

Healthcare-acquired Infections

Lisa Saiman, MD MPH
Professor of Clinical Pediatrics
ls5@columbia.edu

Outline of Today's Lecture

- Epidemiology of hospital-acquired infections (HAI)
- Pathogenesis of most common HAI
- Risk factors for HAI
 - Host
 - Hospital
- Pathogenic organisms
- Prevention strategies
- Interesting Outbreak

Hospitals Perceived as Dangerous

Hospitals told: Clean up or lose out

By: NANCY YOUNG: The Virginian-Pilot © July 3, 2007
Unwashed hands. Urinary catheters left in too long. Potentially lethal bacteria on bed rails. These are specters that have long made hospitals more dangerous than places of healing should be.

Resilient germ spreads through U.S. hospitals

By: MIKE STOBBE: The Associated Press June 25th, 2007
A dangerous, drug-resistant staph germ might be infecting as many as 5 percent of hospital and nursing home patients, according to a comprehensive study.

Hospitals look to improve infection-prevention measures

By: KEN KRIZNER: Managed Healthcare Executive Mar 1, 2007
Simple steps such as hand hygiene can greatly reduce the number of dangerous and costly infections in patients

Epidemiology of Hospital-acquired Infections

Mandatory Reporting of Infections

- In New York State we report:
 - Central venous catheter-related bloodstream infections in ICU patients
 - Post-operative wound infections following:
 - Colon surgery
 - Coronary artery by-pass surgery
 - Spine surgery
- Legislative efforts to expand reporting to include rates of MRSA

Definition of Healthcare-acquired Infections

- Terminology has changed
 - Nosocomial → Hospital-acquired → **Healthcare-acquired**
- Acknowledges changes in healthcare delivery
 - Care delivered in chronic care facilities, outpatient, and non-healthcare settings
 - 'Revolving door' between settings

Epidemiology of Hospital-acquired Infections

- 1.7 million HAI in USA
- 5% hospitalized patients develop HAI
- 98,987 estimated deaths
- \$5 billion cost

Klebens Public Health Rep 2007

Surgical Site Infections

- 24,000,000 procedures performed annually
- 2.7% complicated by infections
- 486,000 cases per year
- 4.3% attributable mortality
- \$3 billion per year

| Timing of infection | \$ per case | Excess hospital-days |
|-------------------------|-------------|----------------------|
| Initial hospitalization | \$3089 | 6.5 |
| Readmission required | \$5038 | 12 |

Kirkland et al. Infect Control Hosp Epid 1999

Most Common HAI

- Device-related infections complicating use of:
 - Urinary tract catheters
 - Central venous catheters
 - Ventilators
- Surgical site infections
 - Wound
 - Artificial joints
 - Valves

Pathogenesis of Common HAI

Device-related Infections

- Catheter-associated urinary tract infections
 - 30,000,000 urinary catheters placed each year
 - 5% risk of infection per day
 - 5% mortality
- Ventilator-associated pneumonia
 - 250,000 cases annually
 - 25% of pneumonias in the hospital
 - 28%-37% crude mortality
- Central venous catheter-related bloodstream infections
 - 5,000,000 central catheters placed each year
 - 3%-8% will become infected
 - 10%-15% of HAI infections
 - 15% attributable mortality
 - 1% of deaths in USA

Potential Sources of Pathogens – Central Venous Catheters

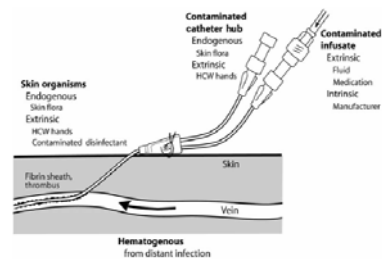


Figure 1. Potential sources of infection of a percutaneous intravascular device (IVD): the contiguous skin flora, contamination of the catheter hub and lumen, contamination of infusate, and hematogenous colonization of the IVD from distant, unrelated sites of infection [1]. HCW, health care worker.

