Pneumonia

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Division of General Medicine and Geriatrics
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Pneumonia types

• CAP - limited or no contact with health care institutions or settings
• HAP: hospital-acquired pneumonia – occurs 48 hours or more after admission
• VAP: ventilator-associated pneumonia – develops more than 48 to 72 hours after endotracheal intubation
• HCAP: healthcare-associated pneumonia – occurs in non-hospitalized patient with extensive healthcare contact

2005 IDSA/ATS HAP, VAP and HCAP Guidelines
### Objectives-CAP

- Epidemiology
- Review cases:
  - Diagnostic techniques
  - Risk stratification for site of care decisions
  - Use of biomarkers
  - Type and length of treatment
- Prevention

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### Pneumonia

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Assistant Professor – Clinical  
Division of Pulmonary, Allergy, Critical Care and Sleep Medicine  
The Ohio State University Wexner Medical Center
Epidemiology

Pneumonia & Influenza – Death Rates by Age Group, 2013

Pneumonia & Influenza - Hospitalization Rate, 1988-2010

American lung association epidemiology and statistics unit research and health education division.
November 2015
Who is at Risk?

- Children <5 yo
- Adults >65 yo
- Comorbid conditions:
  - CKD
  - CHF
  - DM
  - Chronic Liver Disease
  - COPD
- Immunosuppressed:
  - HIV
  - Cancer
  - Splenectomy
- Cigarette Smokers
- Alcoholics

Clinical Presentation

- Fever
- Chills
- Cough w/ purulent sputum
- Dyspnea
- Pleuritic pain
- Night sweats
- Weight loss
- Elderly and Immunocompromised
  - Confusion
  - Lethargy
  - Poor PO intake
  - Falls
  - Decompensation of chronic conditions
CASE #1

- 34 yo female with no pmhx 10 days of:
  - runny nose
  - Documented fevers
  - L sided pleuritic chest pain,
  - productive cough
  - Exam: RR 16, BP 110/70, T 101.6. mildly ill but alert with crackles at R base
Work up

History physical
- Risk of resistant organism
- Immunosuppression
- Abx in past 90 days
- Risk of atypical infection
- Risk of severe illness

Imaging
- CXR Required
- Identify complications of pneumonia
- Consider CT

Labs
- Basic labs
- Biomarkers
- Sputum culture
- Urinary antigens
- Rapid Diagnostic Viral PCR
- Blood cultures

Risk Stratification Tools
1,2,3,9

<table>
<thead>
<tr>
<th>Pneumonia Severity Index</th>
<th>Curb 65</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 criteria</td>
<td>5 criteria</td>
</tr>
<tr>
<td>Heavily weights age and comorbidities</td>
<td>Convenient</td>
</tr>
<tr>
<td>Sensitivity 79-95%</td>
<td>Sensitivity 22-78%</td>
</tr>
<tr>
<td>Specificity 44-70%</td>
<td>Specificity 75-94%</td>
</tr>
</tbody>
</table>
Causes of Community Acquired Pneumonia

<table>
<thead>
<tr>
<th>Bacterial</th>
<th>Viral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streptococcus Pneumoniae</td>
<td>Influenza</td>
</tr>
<tr>
<td>27%</td>
<td></td>
</tr>
<tr>
<td>Haemophilus Influenza</td>
<td>Rhinovirus</td>
</tr>
<tr>
<td>12%</td>
<td></td>
</tr>
<tr>
<td>Atypicals:</td>
<td>Coronavirus</td>
</tr>
<tr>
<td>Mycoplasma</td>
<td>18-33%</td>
</tr>
<tr>
<td>Chlamydia</td>
<td>Adenovirus</td>
</tr>
<tr>
<td>23%</td>
<td></td>
</tr>
<tr>
<td>Legionella</td>
<td>Parainfluenza</td>
</tr>
<tr>
<td></td>
<td>RSV</td>
</tr>
</tbody>
</table>

**Treatment**

According to IDSA/ATS Guidelines

<table>
<thead>
<tr>
<th></th>
<th>Preferred</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outpatient, no comorbidities, low severity</strong></td>
<td><strong>Macrolide monotherapy</strong></td>
<td>Doxycycline</td>
</tr>
<tr>
<td>Outpatient, comorbidities, or increased risk resistance</td>
<td>β Lactam plus Macrolide</td>
<td>Respiratory Fluoroquinolone</td>
</tr>
<tr>
<td>Inpatient, non ICU, moderate severity</td>
<td>β Lactam plus Macrolide</td>
<td>Respiratory Fluoroquinolone</td>
</tr>
</tbody>
</table>
Case #2

- 70 yo male with HTN, DM, mild systolic CHF, and COPD. Recently widowed with no family in the area.
  - productive cough
  - Fevers
  - Dyspnea
  - Exam: Appears mildly ill, alert and oriented, RR 22, temperature 102, and BP 120/80. He has bibasilar crackles, but no lower extremity edema.

Work up

<table>
<thead>
<tr>
<th>History physical</th>
<th>Imaging</th>
<th>Labs</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Risk of resistant organism&lt;br&gt;• Immunosuppression&lt;br&gt;• Abx in past 90 days&lt;br&gt;• Risk of atypical infection&lt;br&gt;• Risk of severe illness</td>
<td>• CXR Required&lt;br&gt;• Identify complications of pneumonia&lt;br&gt;• Consider CT</td>
<td>• Basic labs&lt;br&gt;• Biomarkers&lt;br&gt;• Sputum culture&lt;br&gt;• Urinary antigens&lt;br&gt;• Rapid Diagnostic Viral PCR&lt;br&gt;• Blood cultures</td>
</tr>
</tbody>
</table>
Modifying Factors That Increase The Risk For Infection With Specific Pathogens

<table>
<thead>
<tr>
<th>Organism</th>
<th>Risk Factor</th>
</tr>
</thead>
</table>
| Penicillin-resistant & drug-resistant pneumococci | Age > 65 years  
|                                   | B-lactam therapy within the past 3 months  
|                                   | Alcoholism  
|                                   | Immune-suppressive illness  
|                                   | Corticosteroids  
|                                   | Multiple medical comorbid conditions  
|                                   | Exposure to a child in a daycare center |
| Enteric gram negative bacteria    | Residence in a nursing home  
|                                   | Underlying cardiopulmonary disease  
|                                   | Multiple medical comorbid conditions  
|                                   | Recent antibiotic therapy |
| Pseudomonas aeruginosa            | Bronchiectasis  
|                                   | Corticosteroid therapy  
|                                   | Broad-spectrum antibiotic therapy > 7 days in the past month  
|                                   | Malnutrition |

In The Clinic: Community Acquired Pneumonia

Treatment

According to IDSA/ATS Guidelines

<table>
<thead>
<tr>
<th></th>
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<td>Inpatient, non ICU, moderate severity</td>
<td>(\beta) Lactam plus Macrolide</td>
<td>Respiratory Fluoroquinolone</td>
</tr>
</tbody>
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Case #3

- 74 yo female with DM, HTN, CAD, dementia, presents with 2 days of
  - confusion,
  - shortness of breath
  - lethargy.
  - Exam: BP is 110/70, RR 26, HR 105, temp 101. Ill appearing with bronchial breath sounds on Right
  - Labs show WBC of 14, but the rest are unremarkable.
  - CXR shows R sided infiltrate.
Work up

**History physical**
- Risk of resistant organism
- Immunosuppression
- Abx in past 90 days
- Risk of atypical infection
- Risk of severe illness

**Imaging**
- CXR Required
- Consider CT

**Labs**
- Basic labs
- Biomarkers
- Sputum culture
- Urinary antigens
- Rapid Diagnostic Viral PCR
- Blood cultures

---

**Use of biomarkers**

<table>
<thead>
<tr>
<th>CRP</th>
<th>Pct</th>
<th>ProADM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Useful in primary care setting</td>
<td>Upregulated in response to bacterial infection</td>
<td>Non specific upregulation in severe illness</td>
</tr>
<tr>
<td>May reduce abx use</td>
<td>Guide antibiotic initiation</td>
<td>Useful adjunct to PSI and CURB 65 scores for mortality prediction</td>
</tr>
<tr>
<td>Antibiotics discouraged when crp &lt;20</td>
<td>Length of treatment decisions</td>
<td>Better prognostic accuracy</td>
</tr>
</tbody>
</table>
Treatment

<table>
<thead>
<tr>
<th>According to IDSA/ATS Guidelines</th>
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<th>Alternative</th>
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Determining length of treatment

- Severity assessment
- Site of care
- Microbiological tests
- Empiric antibiotics
- Supportive care

Clinical stability
- Check culture results
- Reassess antibiotics:
  - Stewardship
  - Switch to oral
  - Duration

Clinical reassessment
- Repeat micro testing?
- Change antibiotic?
- Repeat chest X-ray?
- Consider CT scan?

Discharge assessment
- Follow-up scheduled:
  - Vaccination
  - Rehabilitation
  - Resume previous drugs
  - Repeat chest X-ray?

Duration
- 4-8 h
- 72 h
- Reassessment Time
- Discharge Time
- Normal Course
- Prolonged
- Complicated Pneumonia

Community Acquired Pneumonia. Lancet. 2015; 386: 1097-1108
Treatment

Community Acquired Pneumonia

Severity Assessment:
Clinical judgment supported by severity scores

Low Risk
CURB-65 = 0.1
PSI = I, II, III
Outpatient
Inpatient (admitted for social reasons)
Antibiotic monotherapy in patients without comorbidities or risk factors

Moderate Risk
CURB-65 = 2
PSI = IV, V
Inpatient, no ICU
Microbiological tests
Antibiotic combination therapy or quinolone

High Risk
CURB-65 = 3, 4
PSI = IV, V
Severe CAP Criteria ≥ 3 minor or ≥ 1 major
Inpatient, ICU
Microbiological tests
Antibiotic combination therapy (β-lactam + either macrolide or quinolone)

Community Acquired Pneumonia. Lancet. 2015; 386: 1097-1108
Objectives – HAP, VAP, HCAP

- Definitions
- Epidemiology and Pathogenesis
- Risk Factors
- Pathogens and Culture Data
- Antibiotic recommendations
- Duration of treatment
- Complications of pneumonia

Pneumonia types

- CAP- limited or no contact with health care institutions or settings
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2005 IDSA/ATS HAP, VAP and HCAP Guidelines
**HCAP: healthcare contact**

- Intravenous (IV) therapy, wound care or IV chemotherapy within the prior 30 days
- Residence in an extended care facility
- Hospitalization in an acute care hospital for two or more days within the prior 90 days
- Hemodialysis clinic with the prior 30 days

2005 IDSA/ATS HAP, VAP and HCAP Guidelines

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**HAP - Epidemiology**

- 2nd most common nosocomial infection
- 5-15 cases per 1000 hospital admissions
- Increases hospital length of stay 7-9 days
- Cost of over $40,000 per patient

2005 IDSA/ATS HAP, VAP and HCAP Guidelines
HAP – risk factors

- Mechanical ventilation (VAP). Pneumonia in 9-27% of vented patients
- Previous antibiotic treatment
- High gastric pH – secondary to stress ulcer prophylaxis
- Co-morbid medical conditions
- Poor functional status, recent surgery
- Recent respiratory viral infection
HAP - Pathogenesis

- Micro aspiration of bacteria that colonize oropharynx and upper airway
- Hematogenous spread
- Inhalation of bacteria containing aerosols

2005 IDSA/ATS HAP, VAP and HCAP Guidelines

HAP - pathogens

- 70% of patients hospitalized 4 or more days have oropharyngeal colonization with gram-negative bacteria (GNB)
- GNB 55-85% of HAP infections
- Gram-positive cocci 20-40%
- Viral and fungal etiologies
HAP - pathogens

- Distribution of pathogens variable
- Patient populations vary
- Local patterns of antimicrobial resistance

Common HAP bacterial pathogens

<table>
<thead>
<tr>
<th>Pathogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pseudomonas aeruginosa</td>
</tr>
<tr>
<td>Acinetobacter baumanii</td>
</tr>
<tr>
<td>Klebsiella pneumoniae</td>
</tr>
<tr>
<td>Escherichia coli</td>
</tr>
<tr>
<td>Methicillin Resistant Staphylococcus aureus (MRSA)</td>
</tr>
<tr>
<td>Enterobacter spp</td>
</tr>
<tr>
<td>Proteus spp</td>
</tr>
<tr>
<td>Serratia marcesnes</td>
</tr>
<tr>
<td>Streptococcus pneumoniae</td>
</tr>
<tr>
<td>Haemophilus influenzae</td>
</tr>
<tr>
<td>Methicillin-sensitive Staphylococcus aureus (MSSA)</td>
</tr>
</tbody>
</table>
Diagnosis

- No gold standard for diagnosis
- Combination of clinical, radiographic and culture data
- Fever, leukocytosis (or leukopenia), purulent sputum, hypoxia

2005 IDSA/ATS HAP, VAP and HCAP Guidelines
HAP - cultures

- