The Challenge of Implementing Molecular Diagnostics for Infection Control

Fred C. Tenover, Ph.D., D(ABMM)
Vice President, Scientific Affairs, Cepheid

Consulting Professor of Pathology
Stanford University School of Medicine

Adjunct Professor of Epidemiology
Emory University School of Public Heath
*Salary and benefits from Cepheid, a molecular diagnostics company
How often does the laboratory ask you (Infection Preventionist) what tests you need?

Would most Infection Preventionists know what molecular diagnostics or surveillance tests are available?

In many cases, yes!

In fact, Infection Preventionists have had a major influence over test selection in several hospitals.

Infection Prevention can be a key ally that helps the laboratory acquire the new technology they need.
Goal: Get MRSA-negative patients out of costly isolation rooms

Table 3. Single First PCR Test Performance Compared to Three Sequential CA in Intervention Arm Population.

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity % (95% CI)</th>
<th>Specificity % (95% CI)</th>
<th>Positive Predictive Value % (95% CI)</th>
<th>Negative Predictive Value % (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All subjects, series of 3 swabs completed (N=191)</td>
<td>93.9 (85.4 to 97.6)</td>
<td>92.0 (85.9 to 95.6)</td>
<td>86.1 (75.9 to 93.1)</td>
<td>96.6 (91.6 to 99.1)</td>
</tr>
</tbody>
</table>

NPV of 1 negative PCR test available in <2 hours = 3 negative cultures where results took 5 days
### Estimated Effect on Unnecessary Contact Precaution

### Days Avoided and Costs Saved Justified Bringing PCR into the Lab

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Passive cultures</th>
<th>Active surveillance cultures</th>
<th>PCR screening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discontinuation rates of contact precautions</td>
<td>6.6%</td>
<td>26.2%</td>
<td>63.8%</td>
</tr>
<tr>
<td>Fewer contact precaution days</td>
<td>104</td>
<td>418</td>
<td>1841</td>
</tr>
<tr>
<td>Cost savings</td>
<td>$86,950</td>
<td>$349,472</td>
<td>$1,539,180</td>
</tr>
</tbody>
</table>

Clin Infect Dis. 2013 Jul;57(2):176-84
Novel Applications of Rapid Diagnostics: Air and Water

You may think of this...

But for Infection control consider this...
Global Survey of Antibiotic Resistance Genes in Air

Jing Li, Junji Cao, Yong-guan Zhu, Qing-lin Chen, Fangxia Shen, Yan Wu, Siyu Xu, Hanqing Fan, Guillaume Da, Ru-jin Huang, Jing Wang, Alma Lorelei de Jesus, Lidia Morawska, Chak K. Chan, Jordan Peccia, and Maosheng Yao

Environ. Sci. Technol. (on line 2018)
"This study (in India) more than doubles the number of known B1 metallo-β-lactamases. The findings have further elucidated the diversity and evolutionary history of this important class of antibiotic resistance genes and prepare us for some of the challenges that may be faced in clinics in the future."

Reservoirs of antimicrobial resistance genes are growing
Carbapenemase-Producing Organisms are Spreading and the Problem is Getting Worse

Occurrence of CPE using an epidemiological scale of nationwide spread in 38 European countries

Numbers of CPE cases in France between January 2004 and December 2015, with and without a link to a foreign country (N=2026)

ECDC Evidence Brief Nov. 2015; Update on the spread of carbapenemase-producing Enterobacteriaceae in Europe

V. Pontiés et al. Épisodes impliquant des EPC en France - Bilan épidémiologique national au 31 décembre 2015 - Santé Publique
The "BIG 5" Carbapenemases
KPC, NDM, VIM, OXA-48, and IMP

Slide courtesy of P. Nordmann.
CPE in Canada: CPHLN Data

(n=1327)

Courtesy of Dr. Michael Mulvey LCDC
Vital Signs: Estimated Effects of a Coordinated Approach for Action to Reduce Antibiotic-Resistant Infections in Health Care Facilities — United States

