Health Informatics and Surveillance of Antimicrobial Use and Resistance (AUR)

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Responsibility for Views Expressed – My Own

The views expressed in this presentation are my own and do not necessarily reflect the official position of CDC — or any other agency or organization — or the viewpoints of any other individuals.

Financial Disclosure Statement – Nothing to Disclose

I do not have any financial holdings or relationships that would be a conflict of interest with my duties and responsibilities at the Centers for Disease Control and Prevention (CDC) or that would in any way bias the content of this presentation.
Presentation Outline

**Introduction** - Context-setting, background information about informatics, surveillance, and healthcare quality measurement

**Use Case for AU Measurement** - Description of the tightly linked hazards of antimicrobial overuse and loss of antimicrobial efficacy as the impetus for AU quality measurement

**AUR Surveillance Process** - Overview of the CDC’s National Healthcare Safety Network (NHSN) and NHSN’s antimicrobial use and resistance (AUR) surveillance

**NHSN’s new AU Measure** - Synopsis of the Standardized Antimicrobial Administration Ratio (SAAR) and plans for further measure development

**Conclusion** – Taking stock of progress in surveillance and envisioning ways that informatics can help forge future advances
Main Messages

• Health informatics solutions are an integral part of broad-based efforts – well under way – that have added AUR surveillance and a new AU quality measure to the CDC’s National Healthcare Safety Network (NHSN)

• Further development of AU quality measurement and provisioning of enhanced measure data for antimicrobial stewardship programs (ASPs) will depend on new applications of informatics knowledge and skills
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Advances in Healthcare Information Technology Facilitate Reuse of Clinical and Laboratory Data for Public Health Surveillance Purposes

Medication administrations: From peel away labels to bar code scans

Laboratory results: From paper printouts to electronic laboratory reporting

Medical records and databases: From paper-based to electronic systems
National Healthcare Safety Network’s (NHSN’s) New AU Measure: The Standardized Antimicrobial Administration Ratio (SAAR)

Conclusion
This is the first aggregate AU metric that uses point-of-care, antimicrobial administration data electronically reported to a national surveillance system to enable risk adjusted, AU comparisons across multiple hospitals.

https://academic.oup.com/cid/advance-article/doi/10.1093/cid/ciy075/4835069
NHSN’s Antimicrobial Use (AU) Data Supply Chain

Electronic Medication Administration Record (eMAR), Bar Code Medication Administration (BCMA), and Hospital Admission, Discharge, Transfer (ADT) Systems

Numerator: Antimicrobial days aggregated monthly by drug and patient care location

Denominator: Days present and admissions per month

Extract, transform and load AU data by means of a vendor or homegrown IT solution

AU report in standard electronic message

Local AU data access via NHSN’s web interface

Analysis, visualization, and reporting AU data

NHSN Servers
NHSN’s Antimicrobial Resistance (AR) Data Supply Chain

Laboratory Information System (LIS), Electronic Health Record System (EHRs), and Admission, Discharge, Transfer (ADT) System

Numerator: Patient-specific, isolate-based reports
Denominator: Patient days and admissions

Extract, transform and load AR data by means of a vendor or homegrown IT solution

AR report in standard electronic message

Local AR data access via NHSN web interface

NHSN Servers

Hospital-wide antibiogram and additional analytic outputs
Biomedical Informatics: A Key Contributor to Public Health Surveillance

Biomedical informatics (BMI) education and research

Methods, techniques, theories

Health informatics (HI): clinical informatics and public health informatics

Informatics in translational science: translational bioinformatics (TBI) and clinical research informatics (CRI)

Bioinformatics and structural (imaging) informatics

Basic research

Applied research and practice

Molecules, cells, tissues, organs

Patients, individuals, populations, societies

Modified from Kulikowski CA et al. J Am Med Inform Assoc 2012;19:931-938
Biomedical and Health Informatics: Core Knowledge and Skills

Information/Computer Science
- IT foundations (e.g., computers, networks)
- Programming
- Database systems
- Data and knowledge representation
- Data mining, knowledge management, and discovery
- Decision support tools, methods, and evidence-based practices
- Human-computer and human-information interaction

Statistics and Research Methods

Domain-specific Information Systems
- Healthcare information systems
- Geographic information systems

