary antimicrobial stewardship team.\textsuperscript{1,9,11} The role of the infection prevention and control program related to antimicrobial stewardship is to:

- Establish timely communication systems to caregivers when MDRO’s are identified
- Identify MDRO transmission in the acute care setting.
- Recognize MDRO resistance patterns.
- Monitor for and recognize novel resistance.
- Collaborate with laboratory, pharmacy, and other team members to plan and implement effective interventions.

**Role of Clinical Microbiology and Susceptibility Testing in the Antimicrobial Management and Stewardship Program**

The clinical microbiology laboratory plays an essential role by providing patient-specific culture and susceptibility data and in the molecular epidemiologic investigation of outbreaks. The clinical microbiology laboratory collaborates to ensure collection of appropriate clinical specimens, identification and when appropriate, susceptibility testing of clinically significant pathogens (not contaminants or colonizing microbes) using consensus standards. Clinical microbiology laboratories establish methods and algorithms to screen and confirm uncommon resistance. (See also Laboratory Section)

**Figure 1 Example** – Surgical Care Improvement Project Elective Total Hip Replacement Antimicrobial Prophylaxis Orders

<table>
<thead>
<tr>
<th>Antibiotic Prophylaxis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cefazolin _____ IV within 60 minutes prior to incision</td>
</tr>
<tr>
<td>\textbf{OR}</td>
</tr>
<tr>
<td>Cefuroxime _____ IV within 60 minutes prior to incision</td>
</tr>
<tr>
<td>\textbf{OR}</td>
</tr>
<tr>
<td>*Vancomycin _____ IV within 2 hours prior to incision</td>
</tr>
<tr>
<td><strong>Vancomycin is acceptable only with physician/APN/PA, pharmacist, or Infection Control Practitioner documented justification for its use such as antibiotic allergy or documented MRSA. This must be documented pre-operatively.</strong></td>
</tr>
</tbody>
</table>

Rationale for use of Vancomycin

| OR |

If allergic to beta-lactams, give:

| Cefazolin _____ IV within 60 minutes prior to incision |
| \textbf{OR} |
| Clindamycin _____ IV within 60 minutes prior to incision |

| OR |

| Vancomycin _____ IV within 2 hours prior to incision |

D/C antibiotic prophylaxis within 24 hours of surgery end time

courtesy of Julia Moody, MS, SM(ASCP) Clinical Services Group HCA Inc., Nashville, TN
Antimicrobial Susceptibility Testing and Antibiograms

Clinical microbiology laboratories use various testing methods to determine the effectiveness of antimicrobial agents against clinically significant pathogens from diagnostic specimens. The testing methods have been standardized to provide accurate reproducible qualitative and/or quantitative. Variations results expressed as minimal inhibitory concentration (MIC) μg/ml values, are usually accompanied by an S, I, or R on the clinical microbiology laboratory report.

An antibiogram is a cumulative summary of antimicrobial susceptibility results over a prescribed time period. This summary is generated from the individual data of clinically significant pathogens tested against a set of systemic and urinary antimicrobial agents to guide treatment. An example of an antibiogram of gram positive organisms is shown in Table 1. The development and presentation of antibiograms should be a collaborative effort between the clinical microbiology laboratory, pharmacy, physicians, and hospital committees such as Infection Prevention and/or Pharmacy and Therapeutics. Antibiograms can be used by providers to guide decisions regarding appropriate
empiric antimicrobial treatment choices when a definitive susceptibility report is not yet available. It is important for providers to gain a greater understanding as to how to use facility specific antibiogram data when making empiric decisions regarding antimicrobial therapy and promote prudent antimicrobial usage. Antibiograms may be used to track antimicrobial resistance trends over time within a healthcare system.

Antibiograms can be used as evidence the hospital is collecting and aggregating data and information to support care and service delivery and operations for The Joint Commission requirements.

Preparation of a cumulative antibiogram annually is recommended, however, some institutions are able evaluate susceptibility data more frequently. When suspected, unit specific antibiograms can be used to identify suspected healthcare associated outbreaks within defined areas of the hospital or in outpatient areas (i.e., dialysis centers).

CLSI M39-A3 has defined evidence based quality standards for antimicrobial susceptibility testing and reporting. CLSI suggests antibiogram data should be organized and presented as:

- Separate tables for Gram-positive and Gram-negative organisms;
- Total isolate number of each microorganism species tested;
- The first isolate per patient, eliminating duplicates (even if the patient has the same organism in multiple cultures);
- Pathogens from clinical cultures, not surveillance screening tests;
- The percentage of strains fully susceptible to each antimicrobial agent;
- Separate line listings for MRSA and methicillin susceptible *Staphylococcus aureus* (MSSA);
- Facility specific data for healthcare systems with multiple different facilities;
- Isolate data from defined unit or area specific locations (i.e., MICU, SICU) when possible;
- Urinary and non-urinary source pathogens when possible.
Facility factors influencing antibiogram data include antimicrobial use, patient population demographics and infection prevention practices. Analyze significant changes and trends in MRSA susceptibility patterns and other MDRO pathogens by reviewing:

- Compliance with infection prevention policies minimizing transmission risks\(^{12}\);
- Changes to infection prevention practices, e.g. increased screening for MRSA nares colonization on admission to the hospital may have desirable impact on (reduction of) MRSA infection\(^ {14}\);
- Changing resistance patterns within the community;
- Entry of resistant pathogens or new resistant clones into the facility;
- Addition of medical services (ie oncology care, increased number of ICU beds);
- Changes to patient populations who are at risk for MRSA and MDROs.

For example when evaluating increasing or decreasing MRSA rates and trends at the hospital, consider evaluating these additional factors:

- Distribution of isolates among outpatient, ED, inpatient ICU vs nonICU units and adult versus pediatrics populations;
- Proportion of community-acquired MRSA versus healthcare associated MRSA;
- Specimen sources (ie. blood, urine, sputum, skin and soft tissue);
- At risk patient populations (ie long term care, surgical procedures, dialysis);
- Burden of MRSA colonization which may have affect on infection rates;
- Comparison to national databases such as NHSN.\(^ {2}\)

For providers to make timely informed decisions on treatment and prophylaxis, reports of patient specific culture susceptibility results and published facility specific antibiograms are essential. In order to get the right drug to the right bug, clinicians can utilize antibiograms to guide empiric therapy and use clinical culture results to streamline or de-escalate therapy when antimicrobial susceptibility is available.

Antibiograms for designated significant pathogens are compiled from clinical culture susceptibility testing. The up to date antibiogram can be used to guide empiric treatment decisions, but are also important data for antimicrobial management programs. Awareness of local epidemiology of specific significant pathogens can help identify unusual and/or significant antimicrobial resistance. Infection prevention and control professionals must support and facilitate the process of antibiogram development with the hospital laboratory and pharmacy teams.

Figures 1 and 2 are examples of hospital programs or protocols that include antimicrobial stewardship as part of best practice initiatives.

Cited References


MRSA Decolonization Strategies

Key Concepts
Although routine decolonization of MRSA colonized patients is not recommended, decolonization strategies may be indicated:

• When MRSA positive patients are associated with ongoing transmission or in an outbreak situation.
• In colonized MRSA patients having a surgical procedure that has been identified as high risk for MRSA surgical site infection.
• In certain patient populations in an attempt to reduce the risk of subsequent MRSA and methicillin susceptible Staphylococcus aureus infections among colonized persons undergoing dialysis, patients with recurrent S. aureus infections, patients in intensive care and patients undergoing targeted surgical procedures where evidence has shown benefit.

Background
Short term MRSA decolonization strategies are utilized at the time of highest risk or to eliminate colonization. The goals are to:

• Interrupt the transmission of MRSA, not to permanently decolonize patients associated with MRSA outbreaks or ongoing transmission;
• Eliminate MRSA carriage in patients with recurrent MRSA infections;
• Prevent an MRSA or methicillin susceptible S. aureus surgical site infection in high risk surgeries; and
• Reduce the risk of infections in high risk populations such as intensive care patients.

MRSA decolonization therapy is the administration of topical antimicrobial or antiseptic agents, with or without systemic antimicrobial therapy to MRSA colonized persons for the purpose of eradicating or suppressing the carrier state. Most regimens are usually topical agents combined with an antiseptic skin agent. The regimens are very safe with allergic reactions being extremely rare. Thus far, chlorhexidine resistance is rare but rising mupirocin resistance, both low and high level resistance, has been reported in some, but not all studies.

The Society of Thoracic Surgeons has a Class 1 recommendation to include universal mupirocin for all cardiac surgery patients unless there is proof by nares culture that the patient does not have S. aureus based on evidence for this approach showing reductions in S. aureus cardiac surgical site infections. Decolonization regimens may be indicated for both nasal MRSA and S. aureus colonization in patients undergoing vascular surgery with placement of a graft, total joint arthroplasty and neurosurgical procedures with implantation of hardware as well as other surgical procedures.

Preoperative showering with agents such as chlorhexidine has been shown to reduce bacterial colonization of the skin. Although the 1999 CDC Guideline for Prevention of Surgical Site Infections has a IB recommendation for presurgical bathing with an antiseptic agent, a recent Cochrane review evaluated the evidence for preoperative bathing or showering with antiseptics for SSI prevention. Six randomized, controlled trials evaluating the use of 4% chlorhexidine gluconate were included in the analysis, with no clear evidence of benefit noted. Further studies are needed, because of the trial inconsistencies in how chlorhexidine gluconate bathing was performed, instructions for use and contact times (ie apply and wash off immediately, apply and wait 5 minutes prior to washing off, etc).
More recent studies using 2% chlorhexidine gluconate cloths look promising. The antiseptic is applied and not washed off affording a more effective antiseptic action with residual activity and penetration into the skin.\textsuperscript{17}

A decolonization strategy has been shown to successfully decolonize MRSA carriers in the short term, which may be of benefit during the high risk period of an intensive care admission by preventing subsequent MRSA infection.\textsuperscript{6} A cross-over intervention study of universal 2% chlorhexidine bathing for medical intensive care patients showed a reduction in bloodstream events including MRSA.\textsuperscript{19} The concept of universal decolonization in other types of intensive care patients with or without MRSA colonization requires further evaluation.

Although healthcare workers can become colonized with MRSA, colonized healthcare workers are rarely the cause of MRSA outbreaks in acute care settings, and transmission of MRSA from colonized healthcare workers to patients is thought to be rare.\textsuperscript{20,21} Instances associated with increased risk of MRSA transmission from colonized healthcare workers to patients have been noted when healthcare workers have chronic skin conditions, chronic otitis media, or when nasally colonized healthcare workers develop viral respiratory infections which result in increased shedding of MRSA.\textsuperscript{22-26} Unless there is epidemiological evidence linking healthcare workers to ongoing MRSA transmission, screening healthcare workers for MRSA is not recommended.

### Decolonization Strategy Considerations

#### Infection Prevention and Control Strategy Related to Patient Decolonization

Decolonization is not considered a routine infection prevention and control strategy unless:

- Implemented to interrupt MRSA outbreaks or ongoing transmission as part of an intervention for Tier 2 strategies, for a limited time in targeted patient populations\textsuperscript{1}
- Implemented as part of an evidence based prevention bundle to reduce the risk of infections in selected surgical procedures; or
- In identified high risk populations or clinical cases, for clinical benefit and reduced risk of infection.

Decolonization of MRSA colonized patients is not considered a routine MRSA prevention and control intervention prior to transfer to another acute care or long term care facility.\textsuperscript{1}

The most experience for MRSA decolonization\textsuperscript{2} when deemed appropriate has been with the use of a variation of the following regimen for adults:

- Nasal decolonization with 2% mupirocin ointment applied to the nares twice a day for five days; AND
- Skin antisepsis with chlorhexidine or hexachlorophene for 5 days, applied per manufacturer’s instructions.