FIGURE 1. Comparison between the projected number of annual health care–associated infections from selected antibiotic-resistant bacteria* and Clostridium difficile with no intervention and the projected number with an aggressive national intervention — United States, 2014–2019†

FIGURE 3. Projected countywide prevalence of carbapenem-resistant Enterobacteriaceae (CRE) over a 15-year period under three different intervention scenarios — 102-facility model, Orange County, California*
Conclusions.” We observed extensive transfer of KPC-positive patients throughout the exposure network of 14 acute care hospitals, 2 LTACHs, and 10 nursing homes. Although few cases were identified at most institutions, many facilities were affected. Successful control of KPC-producing Enterobacteriaceae will require a coordinated, regional effort among acute and long-term health care facilities and public health departments.”
Hospitals receive only a small proportion (1.8%) of CPE-colonized patients from hospitals outside of their own region. Most spread of CPE was from patients moving from hospital to hospital within their region. Every region showed increase in CPE over study period.

Wide Variety Of CPE Types From 2008 – 2014
The incidence of carbapenem-resistant Enterobacteriaceae (CRE) has increased worldwide with great regional variability. Infections caused by these organisms are associated with crude mortality rates of up to 70%. The spread of CRE in healthcare settings is both an important medical problem and a major global public health threat. All countries are at risk of falling victim to the emergence of CRE; therefore, a preparedness plan is required to avoid the catastrophic natural course of this epidemic. Proactive and adequate preventive measures locally, regionally, and nationally are required to contain the spread of these bacteria. The keys to success in preventing the establishment of CRE endemicity in a region are early detection through targeted laboratory protocols and containment of spread through comprehensive infection control measures. This guideline provides a strategic roadmap for infection control measures based on the best available evidence and expert opinion, to enable preparation of a multifaceted preparedness plan to abort epidemics of CRE.

*Infect Control Hosp Epidemiol* 2017;38:580–594
Carbapenem-resistant Enterobacteriaceae: Causes infections but also colonization

Infection sites: Virtually any body site

Colonization Sites

Detected through routine clinical cultures

Only detected through surveillance testing
* Challenges to Screening for Gastrointestinal Carriage

* Time to detection:
  * PCR-based methods = ≥48 minutes
  * Culture-based methods = 48-72 hours (culture plus susceptibility testing, which may require a day to get a pure culture from chromogenic agar)

* Detecting organism with low carbapenem MICs
  * Not all carbapenem resistance genes are expressed at high MIC levels; this can be species related (low MIC in *Citrobacter* but high MIC in *K. pneumoniae*)
  * PCR-based methods have the advantage here

* Detecting low numbers of organisms
  * Organism may have high carbapenem MICs, but there may be low numbers of organisms present in a rectal swab. Without broth enrichment these may be missed
  * PCR has greater sensitivity than un-enriched cultures; similar to broth enriched culture

* PCR amplification methods: expensive and new mechanisms will escape detection
PCR Can Facilitate Infection Control Activities and Stewardship

**Day 1**
- Rectal swabs for traditional culture method on chromagar
- Perform culture on chromagar (18-20 hr)

**Day 2**
- Presumptive positive; subculture isolate (18-20 hr)

**Day 3**
- Perform susceptibility test for resistance (18-20 hr)

**Day 4**
- Susceptibility test results confirm CRE

**Rectal Swabs for PCR testing**
- PCR results in 48 Min

**Opportunity for early interventions to prevent spread of CPE**
**Determine mechanism of carbapenem resistance from pure colonies for therapeutic strategies and CPE resistance gene typing**

Not all tests available in all countries
Conclusions. The more comprehensive POC CRO testing of patients in the endoscopy suite is feasible and results are available in <1 hour. This strategy may enable rapid risk stratification of duodenoscope exposure to CRO and potentially improve operational efficiency and decrease costs.

Table 2: Feasibility parameters of the point-of-care (POC) assay (Xpert CARBA-R CRO assay, Cepheid, Sunnyvale, CA, United States).