Cmich Clin Infect Dis 2002

Normal Host Defenses to Prevent Pneumonia

- Cough reflex
- Gastric pH
- Mucociliary clearance
 - remove particulate matter and microbes
- Alveolar macrophages and leukocytes
 - Remove particulate matter and pathogens
 - Elaborate cytokines that activate cellular immune response
 - Act as antigen presenting cells
- Immunoglobulins and complement
 - Opsonize bacteria and facilitate phagocytosis

Changes in Upper Airway Flora in Ventilated Patients

- Normal upper airway flora
 - viridans streptococci
 - *Haemophilus* spp.
 - anaerobes
- Critically ill patients upper airway flora
 - Aerobic Gram negative bacilli
 - Antibiotic resistant
 - Gram positive pathogens, *S. aureus*
- Microbial adherence facilitated
 - Reduced mucosal IgA
 - Increased protease production
 - Denuded mucous membranes
 - Increased bacterial receptors

Routes of Colonization in Ventilated Patients

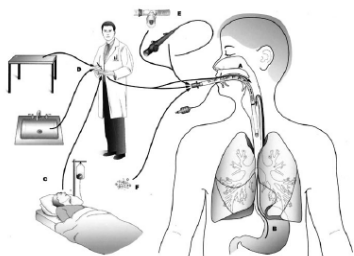


Fig. 1. Routes of colonization/infection in mechanically ventilated patients. Colonization of the aerodigestive tract may occur endogenously (A and B) or exogenously (C through F). Exogenous colonization may result in primary colonization of the oropharynx or may be the result of direct inoculation into the lower respiratory tract during manipulations of respiratory equipment (D), during using of respiratory devices (E), or from contaminated aerosols (F).

Safdar Respiratory Care 2005

Outbreaks of VAP

| Source | Example of Pathogen |
|---|---|
| Contaminated respiratory therapy equipment | Multidrug-resistant gram negative bacilli, e.g., <i>Acinetobacter</i> , |
| Contaminated bronchoscopes | <i>P. aeruginosa</i> , non-tuberculous mycobacteria |
| Medications | <i>B. cepacia</i> , <i>P. aeruginosa</i> |
| Hospital water supplies | <i>Legionella</i> spp. |
| Coincident with viral community outbreaks: Ill staff and visitors | RSV, influenza, SARS |

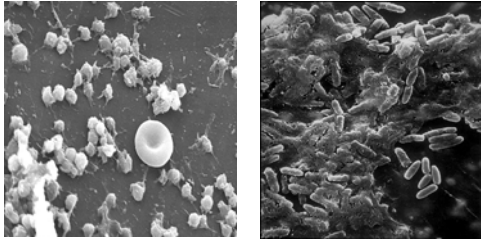
Ventilator-associated Pneumonia

- Immune system impaired:
 - Comorbid illnesses and medications
- Endotracheal tube (ETT) multiple effects:
 - Thwarts cough reflex
 - Compromises mucociliary clearance
 - Conduit for organisms colonizing upper airway above the vocal cords to enter the lower respiratory tract
- Biofilm can develop on ETT
 - Organisms dislodge during suctioning

Role of Biofilm in HAI

- Biofilm is complex 3-dimensional structure of host cells, bacteria, and extracellular matrix
- Adherence of microorganisms to surface of devices (or each other)
- Change in bacterial gene expression results in non-planktonic mode of growth
- Extracellular matrix consisting of:
 - Host components
 - Central venous catheter: fibrin, fibronectin, platelets
 - Urinary tract catheter: proteins, electrolytes, organic molecules
 - Secreted polysaccharide matrix

Biofilm on Intravenous Catheter 24 hours after Insertion



Scanning Electron Micrograph

Type of Surgery – Risk Classification

| | |
|---------------------------|---|
| Clean (<2%) | Elective, primary closure, no transection of mucous membranes |
| Clean contaminated (<10%) | Urgent or emergent, controlled entry into GI, respiratory, biliary tract |
| Contaminated (20%) | Acute, spill from organ, penetrating trauma, no purulence |
| Dirty (30-40%) | Purulence, abscess, pre-operative perforation, penetrating trauma > 4 hours |