For pre-surgical prophylactic decolonization protocols, the most experience has been with the use of the protocol described above. Starting mupirocin decolonization at least 5 days prior to surgery is preferred. When using chlorhexidine or hexachlorophene, avoid contact with eyes and mucus membranes and observe for allergic reactions and skin irritation.

The use of systemic antimicrobials for MRSA decolonization may be considered by the patient’s healthcare provider if deemed clinically appropriate.
Infection Prevention and Control Strategy Related to Indications for Healthcare Worker Decolonization

Healthcare worker decolonization is indicated as an infection prevention and control intervention when a healthcare worker is colonized or infected with MRSA and has been epidemiologically implicated in ongoing transmission of MRSA to patients. The purpose of treating MRSA-colonized healthcare workers implicated in transmission is to interrupt MRSA transmission, not to permanently decolonize the healthcare worker. Healthcare workers implicated in transmission should be screened for MRSA colonization and colonized healthcare workers implicated in transmission are candidates for decolonization.\(^1\) Retain MRSA isolates from healthcare workers and patients for molecular typing during epidemiologic investigations.

Employee health professionals and/or infectious disease physicians should be consulted regarding staff decolonization. When it is deemed appropriate, staff may be directed to also consult with their personal physician regarding the decolonization plan. Evaluate the work situation of the MRSA-colonized or infected healthcare workers associated with ongoing MRSA transmission to determine the need for furlough from patient contact during the decolonization process. The evaluation should take into consideration the location of MRSA infection/colonization, ability of draining MRSA skin infections to be contained and covered, patient population assignments, and healthcare worker compliance with infection prevention and control precautions.

Surveillance When Implementing Decolonization Strategies

Monitor MRSA transmission and infection rates to evaluate the effectiveness and outcomes of the decolonization strategies. Monitoring mupirocin resistance is an adjunctive measure to ensure continued efficacy and impact of use, especially when decolonization failures increase.\(^3,5\) Discontinue the routine use of decolonization when implemented to interrupt ongoing transmission or control outbreaks and the intervention has resulted in sustained success.

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16 Webster J, Osborne S. Preoperative bathing or showering with skin antiseptics to prevent surgical site infection. Cochrane Database Syst Rev 2007; (2): CD04985.


Journal Articles
Barriers to implementing infection prevention and control guidelines during crises: Experiences of health care professionals

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Background: Communicable disease crises can endanger the health care system and often require special guidelines. Understanding reasons for nonadherence to crisis guidelines is needed to improve crisis management. We identified and measured barriers and conditions for optimal adherence as perceived by 4 categories of health care professionals.

Methods: In-depth interviews were performed (n = 26) to develop a questionnaire for a cross-sectional survey of microbiologists (100% response), infection preventionists (74% response), public health physicians (96% response), and public health nurses (82% response). The groups were asked to appraise barriers encountered during 4 outbreaks (severe acute respiratory syndrome [SARS], Clostridium difficile ribotype 027, rubella, and avian influenza) according to a 5-point Likert scale. When at least 33% of the participants responded “strongly agree,” “agree,” or “rather agree than disagree,” a barrier was defined as “often experienced.” The common (“generic”) barriers were included in a univariate and multivariate model. Barriers specific to the various groups were studied as well.

Results: Crisis guidelines were found to have 4 generic barriers to adherence: (1) lack of imperative or precise wording, (2) lack of easily identifiable instructions specific to each profession, (3) lack of concrete performance targets, and (4) lack of timely and adequate guidance on personal protective equipment and other safety measures. The cross-sectional study also yielded profession-specific sets of often-experienced barriers.

Conclusion: To improve adherence to crisis guidelines, the generic barriers should be addressed when developing guidelines, irrespective of the infectious agent. Professional-specific barriers require profession-specific strategies to change attitudes, ensure organizational facilities, and provide an adequate setting for crisis management.

Key Words: Barriers; adherence; crises; outbreak management; infection control; guidelines.

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In outbreak situations that endanger the health care system, outbreak control measures must be initiated promptly to prevent further transmission of the pathogen. In such situations, authoritative guidance is needed. Countries all over the world have established their own structures to disseminate outbreak control guidelines and, if necessary, put outbreak control systems in place. In a crisis, health care professionals with diverse backgrounds need to work quickly together to identify cases, perform laboratory diagnostics, trace contacts, and institute infection prevention and control measures as described in the outbreak control guidelines.1 Optimal compliance with the guidelines, with timely and adequate outbreak control as final outcome, requires good adherence by professionals. Unfortunately, however, their adherence is often not optimal,2-5 due to knowledge, attitudes, and behavior among professionals,6-7 as well as to organizational and other factors. Guidelines are not always clear, and existing facilities are not always adequate or adaptable to the sudden intrusion of crisis measures. A systematic review conducted by Cabana et al8 revealed a variety of barriers that hinder adherence. The authors provide a generic framework for exploring barriers in various settings. According to the authors, barriers to adherence include those related to the professionals, with a more cognitive (knowledge, awareness) or affective (attitude, motivation) component,
those related to the guidelines (their content and target patient population), and those related to the environment (organization, social setting). Many studies have looked at determinants of adherence to guidelines in the routine care of infectious disease, but little is known about determinants of adherence to guidelines in crisis situations.

Crisis situations differ significantly from routine communicable disease control, because health professionals must respond with prompt decisions, uniformity of action, and quick integration of new knowledge and skills. Furthermore, the context of crisis situations is complex, requiring optimal communication and cooperation between public health services and hospitals. A better understanding of the reasons for nonadherence of health care professionals in crises situations is needed to improve crisis management. Identification of generic and profession-specific barriers can lead to customized strategies designed to make guidelines work.

In this study, we assessed reasons for nonadherence (barriers) among key professionals in outbreak control in crisis situations: consultant microbiologists, infection preventionists, public health physicians, and public health nurses. We identified the generic and profession-specific priorities that need to be addressed to improve adherence to outbreak control guidelines.

METHODS

This cross-sectional study used questionnaires tailored to 4 groups: consultant microbiologists (M), infection preventionists (IP), public health physicians (PHP), and public health nurses (PHN). Each group’s questionnaire was designed based on in-depth interviews with professionals in that group.

Questionnaire development

In-depth interviews lasting 1-1.5 hours were performed with 26 health care professionals (14 men and 12 women: M, n = 7; IP, n = 7; PHP, n = 6; PHN, n = 6). All had been actively involved in one or more of 4 recent crisis situations due to infectious outbreaks in The Netherlands: severe acute respiratory syndrome (SARS), *Clostridium difficile* ribotype 027, rubella, and avian influenza AI/H7N7. The participants’ working experience averaged 15 ± 4 years for Ms, 14 ± 8 for IPs, 15 ± 5 for PHPs, and 10 ± 3 for PHNs.

For each of the 4 crises, an overview of control measures issued by the national outbreak management team (OMT) was provided before our interviews to facilitate recall by the professionals. The professionals were then asked to identify barriers they had experienced during the outbreaks as to case finding, infection prevention and control, laboratory testing, and contact tracing. Sampling and interviewing continued until saturation was reached, that is, no new items were identified.

Conducted from January through March 2007 by 3 investigators (A.T., D.V., and F.W.), the interviews were audiotaped and transcribed verbatim. During the study, data collection was validated at intervals by discussion among the interviewers. The content of the tapes was analyzed by 2 investigators independently (A.T. and M.H.) to construct an overview. The investigators extracted the barriers and categorized them under 3 main headings, according to the validated framework to standardize obstacle reporting of Cabana et al: “knowledge/attitude,” “guidelines,” and “organization/social setting.” Interviews elicited a different number of barriers for each profession: 37 items for Ms, 25 items for IPs, 50 items for PHPs, and 38 items for PHNs. Details are available on request.

Cross-sectional study

Using the barrier overviews, questionnaires were designed for each profession. These instruments requested a response to each listed barrier, using a 5-point asymmetric Likert scale (strongly agree, agree, rather agree than disagree, disagree, strongly disagree). The questionnaires were administered to the PHPs and PHNs at public health services (September-November 2007), IPs at hospitals (January-March 2008), and M in various settings (February-April 2008). To cover the entire country, we requested that questionnaires be returned by at least one PNP and PHN from each of 33 public health services and by at least one IP from each of 94 hospitals. Because most microbiologists work in practices serving more than one hospital and/or public health service, we selected a nationwide sample of 30 practices to complete the questionnaire.

Analysis

Data from questionnaires were analyzed using SPSS version 15 for Windows (SPSS Inc, Chicago, IL). For each barrier and for each profession, descriptive statistics were obtained. For the analysis of questionnaires, the answers given in the 5-point scale were dichotomized to enable division between “yes” (barrier experienced) = strongly agree/agree/rather agree than disagree with the proposed barrier and “no” (barrier not experienced) = disagree/strongly disagree. We considered a barrier to be “often experienced” when at least 53% of the participants had experienced it. These barriers were included in the final overviews.

Generic or common barriers were those recognized by at least 3 categories of professionals. These barriers were included in univariate and multivariate
logistic models to assess the differences among the groups and the impact on barriers of selected variables, including profession, sex, years of working experience in communicable disease control, number of working days/week, and number of crises experienced. We predicted the probability of whether or not the barrier was experienced in practice in the logistic regression model. Statistical significance was defined by $P < .05$.

RESULTS

The questionnaires were returned by 45 PHPs, representing 32 public health services (96%); 37 PHNs, representing 27 public health services (82%); 100 IPs, representing 70 hospitals (74%); and all 30 Ms that we approached (100%). Table 1 summarizes the characteristics of the participants. Table 1 summarizes the characteristics of the participants.

<table>
<thead>
<tr>
<th>Sex</th>
<th>M (n = 30), n (%)</th>
<th>IP (n = 100), n (%)</th>
<th>PHP (n = 45), n (%)</th>
<th>PHN (n = 37), n (%)</th>
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<tbody>
<tr>
<td>M</td>
<td>22 (73)</td>
<td>30 (30)</td>
<td>30 (67)</td>
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<td>F</td>
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</table>

M, microbiologists; IP, infection preventionists; PHP, public health physicians; PHN, public health nurses.

2. Control measures are worded with insufficient urgency or definition.
3. Crucial instructions within control measures (concerning isolation, diagnostics, and treatment) are not clear or easily identifiable for each profession.
4. Measures regarding the use of personal protective equipment (PPE) are inadequate and not timely.

Profession, sex, age, number of working days/week, and the number of crises experienced did not influence professionals’ opinion regarding these barriers. In multivariate analysis, however, the number of years of working experience was significantly associated with 2 barriers (Table 2). Compared with professionals with more working experience, those with less experience gave more importance to easily identifiable crucial recommendations on isolation, diagnostics, and treatment (odds ratio [OR], 2.68; 95% confidence interval [CI], 1.17-6.34) and the need for timely and adequate information on PPE and other safety precautions (OR, 2.17; 95% CI, 1.12-4.37).

Microbiologist-specific barriers

Of the 37 barriers extracted from in-depth interviews and used in the questionnaire for microbiologists, 20 (54%) were experienced by at least 33% of the group. Microbiologists reported higher adherence to control measures when they are directly alerted by the national OMT (85%) and when they receive a personal copy of the control guidelines (86%). For these professionals, the scientific basis for the measures was important (60%). They also acknowledged the need for follow-up by the OMT and readjustment.
of the guidelines based on new developments or newly generated evidence during the crisis (83%). According to these professionals, setting-related factors that improve adherence to control measures include the availability of adequate cohorting and isolation facilities (83%), familiarity of hospital clinicians with the outbreak control and diagnostic guidelines (73%), and a leading role for microbiologists in the dissemination of guidelines to clinicians and IPs (83%) (Table 3).