<table>
<thead>
<tr>
<th>Assay characteristics (n = 201)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen collection and handling time, median (IQR), min</td>
<td>3 (3–6)</td>
</tr>
<tr>
<td>Ease of use</td>
<td>97%</td>
</tr>
<tr>
<td>- Very easy, n (%)</td>
<td>107 (54)</td>
</tr>
<tr>
<td>- Easy, n (%)</td>
<td>86 (43)</td>
</tr>
<tr>
<td>Run time, median (IQR), min</td>
<td>55 (53–55)</td>
</tr>
</tbody>
</table>

This is on-label testing done by nurses

Not all tests available in all countries
### Direct Detection of Carbapenem-Resistant Organisms from Environmental Samples Using the GeneXpert Molecular Diagnostic System


**Formula sink drain**

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Organism</th>
<th>PCR Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enterobacter asburiae, Klebsiella pneumoniae</td>
<td>Negative</td>
<td></td>
</tr>
</tbody>
</table>

**Room A sink p-trap**

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Organism</th>
<th>PCR Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citrobacter freundii, Pseudomonas aeruginosa</td>
<td>Negative</td>
<td></td>
</tr>
<tr>
<td>Achromobacter xylosidans, Citrobacter freundii, Stenotrophomonas maltophilia</td>
<td>Negative</td>
<td></td>
</tr>
</tbody>
</table>

**Room A sink p-trap**

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Organism</th>
<th>PCR Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citrobacter freundii, Pseudomonas aeruginosa</td>
<td>Negative</td>
<td></td>
</tr>
</tbody>
</table>

**Room A toilet swab**

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Organism</th>
<th>PCR Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

**Room B toilet swab**

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Organism</th>
<th>PCR Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

**Room C sink drain**

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Organism</th>
<th>PCR Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIM+ Citrobacter amalonaticus</td>
<td>Negative</td>
<td></td>
</tr>
</tbody>
</table>

**IMPORTANT** Use of the Carba-R assay for detection of carbapenem-resistant Gram-negative organisms (CROs) can provide data for implementation of a rapid infection control response to minimize the spread of CROs in the healthcare setting.

**Off-label use:** Not approved for environmental samples

Not all tests available in all countries
Clostridium difficile and your Microbiome – Think Life on the Beach

Normal Gut Flora
Clinical Practice Guidelines for *Clostridium difficile* Infection in Adults and Children: 2017 Update by the Infectious Diseases Society of America (IDSA) and Society for Healthcare Epidemiology of America (SHEA)

L. Clifford McDonald, Dale N. Gerding, Stuart Johnson, Johan S. Bakken, Karen C. Carroll, Susan E. Coffin, Erik R. Dubberke, Kevin W. Garey, Carolyn V. Gould, Ciaran Kelly, Vivian Loo, Julia Shaklee Sammons, Thomas J. Sandora, and Mark H. Wilcox

*If you control for colonization and laxative use, a NAAT alone or an algorithm can be used*

European Society of Clinical Microbiology and Infectious Diseases: update of the diagnostic gui

Toxin A/B testing required
European Society of Clinical Microbiology and Infectious Diseases: update of the diagnostic guidance document for *Clostridium difficile* infection


Clinical Microbiology and Infection 22 (2016) S63–S81

(a) Screen

Step 1: Highly sensitive test: NAAT or GDH EIA

Positive test result

Confirmation step (optional) for GDH EIA

Step 2: Highly specific test: Toxin A/B EIA

Positive test result

CDI is likely to be present

Clinical evaluation: CDI or carriage of (toxigenic) *C. difficile* is possible

Negative test result

No further testing required: CDI is unlikely to be present

(b) GDH +toxin together

Step 1: Highly sensitive test: GDH and Tox A/B EIA

Both negative

Both positive

GOH positive, Tox A/B negative

Step 2 (optional): NAAT or TC

No further testing required: CDI is unlikely to be present

Negative test result

Positive test result

CDI is unlikely to be present

Clinical evaluation: CDI or carriage of (toxigenic) *C. difficile* is possible
1.) Meets clinical definition of CDI
2.) Patient not on laxatives
3.) Stool is not formed

