Learning Objectives
1. Describe magnitude and implication of HAIs
2. Identify the main risk factors for such infections
3. Estimation of Rate and Risk of HAIs per Exposure
4. Explain the various strategies that could be used to prevent HAIs

HAIs in the USA
- Healthcare-associated or Hospital acquired infections (HAI); Also Nosocomial Infection
- Estimated 2 million infections/Yr. (5-10% of persons hospitalized develop HAIs)
- 100,000 deaths yearly
  - Contribute to 0.7-10%
  - Cause 0.1-4.4%
- Increased morbidity
  - 4 extra days in LOS & $2,100/patient
  - 6.5 Billion dollars annually
Risk Factors for HAIs

- **Host factors** — compromised immunity
- **Environment** — hospital is where the sick cluster, microorganisms abound, contamination of tools, unwashed hands, etc.
- **Technology** — new portals of entry for organisms (canula, central line, etc.)
- **Human factors** — cut back of highly trained personnel and substitution with less trained ones.

Host factors

- Extremes of age
  - 37.4% of infections in adults >60
  - Accounts for 24% of all discharges
- Underlying conditions
  - Immunosuppression
  - Diabetes

Environment

- Proximity to other patients
- Inadequate ventilation
- Contamination of common equipment
- Exposure to contaminated water
- Presence of construction and renovation
- Unwashed hands of health care workers
Technology

- Sophisticated means of monitoring patients
- Provide new portals of entry
  - catheters, ventilators, canula
  - Coag neg staph adhere to prosthetic devices, catheters
- Altered normal host flora
- Increase antibiotic resistance

Human factors

- Cost saving measures
  - Due to recent cutbacks, the number and skill of health care providers has decreased
- Busy units, omitting simple infection control practices
  - Hand washing, scrubbing
  - Increasing beds per room

Microbiologic factors

- Virulence factors
- Ability to survive in hospital environment
- Antimicrobial resistance
- Less virulent pathogens can cause disease in immunocompromised patients
Extrinsic factors

- Medical treatment and interventions
  - Placement of devices
  - Surgical procedures
  - Chemotherapy which weakens the immune system
  - Equipment with complicated reservoirs
    - Dialysis
  - Use of antibiotics which change normal flora

National Nosocomial Infection Surveillance (NNIS) system

- Established in the 1970s
- Estimates the type and number of infections
- Consists of 231 self-selected hospitals
  - Voluntary participation
  - Data collection using four standardized protocols
- What type of surveillance system?

Case definition

- An infection developing in a patient who has been hospitalized for 48-72 hours and was not incubating at the time of admission
- May be present upon admission if they developed during/prior to admission
- May not be identified prior to discharge
Four standardized protocols

- All patients (hospital-wide)
- Adult (AICU) and Pediatric Intensive Care Unit (PICU) patients
- High-risk nursery (HRN) patients
- Surgical procedures

NNIS findings

- Urinary tract infections 34.5%
- Surgical site infections 17.4%
- Bloodstream infections 14.2%
- Lower respiratory tract 13.2%
- Others 20.8%
- Prior studies 25% SSI and 10% BSI
- Due to changes in surveillance, not disease

Most common pathogens

- Bacteria account for 90% and 10% by other microorganisms—Candida albicans, Aspergillus, and viruses.
- Common bacteria in NIs.
  - Staph aureus* 13% (SSI, LRTI)
  - E coli 12% (UTI)
  - Coag neg staph 11% (BSI)
  - Enterococcus 10%
  - Pseudomonas 9% (LRTI)
- Dependent upon the site of infection
  * Red-font indicate the most common bacteria by the CDC
Goals of NI Control Programs

- Reduce nosocomial infections
- Reduce the spread of resistant organisms
- Reduce cost of care and LOS
  - Estimated that 1/3rd can be prevented
  - Currently less than 1/10 are prevented

Prophylactic antibiotic use

- 1940s introduced, resulting in widespread use of penicillin
- 1950s first nosocomial penicillinase producing staphylococci identified
- Patients developed staph sepsis

Increasing drug resistant pathogens

- Methicillin-resistant *Staphylococcus aureus* (MRSA)
  - 1975 2.4%
  - 1991 29% in 2013~ 50%; 2016~60%
- Life threatening and only respond to Vancomycin
- Resulting in development of Vancomycin resistant organisms, such as enterococci
- Currently, *S. aureus* with intermediate vancomycin resistance (VR enterococcus)
- If fully resistant, there would be no treatment
Factors essential in decreasing nosocomial infections