Pathogenesis of Surgical Site Infections (SSI)

- Pathogens originate from several sources
 1. Endogenous sources – most commonly, patient’s skin, mucous membranes or viscera
 2. Exogenous sources – contact of wound with contaminated environment, operating room personnel, air, surgical instruments
 3. Hematogenous or lymphatic sources

Host Risk Factors for HAI

- Disruptions to host defenses
 - Devices
 - NG tubes
 - Burns
- Medications
 - Antacids and Proton pump Inhibitors
 - Chemotherapy
 - Steroids
- Extremes of age
 - Lowest birth weight preterm infants at highest risk
- Prolonged length of stay

CDC Classifications of SSI

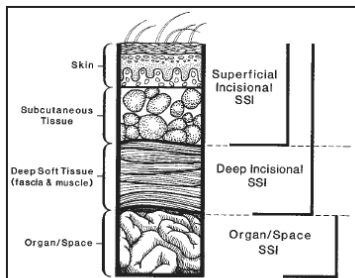


FIGURE. Cross-section of abdominal wall depicting CDC classifications of surgical site infection.²²

Common Pathogens Causing HAI

| Pathogen | Types of Infection |
|--|--|
| <i>S. epidermidis</i> | Bloodstream infections |
| <i>S. aureus</i> (MRSA) | Wound infections |
| <i>E. coli</i> | Urinary tract infections |
| <i>P. aeruginosa</i> , <i>Acinetobacter</i> spp. | Pneumonia |
| RSV, influenza | Lower respiratory tract |
| <i>C. difficile</i> | Diarrhea |
| <i>Candida</i> spp. | Bloodstream infections, Urinary tract infections |
| <i>M. tuberculosis</i> , <i>Legionella</i> spp., <i>Aspergillus</i> spp. | Pneumonia |

Antibiotic Resistance and HAI

- Antibiotic utilization increases selective pressure on flora
- Patients with infections are hospitalized longer
 - Serve as reservoirs for multidrug-resistant pathogens
 - Transmission to other patients
- Ineffective therapy for multidrug-resistant pathogens increases resistance

Role of Inanimate Environment



Green X's show areas of contamination with vancomycin-resistant enterococci

Biofilms and Antibiotic Resistance

- Organisms within biofilm difficult to eradicate
 - Evade host defenses
 - Evade activity of antimicrobial agents
- Biofilms may promote development of antimicrobial-resistant infections:
 - Serve as nidus for deposition and growth of resistant strains that cause infection;
 - Bacteria imbedded in biofilm may be exposed to sub-inhibitory concentrations of drug promoting emergence of resistance
 - Provide matrix in which bacteria can exchange resistance factors.

Diagnosis of CVC-related Bloodstream Infection

- Maintain a high index of suspicion
- Rule-out other sites of infection that could cause bacteremia
 - Urinary tract infection
 - Pneumonia
- Obtain blood cultures
 - ≥ 2 blood cultures including at least one peripheral culture
 - Distinguish colonization, contamination, infection

Hospital Factors Contributing to HAI

- Construction and renovation
 - Dust contains mold spores - *Aspergillus*
- Contaminated water supplies
 - Biofilms within pipes – *Legionella*
- Overcrowding
- Understaffing
- Inadequately trained staff

Diagnosis of VAP

- Radiology signs (≥ 1)
 - New or persistent infiltrate
 - Cavitation
- Clinical signs (≥ 1)
 - Fever
 - Leukopenia or leukocytosis
 - PLUS (≥ 2)
 - Purulent sputum or change in sputum character
 - New or worsening cough, dyspnea, tachypnea
 - Rales or bronchial breath sounds
 - Worsening gas exchange
- Microbiologic criteria (optional, ≥ 1)
 - (+) blood culture
 - (+) pleural fluid culture
 - (+) quantitative culture from Bronchoalveolar lavage
 - Histopathologic evidence of pneumonia

Klompas JAMA 2007

Treatment

- Empiric therapy
 - Based on common pathogens
 - Based on local epidemiology and resistance patterns
- Targeted therapy
 - Use appropriate antibiotics when pathogen is identified
 - Narrow agent
 - Add or change agent
 - Discontinue agent
- Remove the device

Phone call from NICU to Hospital Epidemiologist:

“We have just diagnosed three infants with *Klebsiella pneumoniae* bloodstream infections. These strains are resistant to 3rd generation cephalosporins. Do you think we have a problem?”