Clinical Practice Guidelines for *Clostridium difficile* Infection in Adults and Children: 2017 Update by the Infectious Diseases Society of America (IDSA) and Society for Healthcare Epidemiology of America (SHEA)

Clinicians and laboratory personnel agree at the institutional level to not submit stool specimens on patients receiving laxatives and to submit stool specimens only from patients with unexplained and new onset ≥ 3 unformed stools in 24 h for testing for CDI.

NAAT alone OR stool toxin test* as part of a multiple step algorithm (i.e. GDH plus toxin; GDH plus toxin, arbitrated by NAAT; or NAAT plus toxin) rather than a toxin test alone.

*Approved stool EIA toxin tests vary widely in sensitivity. Laboratories should choose a toxin test with sensitivity in the upper range of sensitivity as reported in the literature [146-149, 156].

Formed stool tested with NAAT may indicate colonization
Checking to make sure patient has diarrhea and did not get a laxative in the prior 48 hours reduces the number of tests run dramatically, lowers the CDI rate, and decreases vancomycin use.
Key Issues About Testing Formed Stool

* None of the *C. difficile* tests, including PCR, GDH, and toxin assays, can reliably differentiate colonization from infection if formed stools are tested.

* However, anyone with toxigenic *C. difficile*, including asymptomatic carriers, needs to be in contact precautions because they can spread disease.
C. difficile Summary

* NAAT as a stand alone test *is acceptable* in the new IDSA-SHEA guidelines as long as the hospital has policies in place to insure that only patients with clinical CDI are tested, they are not on laxatives, and formed stools are not tested in the laboratory.

* ESCMID guideline stresses the importance of *algorithm testing* to take advantage of the sensitivity of NAAT or GDH, coupled with the specificity of toxin testing

* Algorithms that start with GDH may benefit from NAAT testing for GDH-positive/toxin-negative specimens

* Data suggest that placing colonized patients in contact precautions can help control spread of *C. difficile* in a hospital.

* We are still learning about CDI. In terms of testing, isolating, and treating - one size does not fit all.
Rapid Molecular Detection of Tuberculosis and Rifampin Resistance

1. Sputum liquefaction and inactivation with 2:1 sample reagent
2. Transfer of 2 ml material into test cartridge
3. Cartridge inserted into MTB-RIF test platform (end of hands-on work)
4. Sample automatically filtered and washed
5. Ultrasonic lysis of filter-captured organisms to release DNA
6. DNA molecules mixed with dry PCR reagents
7. Seminested real-time amplification and detection in integrated reaction tube
8. Printable test result

Time to result, 1 hour 45 minutes

TB and rifampin resistance results in 110 minutes direct from specimen

From: Boehme, et.al. NEJM 363:1005. Sept. 9, 2010

Not all tests available in all countries
<table>
<thead>
<tr>
<th>Doctor judgment vs PCR</th>
<th>TB (n=13)</th>
<th>Not TB (n=143)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Received empiric TB Rx</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Empiric TB Rx</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **PCR+**
  - 1

- **PCR-**
  - 45

**47→3 Over-treatments**

**Over-Rx Days:**
- 2280→136

**96→140 Early rule-outs**

Added Specificity = +31%
Results: Among a hypothetical cohort of 234 individuals undergoing evaluation for presumed active TB annually, 6.4% had culture-positive TB. Compared to smear microscopy, Xpert reduced isolation bed utilization from an average of 2.7 to 1.4 days per patient, leading to a 48% reduction in total annual isolation bed usage from 632 to 328 bed-days. Xpert saved an average of $2,278 (95% uncertainty range $1582–4570) per admission, or $533,520 per year, compared with smear microscopy.