Domain-specific Knowledge and Competencies
- Healthcare system
- Public health
- Advanced practice nursing
- Clinical and life sciences
- Biotechnology
- Computational biology
- Medical imaging

Management
- Organizational behavior and management
- Business topics
- Project management
- Strategic planning and IT management

Interaction with Society

Biomedical and Health Informatics: Core Knowledge and Skills That are Applicable to Public Health Surveillance

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**Interaction with Society**

CDC Launched Public Health Surveillance Programs in the 1950s That Continue to Evolve and For Which Health Informatics Contributions are Essential

### Disease Surveillance
- Malaria, in 1950, became the first disease that CDC – then the Communicable Disease Center – brought under national surveillance.
- By 1970, CDC had worked with state and local health departments to establish surveillance of nearly 30 nationally notifiable communicable diseases, with about 60 diseases added since then.

### Healthcare Surveillance
- In 1958, hospital outbreaks of healthcare-associated infections (HAIs) due to penicillin-resistant bacteria prompted CDC to issue its first healthcare surveillance guidance.
- In 1970, CDC worked with 62 hospitals to establish the National Nosocomial Infection Surveillance (NNIS) system to track HAIs, and, in 2005, NNIS was superseded by the National Healthcare Safety Network (NHSN).
CDC’s First Foray into Disease Surveillance Led the Agency to Halt its Domestic Malaria Eradication Program

- CDC’s initial post-World War II mission, starting in 1946, was to lead a large scale effort to eradicate domestic malaria.
- National surveillance, introduced by the CDC’s Alexander Langmuir in 1950, indicated that the disease had disappeared before the agency’s eradication efforts began.
- CDC halted its malaria eradication campaign in 1952 after $50 million had been spent.
- The agency’s malaria experience demonstrated the value of systematic surveillance and provided an impetus for bringing numerous additional diseases under national surveillance, starting with polio (1955) and influenza (1957).

• Rampant penicillin overuse in the 1950s contributed to the first-ever, epidemic wave of antimicrobial resistance
• A predominant, epidemic strain of penicillin-resistant *Staphylococcus aureus*—phage type 80/81—was implicated in numerous hospital outbreaks investigated by CDC
• CDC’s response included a recommendation that hospitals establish infection committees with responsibilities for surveillance, control, and education
Resistant Staphylococcus in a Public Hospital’s Newborn Nursery: An Outbreak’s Deadly Toll Draws National Attention

• 28 babies at Jefferson Davis Hospital died from resistant Staphylococcal infections from August 1956 to August 1958
• News coverage of the Houston outbreak focused national attention on the epidemic strain of resistant Staphylococcus and raised the specter of more resistance problems to come
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“Statistics are people with the tears wiped away”
Attributed to Irving Selikoff

Langmuir:
• Traced the origins of modern public health surveillance to 19th century systems for accruing and analyzing cause-of-death statistics
• Introduced national systems for collecting, analyzing, and interpreting morbidity, mortality, and other data needed for surveillance of public health problems

Alexander Langmuir, CDC’s Chief Epidemiologist from 1949-1970, established the agency’s role in public health surveillance

Measures of Various Dimensions of Healthcare Quality are the Vital Statistics for Healthcare Surveillance
More Than Affordable Care: Landmark Law Propels More Measures and More Uses of Measure Data

- Mentions “quality measures,” “performance measures,” or “measures of quality” 128 times
- Ratchets up non-payment for hospital-acquired conditions
- Introduces value based purchasing
- Expands scope of publicly reported quality measure data

The Patient Protection & Affordable Care Act

Signed into law on March 23, 2010
Healthcare Quality Measures and Report Cards: Some Medical Experts Give Them Low Marks

. . . the measurement fad has spun out of control. . . . We need more targeted measures, ones that have been vetted to ensure they really matter . . . for example, measuring the rates of certain hospital-acquired infections has led to greater emphasis on prevention and has most likely saved lives.

Robert Wachter

Healthcare Surveillance:
HAIs, AU, and AR are Among Numerous Measurement Targets

- Healthcare-associated infections (HAIs)
- Antimicrobial use (AU)
- Antimicrobial resistance (AR)
Healthcare Surveillance is Evolving Amid a Broad Challenge: A Tension Between Two Aspirations for Quality Measures

**More Measures**
Societal expectations and legislation calling for greater transparency and accountability in healthcare via more clinical quality measurement

**More Targeted Measures**
Measures and measurement systems that healthcare practitioners and organizations can use for prevention and quality improvement

Tension
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The First Wave of Antimicrobial Resistance in the 1950s Was a Shock to the Medical System

“A new, virulent organism, breeding in nurseries for the newborn, is rocking the medical world” Ladies’ Home Journal, February 1959
<table>
<thead>
<tr>
<th>Class</th>
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<th>Year of Approval or First Marketing</th>
<th>Year(s) to First Clinical Report of Resistance</th>
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<td>Lipoedtides</td>
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Modified from HD Marston et al. JAMA 2016; 316:1193-1204
Early Evidence of Clinical Resistance is the Norm for New Antibiotics

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Whenever an antibiotic is used, bacteria will inevitably develop resistance, either by mutation, gene acquisition, or a combination of the two

Davies JE. *Ciba Foundation Symposium* 1997;207:15-35

Modified from HD Marston et al. *JAMA* 2016; 316:1193-1204
Antibiotic Overuse Spurs AR Proliferation

Population of Mainly Susceptible Bacteria

Population of Mainly Resistant Bacteria

Antibiotic Overuse

Susceptible

Resistant
The Nation’s First Antibiotic Resistance Crisis: Emphatic Calls for Hospitals to Use Antibiotics More Discriminantly

Scientific American 1959;200: 41-45

hospitals should use antibiotics with greater discrimination, especially when considered for prophylactic purposes, and return to the techniques of strict asepsis and vigorous antisepsis. These techniques are designed to minimize a patient’s exposure to all microorganisms.
Medical professionals and facilities have an important role to play, through implementation of antimicrobial stewardship programs, reduction in inappropriate prescribing, immunization against bacterial and viral pathogens, and robust infection control measures including enhanced surveillance for resistant organisms.
Appropriateness has many dimensions, each one of which is a candidate for measurement, e.g.:
   - Indication for use of antimicrobial(s)
   - Choice of drug(s)
   - Drug dose, duration, frequency, and formulation
Antimicrobial prescribing decisions can be cognitively complex, and expressing that complexity for purposes of measuring appropriateness (or for clinical decision support systems) is conceptually and operationally challenging.
At present, appropriateness is more practical to measure in periodic surveys than via ongoing surveillance.
Measures that Compare the Amount of AU at a Hospital With Other Hospitals’ AU Can Serve as Signals of Possible Overuse

- Detection of statistically significant variation in the amount of AU across hospitals provides a quantitative signal that may be clinically significant.
- The finding that the amount of AU at a hospital is significantly higher than predicted is not a definitive measure of inappropriate use but can prompt medication use evaluations and antimicrobial stewardship program (ASP) interventions.
- At present, measures of the amount of AU are more practical for ongoing surveillance purposes than measures of AU appropriateness.
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CDC’s National Healthcare Safety Network (NHSN) – A Healthcare Surveillance System for HAIs, AU, and AR

Healthcare facilities: (1) Join NHSN, (2) complete an annual survey of their care capacities, (3) submit process and outcome data manually or electronically to one or more NHSN components, and (4) use their own data and NHSN statistical benchmarks for analysis and action.

CDC: Collects, analyzes, summarizes, and provides data on healthcare-associated infections (HAIs), other adverse healthcare events, antimicrobial use and resistance, adherence to prevention practices, and use of antimicrobial stewardship programs.
NHSN’s AUR Surveillance: The Basics

- Designed to support clinical and public health efforts to:
  1. Monitor and improve antimicrobial prescribing
  2. Identify, understand, and respond to antimicrobial resistance patterns and trends
- Provides a common set of technical specifications and a single surveillance platform for hospitals to report AUR data
- All data must be submitted electronically using a Health Level Seven (HL7) Clinical Document Architecture (CDA) file format
- Data that are successfully transmitted are available immediately to NHSN users for analysis and visualization
NHSN’s Guides for AUR Surveillance

NHSN AUR Surveillance Protocol – Specifies surveillance methods and data requirements, which serve as business rules for reporting AU and AR data

CDA Implementation Guide – Specifies the file format requirements for standard AU and AR messages to be delivered to NHSN


Release 3, 2nd HL7 Standard for Trial Use (STU)
Manual assessments – NHSN provides validation checklists that hospitals and AU reporting vendors can use to manually compare source data with AU data in CDA files produced by vendor systems.

Automated assessment – NHSN and the Salt Lake City Veterans Affairs Medical Center (SLCVAMC) are developing an automated data validation process in which AU reporting vendors will use synthetic patient level data sets (database schema above), generated by the SLCVAMC, to produce AU data test files (Excel) that will be submitted online to NHSN and validated instantaneously against NHSN’s answer key.
AUR Reporting to NHSN: Implementation Challenges

**Patient care location mapping** – Associate the hospital’s specific ward and ICU patient care locations with NHSN’s generic terms for those locations.

**Other terminology mappings** – Map local terms used for specific antimicrobial agents, routes of administration, microorganisms, and specimen sources to NHSN’s terminology.

**Extract, transform, and load AU and AR data** – Establish a stepwise process for culling AU and AR data, transforming the data (as needed) to conform to NHSN requirements, and packaging the data in CDA files for upload or automated send to NHSN. These steps include aggregating AU data by patient care locations.

**Data Validation and Testing** – Systematically assess the accuracy and completeness of AU and AR data extraction, transformation, and aggregation, and verify that CDA files are created in accordance with NHSN specifications.

**Maintenance** – Update terminology mappings as needed and incorporate any changes in CDA specifications in file production process.
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Standardized Antimicrobial Administration Ratio (SAAR) - A Comparative AU Measure Expressed as a Ratio of Observed-to-Predicted Use

**Observed use** – A hospital’s total antimicrobial days in a patient care location reported for a defined time period and specified group of antimicrobials, in which one dose or multiple doses of each agent administered to a patient on a single day counts as one antimicrobial day.

**Predicted use** – The predicted total of antimicrobial days for a defined time period, patient care location, and antimicrobial group, estimated using nationally aggregated AU data and a negative binomial regression model that takes into account a limited set of AU predictors.

**Antimicrobial Groupings**
- Broad spectrum agents predominantly used for hospital-onset/multi-drug resistant bacteria
- Broad spectrum agents predominantly used for community-acquired infection
- Anti-methicillin resistant *Staphylococcus aureus* (MRSA) agents
- Agents predominantly used for surgical site infection prophylaxis
- All antibacterial agents

**Interpretation** - A high SAAR value (> 1.0) that achieves statistical significance indicates more AU than predicted and can serve as a signal that warrants further investigation.
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Data available for each SAAR predictive model:
- Hospital characteristics, such as medical school affiliation, bed size
- Characteristics of patient care locations reporting AU data, such as ICU or ward types

Data unavailable for each SAAR predictive model:
- Patient-level data — such as infectious disease diagnoses or indications for antimicrobial prophylaxis — are unavailable because patient-level AU records are not reported to NHSN.
The SAAR Provides a Set of 16 Adult and Pediatric AU Measures

- **Broad spectrum agents predominantly used for hospital-onset/multidrug resistant infections**
  - Adult: Medical, medical/surgical, surgical ICUs, Medical, medical/surgical, surgical wards
  - Pediatric: Medical, medical/surgical, surgical ICUs, Medical, medical/surgical, surgical wards

- **Broad spectrum agents predominantly used for community-acquired infections**
  - Adult: Medical, medical/surgical, surgical ICUs, Medical, medical/surgical, surgical wards
  - Pediatric: Medical, medical/surgical, surgical ICUs, Medical, medical/surgical, surgical wards

- **Anti-MRSA agents**
  - Adult: Medical, medical/surgical, surgical ICUs, Medical, medical/surgical, surgical wards
  - Pediatric: Medical, medical/surgical, surgical ICUs, Medical, medical/surgical, surgical wards

- **Agents predominantly used for surgical site infection prophylaxis**
  - Adult: ICUs and wards (medical, medical/surgical, surgical)
  - Pediatric: ICUs and wards (medical, medical/surgical, surgical)

- **All agents**
  - Adult: ICUs and wards (medical, medical/surgical, surgical)
  - Pediatric: ICUs and wards (medical, medical/surgical, surgical)
Sample SAAR values - NHSN table, produced using synthetic data, displaying quarterly SAAR values for antimicrobials predominantly used to treat hospital onset, multi-drug resistant infections in a single hospital's adult medical, surgical, and medical/surgical wards. Agents in this category include aminoglycosides, carbapenems (except ertapenem), 4<sup>th</sup> and 5<sup>th</sup> generation cephalosporins, penicillin B-lactam/b-lactamase inhibitor combinations, and other antimicrobials.

### National Healthcare Safety Network

**SAARs Table - All Standardized Antimicrobial Administration Ratios (SAARs) High-Level Indicators and High-Value Targets**

As of: February 6, 2017 at 1:43 PM  
Date Range: All AU_SAAAR

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**Calculated SAAR values**

- Significantly high SAAR values
NHSN Users Have Multiple Options for AU Data Analysis and Visualization

Basic options available

- SAARs
- Line lists
- Rate tables
- Pie charts
- Bar charts
The SAAR — in its Current Form — is Suitable for Some But Not All Quality Measurement Purposes

NHSN’s recommendations:

- [x] Hospital’s internal analysis of its own performance score(s) without reference to performance scores at other hospitals
- [x] Hospital’s internal analysis of its own performance score(s) with reference to performance scores at other hospitals
- [x] Health system or health agency analysis of hospital performance scores without public reporting of scores
- [ ] Public reporting of hospital performance scores
- [ ] Pay for performance using hospital performance scores
- [ ] Regulatory or accreditation actions using hospital performance scores
Presentation Outline

Introduction - Context-setting, background information about informatics, surveillance, and healthcare quality measurement

AUR Surveillance Process - Overview of the CDC’s National Healthcare Safety Network (NHSN) and NHSN’s antimicrobial use and resistance (AUR) surveillance

Use Case for AU Measurement - Description of the tightly linked hazards of antimicrobial overuse and loss of antimicrobial efficacy as the impetus for AU quality measurement

NHSN’s new AU Measure - Synopsis of the Standardized Antimicrobial Administration Ratio (SAAR) and plans for further measure development

Conclusion – Taking stock of progress in surveillance and envisioning ways that informatics can help forge future advances
Healthcare Surveillance and CDC: Some Important Milestones

1958 - Initial HAI surveillance recommendations for hospitals
1963 - First surveillance training course for infection control nurses
1970 - National Nosocomial Infection Surveillance (NNIS) system launched
1974 - Hospitals participating in NNIS start “regular” reporting of antimicrobial resistance (AR) data for pathogens implicated in HAIs
2005 - National Healthcare Safety Network (NHSN) goes live as the successor to the NNIS system
2006 - First states (VT, NY) require hospitals in their jurisdictions to report to NHSN
2011 - Centers for Medicare and Medicaid Services (CMS) requires that hospitals report to NHSN as part of CMS’ Inpatient Quality Reporting program
2012 - Initial antimicrobial use (AU) reporting to NHSN via electronic messages
2016 - Initial AR reporting to NHSN via electronic messages
Healthcare Surveillance and CDC: Some Important Milestones

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2016 - Initial AR reporting to NHSN via electronic messages
Efforts to Introduce or Upgrade Quality Measures Must Contend with the Limitations of Currently Available EHRs
The Current Crop of EHRs: Shortcomings Include Suboptimal Human-Computer Interfaces
EHRs: Interoperability Remains Elusive

Doctors Hit a Snag In the Rush to Connect

Medical Records Go Digital, but Sharing Them Can Be Costly, or Impossible

By JULIE CHERNOW

The New York Times October 1, 2014
Big Data and Big Data Analytic Techniques Are Promising Opportunities for Advances in Healthcare Surveillance and Quality Measurement

Data Lake
A large, open information space that can accommodate differently formatted data elements. For example:

- EHRs problem lists and progress notes
- Laboratory results
- CDA documents
- Patient Generated Health Data

Big Data Analytics
Can fuse different data types on a massive scale resulting in predictive and real-time analysis capabilities

Modified from Roski J et al. Health Affairs 2014;33:1115-1122
Learning from the Past: Using History as a Tool for Decision Making and Management

- Recognize that decisions are not purely technical choices; they have historical dimensions too
- Develop a deep understanding of an issue’s history
- Learn from case studies, both the mistakes and the successes
- Question assumptions before making decisions!!

Thank You!

Please contact me at dap1@cdc.gov

For more information about NHSN: http://www.cdc.gov/nhsn/