Prevention Strategies

- Hand hygiene
- Cleaning and disinfection
- Sterilization
- Aseptic techniques
- Appropriate antimicrobial use
- Surveillance of HAI
- Patient isolation to prevent transmission to other patients

We established a case definition

- NICU patient with positive culture for ESBL *K. pneumoniae* isolated from any body site during the past year.
- Can be colonized and/ or infected
 - Infection and colonization have same infection control implications as reservoir of potential pathogen
- Calculate incidence as number of cases per 1000 patient days per month.

Outbreak Investigation in the Neonatal ICU



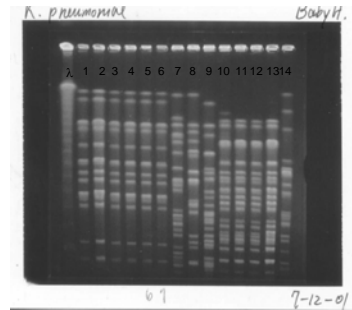
Environmental Sites Cultured

- Tap water and sink drains
- Liquid medications
- Respiratory therapy equipment
- Hand creams
- Water baths used to warm formula
- Designated stethoscopes
 - Case patient's designated stethoscope positive for ESBL *K. pneumoniae*.

These measures were unsuccessful in halting the outbreak. How was transmission occurring?



PFGE of ESBL *K. pneumoniae*, NICU 2001



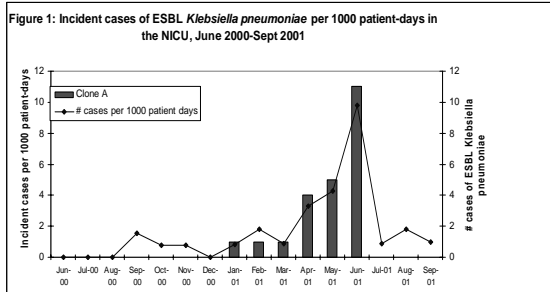
Were healthcare workers playing a role in transmission?

- The hands of healthcare workers were cultured for *K. pneumoniae*.
- Two nurses carried the ESBL *K. pneumoniae*.
- Both wore artificial nails.

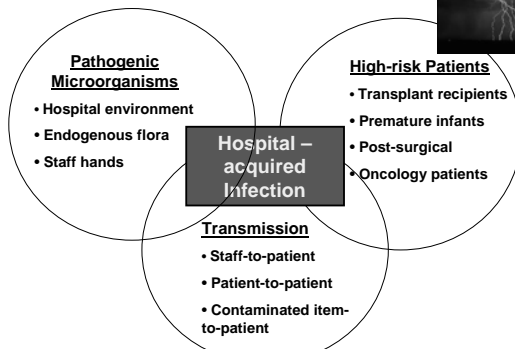
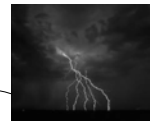
NYPH Policy

- Fingernails are to be neatly manicured and of reasonable length (1/8" beyond finger tip)
- Artificial nail enhancements are not to be worn.
- Nail polish is permitted, but anything applied to natural nails other than polish is considered an enhancement. This includes, but is not limited to, artificial nails, tips, wraps, appliques, acrylics, gels, and any additional items applied to the nail surface.

Epidemiology Curve for ESBL-*Klebsiella* in the NICU



The Perfect Storm



Summary

- Device related infections and surgical site infections are the most common HAIs.
- Both host factors and healthcare environment factors increase the risk of HAIs.
- Pathogens causing HAI can be either endogenous flora or transmitted from patient to patient by healthcare workers.
- Pathogens causing HAI are generally multidrug-resistant and biofilms may contribute to resistance.