Conclusions: Molecular testing for TB could provide substantial savings to hospitals in high-income countries by reducing respiratory isolation usage and overall length of stay.
## Table 2. Length of Hospital Stay and Time Intervals in the Diagnostic Evaluation Process for Patients With Negative Results on Rapid Testing for Pulmonary Tuberculosis

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Median (IQR)</th>
<th>Preimplementation (n = 223)</th>
<th>Postimplementation (n = 250)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital admission to hospital discharge, days$^a$</td>
<td></td>
<td>6.0 (3.8-10.9)</td>
<td>4.9 (2.9-8.9)</td>
<td>.003</td>
</tr>
<tr>
<td>Hospital admission to sputum collection, hours</td>
<td></td>
<td>19.1 (10.3-40.3)</td>
<td>18.0 (9.2-41.8)</td>
<td>.62</td>
</tr>
<tr>
<td>Sputum collection to final negative result reporting, hours</td>
<td>39.1 (35.6-42.9)</td>
<td>22.4 (13.7-30.6)</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Sputum collection to first result reporting, hours</td>
<td></td>
<td>18.4 (15.5-23.6)</td>
<td>4.6 (3.4-6.9)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Sputum collection to sputum receipt in laboratory, hours</td>
<td>1.5 (0.5-2.5)</td>
<td>1.1 (0.5-2.0)</td>
<td>.02</td>
<td></td>
</tr>
<tr>
<td>Sputum receipt in laboratory to first result reporting, hours</td>
<td>16.0 (13.6-22.3)</td>
<td>2.9 (2.5-4.5)</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Final negative result reporting to hospital discharge, hours$^a$</td>
<td>66.5 (26.6-160.3)</td>
<td>49.6 (21.5-139.8)</td>
<td>.08</td>
<td></td>
</tr>
<tr>
<td>Isolation admission to isolation discharge, days$^b$</td>
<td>2.9 (2.0-3.7)</td>
<td>2.5 (1.7-3.4)</td>
<td>.001</td>
<td></td>
</tr>
</tbody>
</table>
# New Xpert® MTB/RIF Ultra

<table>
<thead>
<tr>
<th></th>
<th>Both assays</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System</strong></td>
<td>GeneXpert (6-color)</td>
</tr>
<tr>
<td><strong>Sample type</strong></td>
<td>Sputum, induced sputum, sediment</td>
</tr>
<tr>
<td><strong>Sample Incubation</strong></td>
<td>15 min inactivation with Sample Reagent</td>
</tr>
<tr>
<td><strong>Target(s)</strong></td>
<td>Xpert MTB/RIF</td>
</tr>
<tr>
<td></td>
<td><em>rpoB</em></td>
</tr>
<tr>
<td><strong>Reaction Tube</strong></td>
<td>25 µL</td>
</tr>
<tr>
<td><strong>Detection Method</strong></td>
<td>Hemi-Nested PCR</td>
</tr>
<tr>
<td><strong>Turn around Time</strong></td>
<td>110 minutes</td>
</tr>
</tbody>
</table>

* CE-IVD. In Vitro Diagnostic Medical Device. Product may not be available in all countries
Not all tests available in all countries
One Key Antidote for Controlling Resistance: Antimicrobial Stewardship Programs

*“Antimicrobial stewardship is a coordinated program that promotes the appropriate use of antimicrobial agents, improves patient outcomes, reduces microbial resistance, and decreases the spread of infections caused by multidrug-resistant organisms.”