**IP-specific barriers**

Of the 25 barriers to adherence identified by IPs, 18 (72%) were experienced by at least 33% of the respondents. Like the microbiologists, the IPs predicted improvement if they were alerted directly by the OMT at the beginning of a crisis (70%) and received a personal copy of the guidelines (78%). As particular problems, they emphasized lack of OMT follow-up during progression of a crisis (70%), lack of concrete targets for performance (76%), and perceived delay in OMT communication of risks to local hospitals (68%). The IPs requested easily identifiable crucial instructions on infection prevention and control that IPs need to follow (78%), timely guidance on appropriate PPE (64%), and clear responsibilities regarding diagnosis and infection prevention and control (73%) (Table 3).

**PHP-specific barriers**

Of the 30 barriers identified by PHPs, 17 (56%) were experienced by at least 33% of the respondents. The PHPs cited no barriers related to knowledge, but 70% cited an awareness item (concrete targets for performance) as relevant to adherence. Mostly they emphasized external factors. To overcome these barriers, they urged easily identifiable, profession-specific instructions on diagnosis, infection control, and therapy (78%); timely guidance

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**Table 2. The rating of common barriers per group of professionals (% answers “strongly agree/agree/rather agree than disagree with the proposed barrier”) and the results of the multivariate analysis**

<table>
<thead>
<tr>
<th>Barrier</th>
<th>M, %</th>
<th>IP, %</th>
<th>PHP, %</th>
<th>PHN, %</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control measures are inconvenient to apply in hospital or public health setting.</td>
<td>82.8</td>
<td>64.2</td>
<td>48.9</td>
<td>56.8</td>
<td>.026</td>
</tr>
<tr>
<td>There are no concrete targets for performance of the control measures.</td>
<td>82.7</td>
<td>75.7</td>
<td>71.1</td>
<td>NA</td>
<td>.52</td>
</tr>
<tr>
<td>Guideline</td>
<td>72.4</td>
<td>72.6</td>
<td>28.9</td>
<td>64.8</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Control measures are not sufficiently tailored to the patient population.</td>
<td>58.6</td>
<td>51.0</td>
<td>50.9</td>
<td>64.9</td>
<td>.42</td>
</tr>
<tr>
<td>Crucial instructions within control measures concerning isolation, diagnostics, and treatment are not clear or easily identifiable for each profession.</td>
<td>82.7</td>
<td>77.8</td>
<td>77.7</td>
<td>NA</td>
<td>.84</td>
</tr>
<tr>
<td>Control measures regarding the use of PPE are not timely and adequate.</td>
<td>53.5</td>
<td>67.8</td>
<td>77.8</td>
<td>64.8</td>
<td>.19</td>
</tr>
<tr>
<td>Responsibilities for diagnosis and infection control are not clarified.</td>
<td>6.7</td>
<td>76.9</td>
<td>57.8</td>
<td>86.5</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

**Multivariate analysis of the common barriers, adjusted OR (95% CI)**

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Years of working experience</th>
<th>Sex</th>
<th>Number of working days/week</th>
<th>Experience with crises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control measures are inconvenient to apply in hospital or public health setting.</td>
<td>0.7 (0.3-1.4)</td>
<td>0.9 (0.4-2.0)</td>
<td>0.8 (0.5-1.3)</td>
<td>1.0 (0.9-1.2)</td>
</tr>
<tr>
<td>There are no concrete targets for performance of the control measures.</td>
<td>1.5 (0.7-3.4)</td>
<td>1.2 (0.5-3.0)</td>
<td>0.6 (0.4-1.2)</td>
<td>0.9 (0.7-3.4)</td>
</tr>
<tr>
<td>Control measures are not sufficiently tailored to the patient population.</td>
<td>1.0 (0.5-2.0)</td>
<td>2.0 (0.9-4.8)</td>
<td>0.9 (0.6-1.5)</td>
<td>0.9 (0.8-1.1)</td>
</tr>
<tr>
<td>Control measures are worded with insufficient urgency or definition.</td>
<td>1.4 (0.7-2.7)</td>
<td>1.3 (0.6-2.8)</td>
<td>0.9 (0.6-1.5)</td>
<td>0.9 (0.8-1.1)</td>
</tr>
<tr>
<td>Crucial instructions within control measures concerning isolation, diagnostics, and treatment are not clear or easily identifiable for each profession.</td>
<td>2.7 (1.1-6.3)</td>
<td>0.9 (0.3-2.7)</td>
<td>1.7 (0.9-3.2)</td>
<td>0.9 (0.7-1.1)</td>
</tr>
<tr>
<td>Control measures regarding the use of PPE are not timely and adequate.</td>
<td>2.1 (1.1-4.3)</td>
<td>0.9 (0.4-2.1)</td>
<td>0.9 (0.6-1.5)</td>
<td>1.0 (0.8-1.2)</td>
</tr>
<tr>
<td>Responsibilities for diagnosis and infection control are not clarified.</td>
<td>1.4 (0.7-3.1)</td>
<td>1.1 (0.4-2.8)</td>
<td>0.6 (0.3-1.0)</td>
<td>1.0 (0.8-1.3)</td>
</tr>
</tbody>
</table>

*NA, not applicable (barrier not identified by this group).

<X2 test.*
Table 3. Overview of the commonly experienced profession-specific barriers* in the cross-sectional survey

<table>
<thead>
<tr>
<th>Barriers</th>
<th>M, % yes</th>
<th>IP, % yes</th>
<th>PHP, % yes</th>
<th>PHN, % yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The professional is not directly alerted by the outbreak management team during the crisis.</td>
<td>83</td>
<td>70</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The professional does not receive a personal copy of the outbreak control guidance issued by the outbreak management team.</td>
<td>87</td>
<td>79</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The professional does not have the lead in the dissemination of the guidance to clinicians and IP.</td>
<td>83</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>There is no centralized information system dedicated to hospital staff regarding the outbreak control guidance.</td>
<td>-</td>
<td>84</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Attitudes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control measures are inconvenient or difficult to apply in the hospital or public health setting.</td>
<td>80</td>
<td>83</td>
<td>49</td>
<td>57</td>
</tr>
<tr>
<td>There is no formal status of the outbreak control guidance within the group of professionals.</td>
<td>-</td>
<td>70</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>There is no follow up of the progress by the outbreak management team that issues the guidance.</td>
<td>83</td>
<td>70</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>There are no external audits to assess results, following the acute phase of a health care crisis.</td>
<td>83</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The diagnostic guidelines interfere with and disturb the daily routine in the laboratory.</td>
<td>73</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Additional testing and data collection for research purposes (generating new knowledge) during outbreaks interferes with and disturbs commitment to perform patient care.</td>
<td>80</td>
<td>-</td>
<td>-</td>
<td>76</td>
</tr>
<tr>
<td>Sending each sample to the (national) reference laboratory for typing by molecular techniques is time-consuming.</td>
<td>70</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The professional perceives a delay in communicating risks due to transmission of pathogens in hospitals during international crises.</td>
<td>-</td>
<td>68</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The professional does not agree with the level of PPE advised in the outbreak control guidance.</td>
<td>-</td>
<td>40</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>It is difficult to ensure sustainability of the control measures once the acute phase of the outbreak has passed.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>81</td>
</tr>
<tr>
<td>Guidelines</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control measures are not evidence-based.</td>
<td>60</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Control measures are not sufficiently tailored to the patient population.</td>
<td>72</td>
<td>73</td>
<td>-</td>
<td>65</td>
</tr>
<tr>
<td>Control measures are worded with insufficient urgency or definition.</td>
<td>59</td>
<td>51</td>
<td>51</td>
<td>65</td>
</tr>
<tr>
<td>Control measures advised by the national outbreak control team deviate from the WHO guidance.</td>
<td>-</td>
<td>41</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Crucial instructions within control measures concerning isolation, diagnostics, and treatment are not clearly formulated. and not easily identifiable for each profession.</td>
<td>83</td>
<td>78</td>
<td>78</td>
<td>-</td>
</tr>
<tr>
<td>Case definitions and screening algorithms are not applicable to crisis/outbreak patients in the hospital situation.</td>
<td>77</td>
<td>60</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Control measures regarding the use of PPE and safety precautions are not timely or adequate.</td>
<td>53</td>
<td>68</td>
<td>78</td>
<td>65</td>
</tr>
<tr>
<td>There are no clear instructions on samples collection for laboratory diagnostics (eg, type of samples, materials needed).</td>
<td>-</td>
<td>-</td>
<td>87</td>
<td>-</td>
</tr>
<tr>
<td>When guidance is issued, the increased costs related to outbreak control measures are not considered.</td>
<td>-</td>
<td>-</td>
<td>73</td>
<td>-</td>
</tr>
<tr>
<td>Organization</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>There is a restricted budget for laboratory diagnostics due to cost considerations in hospital care.</td>
<td>43</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>There are no sufficient cohorting and isolation facilities to prevent further transmission.</td>
<td>83</td>
<td>80</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>There is no familiarity and awareness of other clinicians with the outbreak control and diagnostic guidelines.</td>
<td>73</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Responsibilities for diagnosis and infection control are not clarified.</td>
<td>-</td>
<td>77</td>
<td>58</td>
<td>86</td>
</tr>
<tr>
<td>Routine clinical commitments do not allow extra time for implementation of outbreak control guidance.</td>
<td>70</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Providing explanation of control measures, safety precautions and reducing anxiety among public and nurses (including information in foreign languages) is time-consuming.</td>
<td>-</td>
<td>78</td>
<td>-</td>
<td>73</td>
</tr>
<tr>
<td>There are no proper IT tools to generate real time data during crises (eg, vaccination coverage).</td>
<td>-</td>
<td>-</td>
<td>71</td>
<td>-</td>
</tr>
<tr>
<td>There is no centralized purchase and distribution system for PPE.</td>
<td>-</td>
<td>-</td>
<td>69</td>
<td>70</td>
</tr>
<tr>
<td>There are time constraints to up-date local protocols on outbreak control, during crises.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>81</td>
</tr>
<tr>
<td>Setting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Round-the-clock availability of front line physicians is not guaranteed.</td>
<td>-</td>
<td>-</td>
<td>71</td>
<td>-</td>
</tr>
<tr>
<td>The public health service has no means to monitor compliance of front line physicians with the measures.</td>
<td>-</td>
<td>-</td>
<td>80</td>
<td>78</td>
</tr>
</tbody>
</table>

Continued
on the type of PPE and instructions on its use (78%); better instructions on sample collection (86%); and increased OMT awareness of the cost implications of the advised measures (73%). Organization-related factors included the lack of proper information technology systems for real-time surveillance of new cases during a crisis (71%) and the lack of a centralized system for purchasing and distributing PPE (70%). Barriers related to the social setting included the uncertain availability of round-the-clock front-line physicians during crisis situations (71%), uncertain division of responsibilities between community emergency departments and public health services (73%), and the need for endorsement of the control measures by local policy makers (70%) (Table 3).

**PHN-specific barriers**

Of the 38 barriers identified, 12 (31%) were experienced by at least 33% of the PHNs. For nurses, adherence to crisis guidelines is related mostly to practical aspects, such as adequate time to perform control measures (73%) and update local protocols on the basis of newly issued guidance for crisis (81%). The PHNs also favored clear responsibilities for sampling patients, providing PPE, and performing infection prevention and control measures (86%); clear mandates for the public health service to monitor compliance of the front-line physicians (78%); and a clear division of responsibilities between community emergency departments and public health services (76%) (Table 3).

**DISCUSSION**

Four generic barriers were identified and rated as equally important in the cross-sectional study, reflecting requirements for improving adherence to crisis guidelines that cross professional lines. What can we do to make guidelines in crises work? First, to emphasize the degree of urgency, the guidelines should be worded imperatively by the issuing committee. Furthermore, they should include crucial instructions that are easily identifiable for the various professional groups, and should be accompanied by concrete targets for performance. Finally, timely instructions should be provided on the use of PPE, along with precautions to optimize personal safety and minimize the risk of occupational exposure during patient care and contact tracing.