- Surveillance
- Adequate numbers of trained infection control practitioners
- Reports of infection rates to practitioners
- An effective and trained infection control physician

Measures of Disease Incidence: Rate and Risk

- **Rate** is an instantaneous potential of a given *quantity of an event* (disease) to occur per unit change in another quantity (time) for a referent constant (K=10,000 people).
  - Varies between 0 to ∞
  - It does not reflect individual experience in the candidate population
    - E.g. Incidence rate of breast cancer in post-menopausal women 55 cases/year/10,000 population

Measures of Disease Incidence: Rate and Risk (…2)

- **Risk** is the probability that a person develops a given health condition over a specified time conditional on not dying from other causes.
  - Varies between 0 and 1
  - It is dimensionless
  - Needs a temporal boundary as a qualifier
    - E.g. 5-year risk of developing breast cancer
Cumulative Incidence (CI)

- CI is the proportion of a population at risk that will develop an outcome in a given period of time.
- Takes into account time observed for each person at the interval, i.e., Person-time (PT).
- Provides Incidence Density (ID) = \( \frac{I}{PT} \)

\[ CI = IR \times T \]

If IR stays constant

Cumulative Incidence (CI) & Risk

- In a stable dynamic population, the midpoint of a time interval approximates the midpoint average of that population.
- If this assumption stays true, then CI can approximate the Risk for the observed time interval with the following formula.

\[ R_{At} = 1 - \exp[-ID \times \Delta t] \]

where exponent (e) refers to the mathematical constant 2.71828 indicating growth or decay over time.

Example of ID and Risk

- Incidence rate of obstetrical infection after C-Section in Kilinga state over 5-year period

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Observed Cases Person-Years (PY)</th>
<th>Computed Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Infections</td>
</tr>
<tr>
<td>20-24</td>
<td>60,000</td>
<td>90</td>
</tr>
<tr>
<td>25-29</td>
<td>70,000</td>
<td>168</td>
</tr>
<tr>
<td>30-34</td>
<td>65,000</td>
<td>215</td>
</tr>
<tr>
<td>35-39</td>
<td>55,000</td>
<td>227</td>
</tr>
<tr>
<td>40-49</td>
<td>250,000</td>
<td>700</td>
</tr>
</tbody>
</table>

The 5-year risk of obstetrical infection in Kilinga State after C-Section is 1.87%
Infection rates

Crude:

$$\frac{\text{Number of infections}}{100 \text{ admissions or discharges}}$$

Site specific: E.g., BSI rate

$$\frac{\text{Number of blood stream infections}}{100 \text{ admissions or discharges}}$$

Adjusted infection rates

- Adjusted by patient days or number of procedures
  - $$\frac{\text{number of infections}}{1,000 \text{ patient-days}}$$
  - $$\frac{\text{number of infections}}{100 \text{ surgical procedures}}$$

- Standardized rates are employed when comparing two or more hospitals

Risk adjusted infection rate

- Adjusts for risk factors that vary between patients, e.g., the use of certain devices
  - $$\frac{\text{number of infections}}{\text{number of days a device is in place}}$$
Device-adjusted infection rates

- Type of risk adjusted infection rate
- Calculates device-associated, device-day rate, usually per 1,000 days

\[
\text{Number of device-associated:} \left( \frac{\text{infections for a specific site}}{\text{number of device days}} \right) \times 1,000
\]

Calculating device-utilization

- Calculate number of days a device is used
  - Identify number of patients using a given device for each day, and sum the days
- Calculate the number of patient-days
  - Identify the number of patients each day and sum them

\[
\frac{\text{Number of device-days}}{\text{Number of patient-days}} \times 100\%
\]

- Expressed as a percentage
- Not a good estimate if denominator < 50

Risk stratification for surgical procedures

- Categorizes surgical procedures based upon probability of wound contamination at the time of surgery
- Categories
  - Clean
  - Clean-contaminated
  - Contaminated
  - Dirty
- Does not account for host factors or complexity of surgical intervention
NNIS risk index

- Three components
  - ASA preoperative score 3, 4, or 5 (based upon patient condition) [Score=0, R=1.5%]
  - Surgical procedure lasting longer than $T$ hours (varies by surgery) [Score=1, R=2.9%]
  - Procedure classified as contaminated or dirty [Score=2, R=13.0%]

ASA = American Society of Anesthesia

NNIS risk index (2)

- Limitations
  - Does not account for risk of prolonged hospital stay or increased exposure to procedures
  - May be impacted by increase in outpatient procedures
    - If not counted, the number of procedures decreases
    - Outpatient infections maybe more difficult to detect

Measures of frequency

- Incidence - new infections

  Number of new nosocomial infections in a month
  Number of patients discharged or admitted during that month or patient-days
Measures of frequency (2)
- Prevalence - the proportion of patients with an infection at a given time
  Number of active nosocomial infections on a given day
  Number of patients present on the same day

Measures of frequency (3)
- Rates can be site or organ specific
- Prevalence are higher than incidence as it includes duration of individuals in the hospital. People with an infection are likely to remain in the hospital longer.

Evaluation of risk factors
- Surveillance and outbreak investigations
- Basic epi studies
  - Cohort
  - Case control
  - Randomized clinical trials to evaluate interventions
Methodology for detection of nosocomial infection

- Total chart review (gold standard)
- Selective medical review
  - Summaries, nursing kardex, databases
- Reports of clinical symptoms from providers
- Review of microbiology reports
- Antibiotic use
- Models identifying high-risk patients

Sensitivity of detection methods

- Total chart review
  - Gold standard, time intensive
- Selective chart review based upon microbiology reports and the nursing Kardex
  - 74-94% vs. 75-94% (???)

Outbreaks

- Account for fewer than 5% of nosocomial infections
- Outbreak investigation
  - Identifying an unusual occurrence or excessive rate of infections
Sources for transmission of microorganisms

- Exogenous sources
  - Fixed structures
  - Devices or instruments
  - Personnel

- Endogenous
  - Patients
    - Primary — caused by normal flora
    - Secondary — organisms acquired in hospital

Means of transmission

- Contact
- Droplet
- Airborne
- Common vehicle
- Vector-borne

Contact

- Most frequent route for nosocomial infections
- Usually requires personal contact
  - Health care provider
  - Other patients
- Indirect contact
  - Fomites
**Droplet/Airborne**

- Respiratory transmission
  - Coughing, sneezing
  - Air ventilation systems
  - TB has been a big concern

**Other**

- Common vehicle
  - Food, water, medicines
  - Humidifiers
- Vector borne
  - Unusual in US
  - Large concern in developing countries
    - Mosquitoes

**Major types of infection**

- Urinary tract (UTI)
- Lower respiratory tract (LRI)
- Surgical Site (SSI)
- Bloodstream (BSI)
- Other
  - GI
Urinary Tract Infection

- Most common in all facilities
  - Bacteriuria (single +ve culture in pts with a catheter, two +ve without catheter)
  - Stratified by presence of fever
  - Symptoms
    - 67% asymptomatic, 28% fever, 5% organism in blood culture
  - Device-associated (80% indwelling catheters)

UTI (…cont)

- Generally E.coli (endogenous)
- Prevention
  - Avoiding indwelling catheters
  - Maintaining closed system
  - Minimizing duration
- Ineffective
  - Treating meatal catheterization
  - Bladder irrigation

Lower respiratory infection (Pneumonia)

- Second most common nosocomial infection
- Acute care facilities 1% develop LRI
- ICU 28-75%
  - Crude mortality rate 20%-50%
  - Attributable mortality rate 30-33%
- Case definition—— any of the following criteria: cough, purulent sputum, pos x-ray, temp >38C
LRI (…cont)
- Risk factors
  - Severe underlying disease
  - Extremes of age
  - Chronic lung disease
  - Mechanical ventilation
- Prevention
  - Decreasing risk of aspiration
  - Handwashing

Surgical Site Infection
- 3rd most common, 29% of nosocomial infections
- Prolongs hospital stay by 7.4 days
- Causes 2% of all US deaths
- Should be given high priority for surveillance
  - 50% of infection control time

SSI-case definition
- Incisional or organ
- At least one of the following occurs within 30 days post-op*
  - Pus from the incision site
  - Aseptic culture of organisms
  - At least one of the following:
    - Pain or tenderness, localized swelling, redness or heat when surgeon opens the wound
    - Infection diagnosed by surgeon or attending physician
  - * For prosthetic devices up to one year
SSI Risk factors

- **Patient characteristics**
  - Underlying disease, obesity, old age, diabetes, preoperative infection

- **Operative factors**
  - Wound classified as contaminated or dirty
  - Abdominal, long, multiple surgical procedures
  - Hair removal by razor
  - Large blood loss, need for transfusion
  - Presence of drains
  - Less skilled or inexperienced surgeon

SSI Interventions

- **Appropriate use and timing of perioperative antibiotic prophylaxis**
  - **Endogenous infection** – normal flora
    - Use of antibiotics effective for
      - GI surgery, respiratory, genital, urinary
      - Controversial for clean wounds
  - **Exogenous infection** – airborne
    - Infection unlikely to occur after

- SSI surgeon-specific reporting most effective

- Need for post discharge surveillance

Bloodstream Infections

- **14.2% of nosocomial infections**
  - Crude mortality 25-50%
  - Attributable mortality 27-35% in critically ill
  - More common in ICUs, esp. surgical ICU

- Rates vary by the following:
  - Type of population admitted
  - Hospital size and type (teaching vs. not)
  - Length of hospital stay
  - Location within the hospital
Common Source of BSI
The Central Venous Catheter

BSI Case definition
- Primary – caused by unrecognized focus of infection, account for 2/3rds
  - Includes those due to IV or arterial lines
- Secondary – Develop following a documented infection with the same organism occurring at another site
- Classified as transient, intermittent, continuous

BSI Risk factors
- Underlying disease,
- > 65 or < 1,
- Co-morbid illness
- Specific diagnoses, burns, cancer, HIV
- Long hospital stay
- Surgical procedure, esp. complicated
- Decreased nurse/patient ratio
- Male gender
BSI interventions

- Meticulous care of IV catheters
  - Decreased by 35% dedicated IV team
  - Placement under sterile conditions
    - Maximum barrier precautions for central lines
  - Sterile preparation of infusates

GI infection

- Unexplained diarrhea with or without an etiologic agent lasting 2 or more days
- Transmission generally fecal-oral
- Greater problem in developing countries
- Risk factors
  - Extremes of age, antacid use, antimicrobial therapy, NG tube
- Prevention handwashing, good food prep

Eye infections

- 0.5% of nosocomial infection
- Generally occur in specialized hospitals
- More frequent in pediatric hospitals
- Can cause long term disability
- Categorized as surgical or non-surgical
- Intervention
  - Routine infection control
  - Appropriate disinfection of instruments
CNS Infections
- 0.56/10,000 discharges, higher in pediatrics
- Rare, but serious
  - Case fatality – 15%
  - Nosocomial meningitis – 20-67%
- Categorized as surgical or device-related vs. non-surgical
- Risk factors – age, underlying infection, emergency procedure, if gloves were punctured, hair shaving
- Prevention – antiseptic skin prep, limiting preoperative stay, prophylactic antibiotics

Emerging and re-emerging pathogens
- Methicillin-resistant S. aureus
  - More common in large hospitals
  - Only vancomycin is effective
- Vancomycin-resistant enterococcus
  - More common in oncology, prior multiple antibiotics
  - Concern is transfer of resistance
- Streptococcal pneumonia
  - Penicillin resistant strains

Control of emerging and re-emerging pathogens
- Control of antibiotic use
  - Challenging
    • Prescribed by individual physicians
    • MDs focus on specific problem
    • Antimicrobial utilization committee
- Preventing nosocomial infections
  - Infection control dept
  - Employee health service
  - Pharmacy oversight
  - Handwashing
  - Isolation
Preventing nosocomial infections
- Handwashing is most important
  - Predictive factors
    - Profession, hospital ward, time of day, patient/nurse ratio, type of provider
  - Prevention
    - Accessible facilities, education, monitoring of compliance

Isolation
- Two levels of guidelines
  - Standard
    - Combination of universal precautions and body substance isolations
    - All body fluids be considered as potentially infectious
  - Transmission-based
    - Additional precautions for infected or colonized patients

Epidemic control
- Nosocomial infections generally endemic, 5% epidemic
- Vaccination of HCWs
  - Diphtheria, Hep A, Hep B, Flu, Measles, Mumps, Pertussis, Rubella, Varicella (chicken pox)