*Stewardship programs stress choosing the right drug, at the right dosage, for the right duration. Antimicrobial stewardship is not just antibacterial drugs, but antivirals, antifungals, and antiparasitic agents

http://www.apic.org/Professional-Practice/Practice-Resources/Antimicrobial-Stewardship
Interpretation
Restricting fluoroquinolone prescribing appears to explain the decline in incidence of *Clostridium difficile* infections, above other measures, in Oxfordshire and Leeds, England. Antimicrobial stewardship should be a central component of *C. difficile* infection control programmes.
The Effect of Molecular Rapid Diagnostic Testing on Clinical Outcomes in Bloodstream Infections: A Systematic Review and Meta-analysis

Tristan T. Timbrook, Jacob B. Morton, Kevin W. McConoghly, Aisling R. Caffrey, Eleftherios Mylonakis, and Kerry L. LaPlante

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>mRDT with ASP</th>
<th>mRDT without ASP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Event</td>
<td>OR (95% CI)</td>
<td>OR (95% CI)</td>
</tr>
<tr>
<td>1.1.1 mRDT with ASP</td>
<td>15 52 19 74 5.6</td>
<td>0.65 (0.36-1.39)</td>
</tr>
<tr>
<td></td>
<td>3 37 7 58 1.8</td>
<td>0.61 (0.25-1.49)</td>
</tr>
<tr>
<td></td>
<td>2 115 84 0.9</td>
<td>0.79 (0.50-1.28)</td>
</tr>
<tr>
<td></td>
<td>20 72 20 76 60</td>
<td>1.00 (0.48-2.09)</td>
</tr>
<tr>
<td></td>
<td>17 90 37 129 7.0</td>
<td>0.94 (0.28-3.04)</td>
</tr>
<tr>
<td></td>
<td>5 21 19 61 2.7</td>
<td>0.69 (0.22-2.19)</td>
</tr>
<tr>
<td></td>
<td>31 245 52 256 11.6</td>
<td>0.57 (0.35-0.92)</td>
</tr>
<tr>
<td></td>
<td>11 241 14 149 4.9</td>
<td>0.40 (0.25-0.64)</td>
</tr>
<tr>
<td></td>
<td>5 83 3 50 2.1</td>
<td>0.78 (0.21-2.84)</td>
</tr>
<tr>
<td></td>
<td>6 23 16 46 2.8</td>
<td>0.84 (0.21-3.55)</td>
</tr>
<tr>
<td></td>
<td>11 117 19 129 5.3</td>
<td>0.80 (0.27-1.32)</td>
</tr>
<tr>
<td></td>
<td>5 84 37 252 3.6</td>
<td>0.37 (0.14-0.97)</td>
</tr>
<tr>
<td></td>
<td>6 137 19 122 3.3</td>
<td>0.50 (0.18-1.57)</td>
</tr>
<tr>
<td></td>
<td>8 95 13 133 4.0</td>
<td>0.85 (0.34-2.14)</td>
</tr>
<tr>
<td></td>
<td>11 28 7 48 2.8</td>
<td>0.61 (0.19-2.09)</td>
</tr>
<tr>
<td></td>
<td>5 67 4 59 1.0</td>
<td>1.11 (0.28-4.34)</td>
</tr>
<tr>
<td></td>
<td>3 88 19 147 2.3</td>
<td>0.24 (0.07-0.83)</td>
</tr>
<tr>
<td></td>
<td>6 37 19 48 4.3</td>
<td>0.37 (0.16-0.90)</td>
</tr>
<tr>
<td>Total</td>
<td>177 331</td>
<td>0.64 (0.21-1.94)</td>
</tr>
</tbody>
</table>

Meta-analysis of Impact of rapid diagnostic tests

Molecular tests with antibiotic stewardship programs: positive impact

Molecular tests without antibiotic stewardship programs: positive impact

Overall impact is positive
Who is winning the resistance game?

Humans or Bacteria?

Progress is being made (by humans) but bacteria have been on the planet for 1.2 billion years and are very clever at surviving.
Summary

* Reservoirs of antimicrobial resistant organisms are increasing
* Carbapenem-resistant organisms continue to emerge and molecular diagnostics can be useful for surveillance
* *C. difficile* guidelines from Europe and the US differ regarding the need for toxin testing if specimens from patients who may be colonized are excluded from testing
* Molecular diagnostics can aid with infection control decisions with tuberculosis particularly for removing patients from respiratory isolation
* Infection control and antimicrobial stewardship go hand in hand
Thank You.

Visit us at www.cepheid.com