When professionals with different backgrounds suddenly need to work together and depend on each other, as happens in complex crises, unclear or tentative language can sap the strength of guidelines. According to our participants, crucial guidelines should use explicit and even imperative language, reflected by the words “must” and “should,” for example. Guidelines that instead ask professionals to “consider” taking a certain action do not sound crucial and are less likely to inspire adherence.

Which instructions are crucial? Outbreak control guidance consists of comprehensive instructions on case finding, contact tracing, diagnostics, surveillance, treatment, infection prevention, and health promotion. Under time pressure, those concerning infection prevention (eg, isolation, PPE), diagnostics, and treatment are the ones that matter most to the involved professionals, because they are essential to stop further transmission and improve patient outcomes. Especially in these areas, instructions must be not only definitive and imperative, but also easily identifiable by various professionals as to their own particular responsibility areas. Interestingly, Lo et al3 found that adherence to crucial recommendations in hospital settings during routine infectious diseases consultations was significantly higher than adherence to noncrucial recommendations, which is consistent with our findings.

Besides clarity of wording and crucial recommendations for each group of professionals, crisis guidelines should contain concrete targets for performance to guide successful implementation. For instance, when advising contact tracing and chemoprophylaxis, additional criteria should be provided, such as the percentage of persons who should be approached and the optimal time frame in which to do so. These criteria

---

<table>
<thead>
<tr>
<th>Barriers</th>
<th>M, % yes</th>
<th>IP, % yes</th>
<th>PHP, % yes</th>
<th>PHN, % yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is no reimbursement system for outbreak control tasks undertaken by front line physicians.</td>
<td>-</td>
<td>-</td>
<td>75</td>
<td>-</td>
</tr>
<tr>
<td>There are problems in the communication between various groups of professionals.</td>
<td>-</td>
<td>-</td>
<td>71</td>
<td>-</td>
</tr>
<tr>
<td>There is no clear chain of command and control at regional level.</td>
<td>-</td>
<td>-</td>
<td>69</td>
<td>-</td>
</tr>
<tr>
<td>There is no clear division of responsibilities between the community emergency departments and public health services in crises.</td>
<td>-</td>
<td>-</td>
<td>73</td>
<td>76</td>
</tr>
<tr>
<td>There is no endorsement of outbreak control measures by local policy makers.</td>
<td>-</td>
<td>-</td>
<td>69</td>
<td>-</td>
</tr>
</tbody>
</table>

*Barrier experienced by at least 33% of the group.

1Yes, strongly agree/agree/rather agree than disagree with the proposed barrier.
are considered important for the professionals who have to implement the measures, because they reduce uncertainty about what is expected, and they also could be helpful to external assessors who evaluate crisis control. Our participants agreed that such targets will increase the internal motivation to adopt the measures and also enable readjustment of expectations when necessary.

Finally, there is the issue of professional safety. More than in other fields of health care, dealing with outbreaks raises major concerns with respect to personal safety and prevention of nosocomial spread. In crises, especially when facing a new pathogen, health care professionals expect immediate information on which infection control procedures to put in place. Timely, solid guidance for health care professionals on ways to minimize their own risk by wearing PPE and complying with safety instructions will increase not only their protection, but also their confidence and motivation. Apart from motivation, beliefs, and attitudes, adherence to individual protective measures also depends on organizational factors. According to Gershon et al, a safety climate characterized by a strong organizational commitment to safety leads to increased compliance with the use of PPE. As in our study, approval of the guidelines by coworkers and endorsement by the management were reported to facilitate adherence.

These 4 priorities are, in our opinion, the starting point for improving adherence to outbreak control guidelines in crises. They are generic, in that they affect all 4 professions that we studied. However, we also found that different groups of professionals have different expectations and experience different problems with respect to the crisis guidelines. These depend on the context in which they work and the degree to which control measures interfere with daily routines, increase workloads, and require new skills and equipment. Our study confirms earlier results reported by Grol et al indicating that general practitioners’s adherence decreases when guidelines demand changes to existing routines and when they lack pertinent advice on actions and decisions. Outbreak committees that issue the guidelines must be aware of these factors so they can tailor instructions to the specific needs and problems of the diverse professional groups involved.

From the perspective of professionals working in hospitals (ie, microbiologists and IPs), improving adherence should aim at increasing crisis awareness in that setting through, for example, better alerting systems and more transparency in the dissemination of crisis measures. These professionals emphasized the need to directly involve hospital professionals. They also urged increased availability of organizational facilities for outbreak control, such as the capacity for cohorting and isolating patients. Our results are consistent with findings of recent studies of preparedness in hospital emergency departments. In a survey conducted by Rebmann et al, 15% of IPs reported that their hospital had insufficient isolation facilities (eg, negative-pressure rooms) for routine needs. Even when facilities were sufficient, only 47% of the hospitals were equipped to accommodate an isolation surge.

The PHPs and PHNs reported barriers related mostly to the organizational and social setting. For them, commitment and round-the-clock availability of local frontline physicians are crucial. Moreover, the PHPs and PHNs need ways to monitor and encourage the compliance of these physicians with the crisis measures. Another commonly reported barrier was the need to define responsibilities between public health professionals and hospital professionals with respect to sampling patients and performing infection prevention and control measures. In the social context, implementing crisis guidelines and improving outcomes of measures require a clear chain of command, with control and endorsement by local policy makers.

This study has several limitations. We first explored barriers to adherence through in-depth interviews, then assessed the frequency of these barriers in the cross-sectional study to generate priorities for future strategies. In contrast, Barlow et al began with the cross-sectional part and followed with in-depth interviews. However, they studied adherence to guidelines in routine care situations and had access to previous publications when constructing their framework of barriers. Given that no systematic research has been published on barriers in times of crisis, we needed in-depth interviews to explore these barriers and build the baseline framework. This qualitative approach enabled optimal exploration of hidden reasons for nonadherence. We were able to describe patterns of barriers that influence adherence, together with more individual specific constraints. Because the reported barriers might be different from those observed during outbreaks, they should be regarded as a proxy for reality. Nevertheless, they provide a basis for formulating priorities to improve adherence to guidelines in crises. We believe that our results are applicable to other industrialized countries with similar health care organization and professions as The Netherlands.

Making crisis guidelines truly effective requires a multidisciplinary approach and optimal professional knowledge and attitudes, along with organizations capable of crisis management in social settings that facilitate adequate preparation and quick response. This is the first study to systematically assess the barriers that can obstruct adherence to crisis guidelines from the standpoint of the individual health care professional. To improve adherence of these professionals
in outbreak crises, priority should be given to the 4 generic barriers that we have described, irrespective of the infectious agent involved. Furthermore, for each group, profession-specific barriers need to be addressed through specific implementation strategies regarding improvement of knowledge, changing of attitudes, ensuring organizational facilities (eg, sufficient capacity for single room isolation, surge cohorting capacity, and surge laboratory capacity), and providing an adequate setting for performing crisis management.

We thank D. Ves, O. Jacobs, and F. Weidema for their help with data collection and J. van Doremalen for his support with the data analysis. We also thank L. Phillips for editing the manuscript. We are grateful to the professionals who anonymously agreed to participate in the in-depth interviews and to all of the respondents to the barriers questionnaires. This research was supported by a grant from the Dutch Organization for Health Research and Development (ZonMw).

References

Special article

Antimicrobial stewardship: A collaborative partnership between infection preventionists and health care epidemiologists

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APIC-SHEA Position Paper

Misuse and overuse of antimicrobials, primarily involving therapeutic agents used to treat infection in humans, is considered one of the world’s most pressing public health problems.1 Not only does such inappropriate use diminish the therapeutic benefit of essential medications, it also facilitates the development and spread of multidrug resistant organisms (MDROs).2 Antimicrobial resistance and the rise in MDROs globally are associated with increased morbidity and mortality, cross-transmission within and between health care settings, and increased consumption of limited patient care resources. Despite elevated awareness, publication of guidelines on antimicrobial stewardship,3 and several initiatives, the proportion of resistant strains causing both health care and community-associated infections continues to increase and the number of new antimicrobials continues to decline.4,5

In response to this growing problem, the Centers for Disease Control and Prevention (CDC) launched the Get Smart for Healthcare initiative6,7 in 2004, which includes a national campaign to promote collaboration across health care settings and mobilize national and local health officials in educating patients, consumers and health care practitioners about appropriate use of antibiotics. The importance of antimicrobial resistance was recently highlighted by the World Health Organization (WHO), which dedicated World Health Day 20118 to halting the spread of antimicrobial resistance. The CDC and WHO are leading voices working towards an international solution with a three-pronged focus: 1) optimizing use of existing antimicrobial agents, 2) preventing transmission of MDROs and, 3) pursuing new therapeutic tools to treat emerging pathogens.

Antimicrobial Stewardship (AS) is an interprofessional effort and involves optimal, prudent antimicrobial use for patients across the continuum of care: acute, inpatient, long-term care, and outpatient settings.9

This position paper highlights the critical importance of health care epidemiologists (HEs) and infection preventionists (IPs) in effective antimicrobial stewardship programs (ASPs). The skills and knowledge each of these highly-skilled professionals brings to a facility’s ASP, when combined with other disciplines, can accelerate progress towards preventing emergence and cross transmission of MDROs (Table 1). APIC and SHEA are the professional organizations with historical focus, expertise and credibility in articulating and implementing best practice in antimicrobial stewardship and infection prevention and control.

The Association for Professionals in Infection Control and Epidemiology (APIC) and the Society for Healthcare Epidemiology of America (SHEA) believe the following:

- MDROs cause a significant proportion of serious health care-associated infections (HAIs) and pose significant risk to patient safety across all points of health care delivery.
- Regulatory and accreditation organizations, along with legislative bodies, must continue to make HAIs, including those caused by MDROs, a greater priority in health care.10,11
- Integrated, multidisciplinary ASPs led by a physician and a pharmacist with training in antimicrobial stewardship are crucial to promoting the prudent use of antimicrobials and in combating the development of MDROs in all health care settings.
Table 1
Examples of HE/IP strategies to improve stewardship

- Identification of MDROs detected among the population served by a health care facility
- As part of surveillance, the monitoring and reporting of trends over time involving MDROs
- Oversight of the use of standard and transmission-based precautions aimed at preventing cross transmission of pathogens
- Compliance with hand hygiene
- Use of surveillance data to inform risk assessment and planning for prevention of infection
- Education of clinicians on prudent and appropriate use of antibiotics
- Development of clinical algorithms for treating infections
- Audit, analysis and reporting of data on HAIs
- Implementation of strategies aimed at prevention of infection and elements involving prescribing and therapeutic use of antimicrobials, (eg, guidelines, decision support involving order/entry, de-escalation)

SUMMARY

It is clear that the widespread and injudicious use of antimicrobials has greatly increased the presence of MDROs that threaten the health of all. There is worldwide acknowledgement that this threat is growing, and that prudent use of antimicrobials combined with infection prevention can prevent harm and improve patient safety. Antimicrobial stewardship programs must harness the talents of all members of the health care team to effectively identify the organism, determine its susceptibility, institute any precautions required, and prescribe the narrowest-acting antibiotic that will destroy it. IPs/HEs play a pivotal role in this approach, by assisting required, and prescribe the narrowest-acting antibiotic that will destroy it. IPs/HEs play a pivotal role in this approach, by assisting.

Acknowledgment

The authors acknowledge Arjun Srinivasan, MD, FSHEA, for his insightful review and commentary.

References


Additional resources

Major article

Wide variation in adoption of screening and infection control interventions for multidrug-resistant organisms: A national study

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Key Words:
Infection prevention and control programs
Methicillin-resistant Staphylococcus aureus
Vancomycin-resistant Enterococcus
Clostridium difficile

Background: We performed a survey of National Healthcare Safety Network hospitals in 2008 to describe adoption of screening and infection control policies aimed at multidrug-resistant organisms (MDRO) in intensive care units (ICUs) and identify predictors of their presence, monitoring, and implementation.

Methods: Four hundred forty-one infection control directors were surveyed using a modified Dillman technique. To explore differences in screening and infection control policies by setting characteristics, bivariate and multivariable logistic regression models were constructed.

Results: In total, 250 hospitals participated (57% response rate). Study ICUs (n = 413) routinely screened for methicillin-resistant Staphylococcus aureus (59%); vancomycin-resistant Enterococcus (22%); multidrug-resistant, gram-negative rods (12%); and Clostridium difficile (11%). Directors reported ICU policies to screen all admissions for any MDRO (40%), screen periodically (27%), utilize presumptive isolation/contact precautions pending a screen (31%), and cohort colonized patients (42%). Several independent predictors of the presence and implementation of different interventions including mandatory reporting and teaching status were identified.

Conclusion: This study found wide variation in adoption of MDRO screening and infection control interventions, which may reflect differences in published recommendations or their interpretation. Further research is needed to provide additional insight on effective strategies and how best to promote compliance.

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for Disease Control and Prevention (CDC) guidelines recommend use of barrier precautions for confirmed cases but do not recommend routine surveillance cultures in low MDRO prevalence settings. Conversely, the Society for Healthcare Epidemiologists of America recommends surveillance cultures for all high-risk admissions and use of preemptive barrier precautions for patients with pending cultures. Several European countries employ more stringent approaches that include screening and isolation of patients considered high risk for MRSA carriage.

Although several studies have been conducted on the use of different infection control practices, adoption of specific MDRO and C difficile screening and infection control policies in US hospitals is not well described. Additionally, research on setting characteristics that influence implementation of these interventions in intensive care units (ICUs) is lacking. Therefore, the aims of this large, cross-sectional study of National Healthcare Safety Network (NHSN) hospitals were to (1) describe adoption of MDRO and C difficile screening and infection control interventions, as well as their implementation in ICUs; and (2) investigate whether the presence, monitoring, and/or implementation of screening and infection control interventions aimed at MDRO in ICUs varies with setting characteristics (ie, hospital, infection control department, and ICU characteristics).

METHODS

As part of a larger study, “Prevention of Nosocomial Infections and Cost Effectiveness Analysis,” R01NR010107, select NHSN hospitals were surveyed in 2008. A total of 441 hospitals were eligible to participate in this study, and the eligibility criteria included conducting NHSN HAI surveillance in 2007 and a minimum of 500 device-days. The eligibility criteria reflected the aims of the larger study, which were to investigate the effectiveness of infection control bundles in reducing device-associated HAI rates. A modified Dillman technique was used, and participant recruitment and study methodology are described in detail elsewhere.18 The online survey was designed to be answered by the infection control department director. Respondents provided data on each medical, medical/surgical, and surgical ICU at their hospitals. Test-retest reliability of the survey was assessed ($k = 0.88$), and the survey was pilot tested by 3 infection preventionists (IPs) and 2 doctoral students. Study procedures were reviewed and approved by the Columbia University Medical Center Institutional Review Board.

The conceptual framework guiding our work was based on the quality of care definition developed by Donabedian who defined quality of care as being composed of the structures, processes, and outcomes of care19 (Fig 1). Specifically, we investigated the relationship between structures of care (ie, hospital and infection control characteristics) and processes of care (ie, adoption, monitoring, and implementation of infection control policies aimed at MDRO).

**Independent variables**

Hospital characteristics examined included geographic region (Northeast, South, Midwest, West) and state mandatory reporting of HAI (yes/no). Teaching status and bed size were not collected as part of the original survey but subsequently obtained from public data sources and telephone calls to hospitals that completed the survey. Hospital teaching status was defined as the hospital being affiliated with a medical school, and bed size was defined as the number of licensed in-patient beds. Infection control department characteristics included the following: presence of hospital epidemiologist (full-time defined as 40 hours per week devoted to infection control, part-time defined as less than 40 hours and any [either part- or full-time]), proportion of IPs certified in infection control, number of IP full-time equivalents (FTE) per 100 beds, number of infection control staffing hours per week, number of IP staff, and use of electronic surveillance systems for tracking of HAI (yes/no).

**Dependent variables**

To assess screening practices for specific organisms, respondents were asked whether each ICU routinely screened for MRSA, VRE, C difficile, and MDR GNR. Data were collected on 5 screening and infection control policies (aim 2): (1) screening ALL ICU admissions for any MDRO, (2) screening for any MDRO periodically after admission, (3) presumptive isolation/contact precautions pending a screen, (4) contact precautions for culture-positive patients, and (5) cohorting of colonized patients. For each of these 5 policies, we asked the following: Was a written policy in place? If yes, was it monitored? If monitored, what proportion of time was the policy correctly implemented? Answer choices included the following: all the time (95%-100%), usually (75%-94%), sometimes (25%-74%), rarely/never (less than 25%), and don’t know. Fifteen outcomes were examined: presence, monitoring, and correct implementation of each of the 5 policies. Correct implementation was defined dichotomously as $\geq 75\%$ versus $< 75\%$ of the time based on distributions of responses.

**Data analysis**

Data were analyzed using Stata 11.1 (Stata Corporation, College Station, TX). Descriptive statistics were examined. We computed frequencies and percentages to determine adoption of different interventions (aim 1). To examine whether presence, monitoring, and implementation of interventions for any MDRO varied with setting characteristics (aim 2), we constructed bivariate logistic regression models. The independent variables were the hospital, infection control department, and ICU characteristics outlined previously. Because of an exploratory nature of this study, we used an empirical approach to include variables in the multivariable model because not a lot is known about predictors of adoption and implementation of these policies. Those variables with a P value of $< 0.1$ were entered into multivariable logistic regression models to estimate the independent effect of each predictor on the presence, monitoring, and implementation of interventions aimed at any MDRO. Additionally, potential confounding variables were added one by one into the model, and, if the coefficient of a covariate changed by 10% or more, the variable was considered a confounder and entered into the final model. Because data were collected on more than 1 ICU, we calculated robust variance estimators for all analyses to adjust for clustering at the hospital level.
among variables were examined to assess collinearity. A P value of <.05 was considered statistically significant.

RESULTS

Of 441 eligible hospitals, 250 provided data on 413 ICUs (57% response rate). Table 1 provides demographic data of study hospitals. The majority of respondents (n = 142, 57%) provided data on only 1 ICU, with an additional 74 (30%) providing data on 2 ICUs. Almost half the hospitals were located in the Northeast (44%), and the majority was located in states with mandatory reporting of HAI (76%). Two-fifths reported presence of a part-time hospital epidemiologist (42%), whereas a full-time epidemiologist was present in only 6% of the hospitals. Of the independent variables, only total hours of infection control staffing and number of infection control staff were highly correlated (r = 0.90).

Aim 1: Describe adoption of MDRO and C difficile screening and infection control interventions

Study ICUs routinely screened for MRSA (59%), VRE (22%), MDR GNRs (12%), and C difficile (11%). A written policy to screen all admissions for any MDRO was reported for 40% of ICUs, and 27% had a policy for periodic screening following admission (Table 2). Of those ICUs that reported the presence of these 2 policies, the majority monitored implementation (80% and 79%, respectively), and correct implementation ≥75% of the time was reported for 96% and 91% of the ICUs, respectively. Approximately one-third reported a policy requiring isolation/contact precautions for patients with pending screens; 98% and 42% reported a policy for contact precautions for culture-positive patients and cohorting of colonized patients, respectively.

Aim 2: Examine whether presence, monitoring, and/or implementation of screening and infection control interventions aimed at any MDRO vary with setting characteristics

In bivariate analysis, state mandatory reporting (odds ratio [OR], 2.52; 95% confidence interval [CI]: 1.36-4.66; P = .03), teaching status (OR, 1.80; 95% CI: 1.01-3.21; P = .048), hospital bed size of 201 to 500 beds (OR, 2.73; 95% CI: 1.28-5.79; P = .009), and location in the West (OR, 0.31; 95% CI: 0.12-0.80; P = .015) were associated with a policy to screen all admissions for any MDRO. In the multivariable model, mandatory reporting, teaching status, and location in the West remained significant independent predictors of the presence of this policy (Table 3).

Mandatory reporting (OR, 2.25; 95% CI: 1.09-4.64; P = .028), teaching status (OR, 2.68; 95% CI: 1.36-5.29; P = .004), and use of electronic surveillance systems (OR, 1.95; 95% CI: 1.00-3.82; P = .050) were positively associated with a policy to screen periodically after admission in bivariate analyses. Additionally, ICUs in hospitals with 201 to 500 beds were more likely to report this policy as compared with smaller hospitals (OR, 2.47; 95% CI: 1.03-5.94; P = .043), and ICUs located in the Midwest and West were less likely to report this policy versus the Northeast (OR, 0.20; 95% CI: 0.08-0.53, P = .001 and OR, 0.28; 95% CI: 0.10-0.79, P = .016, respectively). However, the presence of an electronic surveillance system, Midwest location, and hospital size remained the only independent predictors of periodic screening in multivariable regression (Table 3).

Mandatory reporting status was negatively associated with having a policy for presumptive isolation/contact precautions pending a screen (OR, 0.47; 95% CI: 0.25-0.85; P = .012) and was the only significant predictor of this policy in bivariate analysis. Although mandatory reporting was significantly associated with a policy to cohort colonized patients in bivariate analysis (OR, 1.91; 95% CI: 1.06-3.42; P = .031), it was not an independent predictor of having this policy after controlling for region and the number of infection control staff.

In bivariate analyses, ICUs in hospitals with a full-time epidemiologist were more likely to monitor compliance with cohorting of colonized patients (OR, 6.65; 95% CI: 1.08-40.96; P = .041) but was not significantly associated with monitoring the implementation of this policy after controlling for state mandatory reporting, region, number of infection control staff, and proportion of IPs certified in infection control (data not shown).

Several setting characteristics predicted correct implementation of infection control policies ≥75% of the time. ICUs in hospitals with a greater proportion of certified IPs were less likely to report correct implementation of policy to screen new admissions (OR, 0.19; 95% CI: 0.05-0.64; P = .008) after controlling for the number of infection control staff and region. In bivariate analyses, higher infection control staffing hours were positively associated with correct implementation of periodic screening (OR, 1.01; 95% CI: 1.00-1.02; P = .004) and the presence of any hospital epidemiologist approached statistical significance (OR, 6.11; 95% CI: 0.86-43.47; P = .070). Higher number of infection control staff, and infection control staffing hours were positive predictors of correct implementation of the policy to isolate culture-positive patients in bivariate analysis (OR, 1.32; 95% CI: 1.01-1.71; P = .042 and OR, 1.01; 95% CI: 1.00-1.01, P = .017, respectively). Lastly, ICUs in the Midwest were significantly less likely to report correct implementation of a policy to cohort colonized patients (OR, 0.03; 95% CI: 0.01-0.40; P = .008).

However, we lacked sufficient power to assess these variables in multivariable analysis or to assess the relationship between setting characteristics and contact precautions for patients with pending screens.
State mandatory reporting was a significant independent predictor of screening for MDRO, which is expected given that hospitals may have an incentive to screen new admissions for MDRO to identify infections not attributable to the hospital stay. Teaching status was an independent predictor of screening all admissions for any MDRO. Other studies found similar relationships among teaching status, use of procedures to monitor antimicrobial resistance, and greater surveillance scores. Interestingly, ICUs in hospitals with higher percent of IPs certified in infection control were less likely to report correct implementation of policy to screen all admissions. One explanation is that more experienced IPs may be more accurate in reporting implementation, whereas less experienced IPs may over report adherence. Additionally, it may be the case that certified IPs are less strict about complying with policies for which the evidence base is lacking.

Infection control staffing did not independently predict the presence and/or implementation of interventions, which suggests that factors other than staffing are influencing the likelihood of implementing these policies. Several studies have examined the role of organizational factors such as institutional culture and suggest that these may be important in fostering adoption of infection control policies; however, we did not assess these in this analysis. Future studies should investigate the relationship between staffing and organizational support and the effect both may have on policy implementation. Additionally, with the current increase in mandatory reporting, IPs may be focusing on fulfilling mandates rather than implementing policies based on their experience and hospital needs. Further studies are warranted to assess how mandatory reporting influences the role, activities, and goals of the infection control department including policy implementation.

This study has several limitations. The data are cross-sectional preventing us from establishing temporality. Our study involved a convenience sample of NHSN hospitals, which in 2008 tended to be larger and more likely to be teaching. In addition, our eligibility criteria included a minimum number of device-days; therefore, surveyed hospitals were on the larger end of the NHSN spectrum. Hospitals located in the Northeast were overrepresented, which may further limit generalizability. Data were self-reported by IPs, which may be problematic in that IPs may have overestimated adoption of policies. Additionally, reported compliance may not be accurate because IPs do not spend substantial amounts of time in the ICU. Because this was an exploratory analysis, we did not adjust for the multiple comparisons made. Our response rate was 57%, leaving potential for nonresponse bias. To examine the possibility of this type of bias, we compared HAI rates in surveyed hospitals to those found in published estimates of all NHSN hospitals and found them to be similar. Despite these limitations, we were able to observe several significant predictors of full compliance with policies.

### Table 2
Extent to which ICUs have written infection control policies related to MDRO, monitor their implementation, and proportion of time these policies are correctly implemented: N = 413

<table>
<thead>
<tr>
<th>Presence of written policy</th>
<th>Presence of monitoring for implementation*</th>
<th>ICUs reporting correct implementation at least 75% of the time*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen ALL patients for any MDRO upon admission</td>
<td>164</td>
<td>131</td>
</tr>
<tr>
<td>Screen periodically after admission</td>
<td>110</td>
<td>87</td>
</tr>
<tr>
<td>Presumptive isolation pending screen results</td>
<td>128</td>
<td>61</td>
</tr>
<tr>
<td>Contact precautions for culture-positive patients</td>
<td>404</td>
<td>264</td>
</tr>
<tr>
<td>Cohortting of colonized patients</td>
<td>175</td>
<td>87</td>
</tr>
</tbody>
</table>

ICU, intensive care unit; MDRO, multidrug-resistant organism.

*Monitoring of implementation was assessed among those ICUs that reported the presence of a written policy and correct implementation was assessed among those ICUs that reported monitoring of implementation of the written policy.

### Table 3
Predictors of presence of infection control policies in multivariable analysis

<table>
<thead>
<tr>
<th>Predictor</th>
<th>OR 95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screening all patients for any MDRO (n = 361)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mandatory reporting</td>
<td>3.34</td>
<td>1.51-7.38</td>
</tr>
<tr>
<td>No. of FTE IPs per 100 beds</td>
<td>1.01</td>
<td>0.54-1.98</td>
</tr>
<tr>
<td>Teaching</td>
<td>2.30</td>
<td>1.18-4.46</td>
</tr>
<tr>
<td>Region (vs Northeast)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>1.38</td>
<td>0.64-2.97</td>
</tr>
<tr>
<td>Midwest</td>
<td>0.97</td>
<td>0.34-2.78</td>
</tr>
<tr>
<td>West</td>
<td>0.28</td>
<td>0.10-0.78</td>
</tr>
<tr>
<td>Bed size (vs &lt; 201)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>201-500</td>
<td>2.74</td>
<td>0.93-8.10</td>
</tr>
<tr>
<td>&gt;500</td>
<td>1.78</td>
<td>0.56-5.78</td>
</tr>
<tr>
<td>Screening periodically after admission (n = 411)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mandatory reporting</td>
<td>1.62</td>
<td>0.56-4.67</td>
</tr>
<tr>
<td>Electronic surveillance system</td>
<td>2.45</td>
<td>1.05-5.71</td>
</tr>
<tr>
<td>Teaching</td>
<td>2.44</td>
<td>0.95-6.24</td>
</tr>
<tr>
<td>Region (vs Northeast)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>1.64</td>
<td>0.65-4.12</td>
</tr>
<tr>
<td>Midwest</td>
<td>0.22</td>
<td>0.05-0.93</td>
</tr>
<tr>
<td>West</td>
<td>0.37</td>
<td>0.11-1.31</td>
</tr>
<tr>
<td>Percent IP certified</td>
<td>1.67</td>
<td>0.52-5.01</td>
</tr>
<tr>
<td>Number of infection control staff</td>
<td>1.00</td>
<td>0.76-1.32</td>
</tr>
<tr>
<td>Bed size (vs &lt; 201)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>201-500</td>
<td>7.05</td>
<td>1.12-44.40</td>
</tr>
<tr>
<td>&gt;500</td>
<td>4.43</td>
<td>0.61-31.88</td>
</tr>
<tr>
<td>Contact precautions for culture positive patients (n = 355)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mandatory reporting</td>
<td>0.73</td>
<td>0.13-4.16</td>
</tr>
<tr>
<td>No. of FTE IPs per 100 beds</td>
<td>0.63</td>
<td>0.32-1.22</td>
</tr>
<tr>
<td>Percent of IPs certified</td>
<td>0.02</td>
<td>0.01-1.18</td>
</tr>
<tr>
<td>Cohortting of patients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mandatory reporting</td>
<td>1.16</td>
<td>0.51-2.62</td>
</tr>
<tr>
<td>Region (vs Northeast)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>0.52</td>
<td>0.21-1.29</td>
</tr>
<tr>
<td>Midwest</td>
<td>0.30</td>
<td>0.10-0.92</td>
</tr>
<tr>
<td>West</td>
<td>0.47</td>
<td>0.17-1.32</td>
</tr>
<tr>
<td>Number of infection control staff</td>
<td>1.14</td>
<td>0.96-1.35</td>
</tr>
</tbody>
</table>

FTE, Full-time equivalent; IP, infection preventionist; MDRO, multidrug-resistant organism.

NOTE: All variables entered into each model are presented in the Table.

### DISCUSSION

To our knowledge, this is one of the first studies to examine adoption of these specific policies and to identify predictors of their presence and implementation. In our study, over half the ICUs reported having a written policy for MRSA; but only a small proportion screened for VRE, MDR, GNR, and *C. difficile* (11%-22%). The vast majority reported a policy for contact/isolation precautions for culture-positive patients, which is congruent with other studies that reported high use of barrier/isolation precautions for infected patients. The presence of other MDRO-related infection control policies in our sample was low and may reflect wide variation in published recommendations on these interventions or their interpretation.
There is significant variation in adoption of screening and infection control interventions aimed at MDRO and *C difficile* in NHSN ICUs, which is congruent with data from other studies and may reflect wide variation in published recommendations or their interpretation. Several setting characteristics hypothesized to be important in predicting these interventions did have an independent effect on their presence and implementation, specifically, mandatory reporting, geographic region, bed size, presence of a hospital epidemiologist, teaching status, and presence of an electronic surveillance system. Further research is needed to confirm these findings and to identify additional factors that foster adoption of these interventions. Additional research is also needed to strengthen the evidence base on the effectiveness of these interventions and facilitate the development of more standardized guidelines to aid in implementing these interventions in the acute care setting.

**Acknowledgment**

The authors thank all of the participating hospitals.

**References**


Enhancing the Function of Clinical Microbiology Laboratories: Can We Navigate the Road Less Traveled?

Duane W. Newton and Susan Novak-Weekley

Enhancing the Function of Clinical Microbiology Laboratories: Can We Navigate the Road Less Traveled?

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This is a very exciting and dynamic period for clinical microbiology: not only are we seeing changes in the way we practice, but we also have a very sophisticated array of tools that are increasingly at our disposal. These tools, and the changes they impart, can substantially improve the quality and delivery of service being provided for patients. With change, though, as always, there are challenges: technology is developing at an almost too-rapid pace, vast amounts of information which are difficult to manage and communicate are being generated, standards either do not exist or are not adequately useful for many targets/platforms, and many decisions in clinical microbiology practice are not being made using evidence-based information. Ultimately, we need to be able improve how we communicate so that we are more effective in our ability to report results and ensure appropriate interpretation. Improved communication with vendors and administrators is also necessary so that improved products can be developed and be appropriately implemented within the laboratory. The important question over the next 5 years is how clinical microbiology can overcome the potential barriers to reaching our goals, leveraging to our advantage opportunities in technology development and information management. To accomplish this, we will likely be required to travel down potentially unfamiliar paths, engaging our partners on new and different levels.

In anticipating the direction(s) in which we may be moving in the near future, it may be useful to look at where we have been and where we now appear to be. A quick review of the Journal of Clinical Microbiology tables of contents from the first quarter of 2006 provides an interesting perspective on the development of technology. Although real-time PCR platforms were already an integral part of many laboratories at that time, this has not been a panacea. For example, the design of some commercial hepatitis C virus (HCV) assays needed to be improved in order to accurately quantify all genotypes (10). Nevertheless, the power of the technology was clearly being applied to assess the clinical significance of novel pathogens (6) and determine whether quantitative molecular methods could be applied to address existing clinical questions in new ways (5). These studies show that although new technologies are not always “magic bullets,” improvements can be made and ultimately their strengths can be exploited.

Technological advancements are also beginning to push the boundaries of basic, long-standing paradigms in clinical microbiology. The Human Microbiome Project has been a natural extension of the Human Genome Project and is really a collection of projects designed to characterize, at a molecular level, the microbial populations in various body sites (for example, the gastrointestinal tract) of both normal individuals and persons with certain diseases (such as Clostridium difficile infection) (11). The information being gained from these projects will undoubtedly revolutionize our understanding of “normal flora.” It also has the potential to shift our diagnostic paradigms not only through the appreciation of the contributions of previously unrecognized organisms but also by delineating the importance of population dynamics in characterizing “healthy” and “disease” states. “Ultra-deep” or “next-generation” sequencing platforms are being utilized extensively to generate this information, but can the cost, complexity, and data management requirements of this technology be brought to a level where it can be implemented in a clinical laboratory?

With technological development comes, especially in the area of molecular diagnostics, an increasing necessity for standardized reference materials/information. The publicly available sequence databases provide extensive information that is both broad and deep, yet the overall quality (accuracy and reproducibility) of the information is often suboptimal. Well-characterized and curated databases are mostly limited to expensive, commercially available products whose clinical utility is still being established. When molecular assays are developed for new targets, the availability of standardized proficiency testing material often lags behind for years. Furthermore, the characteristics of this material and the nature of the challenge (qualitative versus quantitative) have not always reflected existing laboratory experience or practice. Proficiency material has improved considerably now that the specimens are liquid and because of the development of supplemental challenge panels for a variety of quantitative and qualitative molecular assays. Nevertheless it is difficult for commercial providers of proficiency testing samples to keep pace with all of the advancements, which is expected to remain a challenge into the near future.

Advances in technology have also increased the complexity of information management. These developments have given rise to challenges in capturing and analyzing the information being generated, as well as in communicating it effectively. It is often very difficult to practically manage the volumes of information generated in the laboratory, getting the word out not only to clients or customers but also within and between laboratories. As presented by P. Schreckenberger in this supplement, although Clinical and Laboratory Standards Institute (CLSI) guidelines such as the M100 tables have existed for

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years, there are still clinical laboratories that do not update or even use this available information. Within the laboratory, not only are our sample submission guidelines, testing protocols, and result reports complex, but any deficiencies in these processes can be quickly amplified when combined with a significant clinical and laboratory challenge. This was no more apparent than during the novel H1N1 influenza A pandemic of 2009 to 2010: samples were collected by many providers who had never collected such specimens before, from many patients in whom testing was not appropriate, and with a lack of a clear understanding of what information the testing was and was not able to provide. In many institutions, there were tremendous challenges in determining the structure that the relevant information should take, identifying appropriate mechanisms to disseminate this information, and determining the frequency of provision of updates to ensure currency. Even in a routine setting, are there better ways to accomplish this without information overload? Furthermore, combining appropriate clinical care and lab utilization will play an even greater role once health care institutions are faced with the impact of universal health care. An appropriate balancing of health care costs with increased patient load/test utilization can be accomplished only with evidence-based outcome data. The lack of outcome data will be addressed specifically below, since this will be a major consideration in how technology will actually impact clinical care algorithms.

DISCUSSION

In our role as clinical microbiologists, there are significant barriers which currently limit our ability to function at the highest level possible. We have described examples of some of these barriers and below provide several approaches to overcome various obstacles. It is hoped that this will lead to enhanced communication of laboratory information and increased quality of care to our patients, whom we ultimately serve.

How can we leverage technological developments to our advantage? Enhanced partnerships between vendors and the clinical microbiology laboratory are necessary to generate important cost justification data. The process of new technology implementation is a journey that the laboratory cannot take alone. Clinical laboratories need to impart to vendors that purchasing a product or instrument is just one aspect of implementing a test. Other aspects that need to be supported are work flow, space planning, training, ergonomics, and detailed cost analyses, which at times may include outcome data supporting a specific clinical algorithm or decision. Vendors supplying new technology have a vested interest in its success and must provide resources to adequately address all of the above issues tailored to each individual laboratory or institutional need. Although hospital administrators may be skeptical about the validity of information provided by vendors, the process and information generated can be used as a template and modified to suit the user’s needs.

In addition to financial or physical barriers, the emotional barrier to change that exists in the laboratory workforce can also be difficult to overcome. We should take advantage of local and distance training opportunities offered by vendors for our technologists, not just to present technical/procedural information but also to provide scientific information surrounding the technology. Engagement of interested technologists at both the theoretical and practical levels can have a tremendous impact on the willingness to be a partner of change. Vendors can also partner with laboratories by developing templates for competency testing, technologist training, and educational materials for varied professional groups, such as clinicians or nurses who might be ordering a specific test. More and more, the administrative and clinical areas are looking to the laboratory to provide guidance that transcends just providing a test result. Vendors can assist in this process by thoroughly evaluating their assays during the entire testing process, from the beginning of specimen collection to the result released in the laboratory computer system, providing support to laboratories so that each step can be optimized.

Clinical microbiologists should also play a direct role in leveraging technology to our advantage. It is paramount that clinical laboratories participating in translational research understand the importance of publishing the data generated so that laboratories unable to support these types of endeavors can benefit from important discoveries. Although presentation of data in abstract form is an appropriate first step, it is frequently the last step (see references 1 and 2). Participation in extensive clinical trials and the opportunity to be an early adopter of technology often seem to be limited to relatively few laboratories. Those of us fortunate enough to have the resources to engage in these activities must recognize that the information generated from these studies will form the basis of the technical, operational, and financial decisions regarding implementation of this technology by our colleagues. Unless this information is published, it will remain a resource that is virtually “untappable.”

Molecular technology has continued advancing to include multiplex PCR and array-based assays for the detection of respiratory viruses, as well fluorescent in situ hybridization (FISH) for the identification of pathogens in blood cultures. This is quickly being supplemented with rapid (taking minutes) technologies for the identification of microorganisms, including matrix-assisted laser desorption ionization–time of flight (MALDI-TOF) mass spectrometry and PCR-mass spectrometry. Although up-front costs for these technologies are currently high, the low cost per test and/or short time to results are certain to change the process by which we approach organism identification. A better job needs to be done in determining how best these technologies fit into the whole patient care algorithm.

While it is novel to provide organism identification within a short period of time using these newer technologies, if the clinician or the pharmacy is not adequately staffed or educated in terms of how to use the results, the benefit could be lost. Even if cost-benefit studies in some institutions show that money can be saved and prescriptions can be reduced (as in the case of using in situ hybridization techniques on blood cultures), these metrics do not always apply to every institution. Manufacturers need to partner with laboratories so that limitations and challenges are fully understood. The majority of work for the laboratory is often felt to be completed once the technology is integrated, standardized, and effectively communicated, yet this is the point where the most important and relevant efforts for clinical microbiologists should be initiated.
but are generally lacking. There is a paucity of information in the clinical microbiology literature providing outcome data on which to base our laboratory decision making. Even when data supporting the analytical benefits of a diagnostic approach exist, there is hardly ever an assessment of its effectiveness in clinical practice. Examples of such studies include data presented in the early 1990s showing that without any intervention, physician-directed changes in therapy based on laboratory-reported antibiotic susceptibility patterns took almost 4 days. When the same data were monitored and actively managed by a clinical pharmacist, the time to appropriate therapeutic changes was reduced to just over 12 h (1). At the University of Michigan Health System (UMHS), we reported similar experiences regarding active interventions from clinical pharmacists in order to optimize vancomycin utilization following mecA PCR testing in *Staphylococcus aureus* (3) and optimal antifungal use following peptide nucleic acid (PNA)-FISH in *Candida* bloodstream infections (2). These studies found that although the laboratory was investing significant resources in order to provide this information rapidly, the information was not being acted upon by physicians. In the coming age of health care reform, will we not be able to continue utilizing our resources, especially on more expensive technologies, without providing the evidence that these efforts are having the desired impact on patient care.

**How can we enhance the quality and availability of standardized reference and proficiency testing materials?** Most clinical microbiologists realize that laboratories are under-served in terms of FDA-approved or -cleared molecular assays for many important infectious diseases. Because of this, laboratories are still pressured to develop “home brew” or analyte-specific reagent (ASR)-based assays within their own institutional setting. There is an overwhelming problem in comparing the analytical performance of one “home brew” assay to another when there is no standardized reference material available. In addition, the standards available for use in molecular diagnostics have historically been developed to assess the performance of qualitative assays used in screening of blood products and have had limited utility in standardizing in-house-developed or commercially available quantitative assays (7). Several studies evaluating the interlaboratory performance of quantitative viral load assays have shown that while within-laboratory reproducibility is often good, substantial differences in performance between laboratories are observed (4, 8, 9), which could be mitigated through the availability of commutable quantitative standards.

What laboratories need is increased participation by clinical microbiologists, especially those based in the United States, in organizations involved in development of these materials. There are a variety of organizations whose functions include the development of standardized reference material: the World Health Organization (WHO) (www.who.int/biologicals/en), the National Institute for Biological Standards and Controls (NIBSC) (part of the Health Protection Agency of the United Kingdom) (www.nibsc.ac.uk), the National Institute of Standards and Technology (NIST) (a federal agency in the U.S. government) (www.nist.gov), the Joint Commission on Traceability in Laboratory Medicine (JCTLM) (an international cooperative organization based in France) (www.bipm.org/en/committees/jc/jctlm/), and groups representing manufacturers, such as the Industrial Liaison Committee (ILC). Each has been involved in the production of quantifiable standards for molecular diagnostics, but one of the challenges that arises from this is that each organization can pursue the development of completely different material (e.g., intact virus/biological standards versus recombinant nucleic acid/chemical standards), and the impact of these differences is not known. Nevertheless, opportunities for clinical microbiologists to contribute to this process exist: a working group of NIBSC, Standardization of Genomic Amplification Techniques (SoGAT) (www.nibsc.ac.uk/spotlight/sogat.aspx), meets twice a year and has been very active in facilitating the development of quantitative standards. Through the collaboration of WHO, NIBSC, and SoGAT, the first WHO international standard for cytomegalovirus (CMV) was recently released (NIBSC code 09/162), and a similar standard for Epstein-Barr virus (EBV) is in development. Currently, participation in SoGAT by United States-based clinical microbiologists is limited, and there is thus an opportunity for this to be enhanced. This could be facilitated through more visible involvement with these organizations by professional societies such as ASM and AMP. Furthermore, sponsorship of clinical microbiologist attendance at these meetings by the professional societies would encourage greater participation. The selected attendee(s) would be able to represent the society and our profession but would be provided with the resources to attend, thereby offsetting time/financial challenges to participating.

Obstacles similar to those that exist in the development of standard reference materials also exist with regard to proficiency testing samples. This process is becoming increasingly difficult due to the expansion of platforms for testing, the breadth of analytes/targets needing to be assessed, and the limited number of vendors available to manufacture, test, and distribute this material. Although these limitations can make the rate of change/enhancement low, the Microbiology Resource Committee of the College of American Pathologists has been very responsive to input, and continued support of the process is important. Users are encouraged to communicate with the Microbiology Resources Committee regarding problems, issues, or changes and also to be willing to participate in the improvement process if called upon to serve.

**How do we better access, manage, and disseminate the important information being generated by the laboratory?** Clinical microbiologists need to increase their participation in non-laboratory forums, working to break down silos by, e.g., participating in broader hospital- or health system-wide committees, participating in Joint Commission audits and reviews to increase laboratory visibility, and working to enhance relationship development with local, state, and federal public health entities. Engagement of “nontraditional” professional organizations by clinical microbiologists is a necessity. More technologists, especially from smaller institutions with limited microbiology depth, are attending American Association of Clinical Chemistry (AACC) meetings to access microbiology and molecular infectious disease testing information. As a result, more clinical microbiologists are presenting there, and more clinical microbiology vendors are exhibiting there. AACC, and to a related extent the local and regional clinical microbiology organizations, should not be perceived as competition but rather should be seen as a partner in the commu-
nication of accurate and timely clinical microbiology information. Furthermore, laboratory and hospital administrators are going to be critical partners in our ability to integrate new technologies into the laboratory, so there would be utility in participating in meetings such as those of the American College of Healthcare Executives, not only to gain a better understanding of the drivers of change (financial, regulatory, etc.) from the administrative perspective but also to utilize such a forum to educate nonlaboratorians (but translated so that it can be understood) on the issues facing the laboratory. Individual clinical microbiologists can certainly initiate interactions with these organizations and participate in these forums. Long-term sustainability and maximum impact, however, would be best achieved through the development of strategic partnerships with such organizations by ASM.

The potential exists to also use new tools (Twitter, Facebook, and wikis) to communicate within and between laboratories and partners, as there are certainly individual/generational differences in how information is accessed as well as in abilities to multitask. There are also opportunities to enhance the utilization of established tools; for example, at one institution an email alert mechanism was generated though the laboratory information system to notify providers on the bone marrow transplant service of CMV viral load results on a daily basis. This was a relatively simple process that met the needs of the clinicians while having minimal impact on the laboratory.

In order to get the information into the hands of the right people, laboratory personnel need to take an active role, get out of the laboratory, and be indispensable. An article in the December 2005 issue of CAP Today (www.cap.org) described the Lab Ambassador program at the University of North Carolina Hospitals. The University of Michigan Health System has modeled a similar program; it matches laboratory technologists with nurses in different units, whereby they can be liaisons for each other and their departments to more effectively communicate regarding issues impacting each (partnering to find solutions). A compendium of resources should be available to laboratories, ideally in an electronic format available on the ASM website, that provides examples of these types of initiatives or best practices so that many can benefit from what has already been successful in other institutions.

How can we enhance evidence-based practice in clinical microbiology? Efforts need to be initiated to provide more support to ASM in the development of practice guidelines (led by Susan Sharp and Alice Weissfeld), to “fix” processes whereby clinical microbiologists are not included in laboratory guideline development, and to become more involved with the FDA so that clinical needs are better understood in the regulatory process. To these ends, there has been an increased movement to develop and enhance practice guidelines in clinical microbiology, e.g., continued development of the Cumitech series, CDC updates on group B Streptococcus screening and detection of Shiga toxin-producing Escherichia coli, and ASM guidelines on testing for Clostridium difficile, Vibrio cholerae, and Cryptococcus gattii. More importantly, ASM, CDC, and Battelle have recently partnered to develop the first evidence-based practice guidelines for the rapid identification of bloodstream infections. The goal is to model these guidelines after those existing in other professional organizations (e.g., IDSA and ATS), with categories of recommendations based on the integrated management of microbial identification, antibiotic susceptibility, and pharmacy dosing information reduces morbidity and mortality of MRSA bacteremia in a surgical ICU. 2016. Journal of Clinical Microbiology.


FIG. 1. Potential manuscript titles for publication in 2016.

strength of the data supporting them. The quality of the information contained in these and future guidelines will be dependent on our professional willingness to produce and publish the data necessary to support the recommendations and to participate in the guideline review/evaluation process during their development. Fundamental in this process is the availability of well-designed clinical trials, developed through consultation between regulatory agencies, manufacturers, and customers, to establish the analytical and clinical performance characteristics of emerging technologies. As presented by R. Shawar in this supplement, the U.S. Food and Drug Administration is a willing partner in this process. However, there are underutilized processes available for these groups to be engaged (e.g., the FDA Clinical Laboratory Advisory Panel). It seems that the FDA is waiting for users (clinical microbiologists) to provide input, and we are waiting for an invitation to come to the table. We cannot sit back and wait; we have to initiate these conversations.

This theme of engagement is a recurring one: we need to improve our engagement with manufacturers, hospital administrations, regulatory agencies, and our professional colleagues. The enhancements desired for the engaged clinical microbiology laboratory 5 years into the future will require us to be nimble, innovative, and connected. While this path may not be familiar or comfortable, it will keep us professionally viable and relevant. Although barriers and challenges exist, it should not be hard to imagine and realize that these changes can be made. The last 5 years have been interesting, exciting, and challenging—what will the next 5 years hold? The theoretical manuscript titles shown in Fig. 1 might give a clue and need not be that far off.


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Fostering Partnerships between Industry and the Clinical Microbiology Laboratory

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The clinical microbiology laboratory plays a pivotal role in the health care system and provides services that are critical to the well-being of a large population of patients. The laboratory is reliant, to a large extent, on the commercial manufacturing sector for the availability of products that generate medically useful information for the diagnosis, treatment, and management of patients with infectious diseases. Relationships between industry and the clinical microbiology laboratory are exceedingly valuable and serve as the basis for technological advancements in these products. Industry plays a key role in essentially every aspect of laboratory medicine and is an intrinsic partner in providing the tools that the laboratory requires to serve the needs of the individual patient.

Needs of industry. Commercial manufacturers are dependent upon clinical microbiology laboratories for many critical needs, including product design and development, registration and licensure, reimbursement, and marketing goals. Industry must be able to call upon the expertise of those in the clinical microbiology laboratory in order to facilitate the process of implementing the latest technological advances into routine clinical practice. To accomplish these goals, industry needs (i) access to clinical sites and patients; (ii) access to clinical specimens, relevant organisms, and laboratory results; (iii) timely execution of clinical trials; (iv) rigorous adherence to trial protocols; (v) accessible personnel, records, and data for site monitors; and (vi) reasonable and customary costs for work performed. Industry sponsors of clinical laboratory studies face costly regulatory barriers to license products with the U.S. Food and Drug Administration (FDA). These procedures need to be streamlined and less burdensome for manufacturers so that new technologies can be implemented in a more timely manner for routine diagnostic use. Industry raises the funds, takes the risks, invests in licensure with the FDA, and should reap the rewards for its role in fostering developments in clinical laboratory medicine.

Needs of laboratories. Clinical microbiology laboratories need products that have reliable performance characteristics, such as sensitivity, specificity, and accuracy. The products need to be affordable and have capabilities for diverse patient populations. A major issue facing the clinical microbiology laboratory is the difficulty in translating basic research advancements into routine clinical practice to improve the diagnosis and management of infectious diseases. Significant amounts of time and investment are required before medically useful products or developments make it from the research sector into the clinical laboratory. A collaborative relationship with industry colleagues will allow for laboratories to provide meaningful feedback and convey the needs of diagnostic testing. For clinical trials, agreements between laboratories and industry sponsors should be established in writing prior to initiating the study and should clearly identify researchers as the directors of data collection, analysis, writing, and reporting. Research findings should be reported in a timely, accurate, and complete manner whenever the findings have the potential to increase the body of scientific knowledge or improve laboratory medicine. Companies need to be complete in using all data from all study sites for FDA licensing submissions. Financial reimbursements provided to laboratories should be fair, to cover reasonable expenses and compensate for time and effort, but not coercive. Some institutional postures complicate negotiations with industry, effectively inhibiting technological advancements in the clinical laboratory. Ultimately, the laboratory seeks an open, informed, transparent, and timely process to facilitate the study, licensure, and implementation of medically necessary diagnostic advancements.

Action items. (i) New study sites and investigators should be sought out. Many important scientific, commercial, and societal goals can be attained only by effective collaboration between clinical laboratories and industry. These relationships need to be formed, reformed, and refreshed on a continuous basis. Industry, oftentimes having developed a productive relationship with one investigator, keeps returning to the same lab time after time. This can make it difficult for young investigators to participate in clinical studies and to develop strong, working relationships with industry.

(ii) Institutional rules and regulations should be streamlined. While all possible speed is of the essence for successful commercial development of products, contracts between laboratory entities/institutions and industry can be complicated and slow to develop. The need for review by legal departments on both sides and by institutional review boards usually introduces frustrating delays, especially when multisite or multinational studies are involved. Industry-wide standard contracts would facilitate this process. Increasingly, concerns over perceived or real conflicts of interest have led institutions to establish rules and restrictions governing interactions with industry. This can limit or exclude any opportunities for investigators to receive any financial incentive whatsoever, even for the support of trainees or other legitimate indirect benefits, such as travel expenses to attend relevant professional meetings. Some institutions insist on high overhead costs, which in excess may compel industry to take their trials elsewhere.

(iii) Products and protocols should be study ready. Occasionally, after a proposal has been accepted, there may be an
unexpected change of plans by the industry sponsor. There are many possible reasons for such changes, particularly if the test product fails to perform as expected, requiring revision, redesign, or even cancellation of the entire study. Industry’s need for rapid commercialization of products can often drive manufacturers to plan a trial before the test product is fully study ready or in “design freeze.” Studies may be delayed if the test product is not ready for release to the investigator on the planned deadline. Such delays can leave otherwise good plans in disarray. For example, a clinical site may have hired study-dedicated personnel funded by industry only to have the study delayed by long periods or even cancelled. Clinical microbiology laboratories should be provided with reasonable contractual protections to cover time and investment in such cases, and commercial sponsors should be willing to provide such contingent protections.

(iv) **Industry’s trial site representatives should be trained and experienced.** Effective monitoring of study sites is essential for successful trials and is needed to comply with regulatory requirements. Industry should provide site monitors that have appropriate training and experience in the clinical microbiology laboratory setting. In addition, laboratories should ensure that these monitors are provided with easy and full access to records and personnel in order to carry out their essential work.

(v) **A Web-based clearinghouse for clinical studies should be developed and maintained.** The effectiveness of laboratory-industry interactions could be enhanced by the development of a national clearinghouse to match investigators and sites with companies and studies. An evergreen listing of upcoming studies and clinical trials needed for investigations of drugs, diagnostics, and devices could be combined with a catalog of competent clinical microbiology laboratory sites. This would build upon existing relationships while facilitating the entry of new companies and young investigators into the field. A nonprofit organization such as the American Society for Microbiology could host such a clearinghouse, and funding could be achieved by charging a modest fee for each listing. An efficient and relatively inexpensive Web-based portal such as this would be representative of a new model of cooperation between clinical microbiology laboratories and the commercial world.

There is a need for appropriate collaboration between industry and the clinical microbiology laboratory. Many prior advances in laboratory medicine would not have been possible without this collaboration. The work of the clinical microbiology laboratory and industry is often aligned, as both have the capacity to improve the health and well-being of patients. Both industry and the clinical microbiology laboratory seek interactive, bidirectional relationships that involve the exchange of ideas, resources, and expertise. Collaborations should be formed with the goal of accelerating the pace of basic discovery and development and its translation into routine clinical laboratory practice. The potential benefits of these relationships are manifold: they are relevant to the patients who constitute the ultimate beneficiaries, to the medical profession at large, to laboratory entities, and (without question) to industry.

**Session discussants:** Stephen Brecher, Carey-Ann Burnham, David Craft, Christine Ginnochio, George Goedesky, Amanda Harrington, David Hooper, J. Stacey Klutts, DeAna Paustian, David Persing, and Hemant Vaidya.
The Role of the Clinical Microbiology Laboratory in the Diagnosis of Selected Infectious Processes

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The Role of the Clinical Microbiology Laboratory in the Diagnosis of Selected Infectious Processes

Although clinical microbiology laboratories have been practicing their specialty for at least half a century, there are still numerous differing opinions even among the acknowledged experts regarding how best to diagnose almost every infectious disease. The following section contains discussions led by some of the best minds in the profession, with participation of other clinical microbiology leaders, new and upcoming, on laboratory strategies for four infectious syndromes for which consensus has not been reached. What are the issues, and what agreements or challenges exist surrounding these important clinical entities?

Bloodstream infections are among the most important for patients of all types in all situations. In fact, blood cultures comprise one of the most common categories of samples received by the microbiology laboratory, even though 90% of them usually fail to reveal a pathogen. And despite numerous published studies clarifying the volume of blood required from various patient types, the importance (or lack of it) of timing of blood cultures, and the length of time to incubate the cultures, many laboratories have not adopted the recommendations (1, 2, 4). Issues such as how many blood cultures are necessary and what volume of blood is ideal, how to influence collection of the appropriate samples, and what practices should be standard in today’s laboratories were all grist for discussion, as reported in the first paper of this section. Certain practices should be universal, and sufficient studies have been published and reviewed to substantiate the recommendations, as summarized in the document; others are challenges for microbiologists to attack in the near future.

With regard to lower respiratory tract infections, arguably the most important aspect of laboratory diagnosis is the quality of the sample, the only aspect of the process that is at least partially out of the control of the microbiologist. The value of Gram staining was agreed upon, and some recommendations to utilize its benefits more actively were proposed. Although quantitative cultures are theoretically useful, challenges exist surrounding their performance and clinical relevance. The participants called for more extensive studies in that area. Cystic fibrosis patient microbiology, always a difficult topic, came under discussion, with good agreement among participants with respect to best practices, as highlighted in the document to follow. Comments on laboratory diagnosis of tuberculosis centered on the role of nucleic acid amplification tests (NAATs). The group disagreed with the CDC’s recommendation to test all suspected patients by the use of an NAAT for at least one sputum specimen, citing high costs and a paucity of clinical relevance or cost-effectiveness studies, in addition to the lack of broadly available commercial or laboratory-developed NAAT assays (3). Despite broad agreement, the group listed a number of future studies, standardized protocols, and other resources that are still needed.

Urine samples are the most common specimens received in most microbiology laboratories. Like blood cultures, the majority of urine cultures do not yield clinically significant results. The next discussion centered on challenges with samples; not surprisingly, collection methods were again seen as important. Topics included whether outpatient urine cultures are actually needed, which nonculture tests may help in interpretation of culture results, the importance of pyuria in interpreting urine culture results, reiteration of interpretive criteria for CFU per milliliter of urine, and susceptibility testing of urine culture isolates. The group called for studies on the numbers and meaning of data for yeast isolated from urine samples and more urine-specific susceptibility breakpoint determinations, among other recommendations.

The fourth discussion in this section centered on diagnosis of invasive fungal infections, a problem for clinicians and laboratorians that continues to elude a solution. The group reviewed current test methods, all of which fall short of the needs of the increasing numbers of immunocompromised and other at-risk patients today. Discussion points included the pathogens of most concern, the changing populations of patients who are susceptible, and whether the current practice treating patients by the use of antifungal prophylaxis is interfering with our ability to make diagnoses.

Invasive fungal infections probably represent the most difficult of the topics covered in the discussion groups, and the dialogue ended with recommendations for more evidence-related guidelines. It seems that microbiology is still a science in development, and that is one reason why it is still exciting and challenging.

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Ellen Jo Baron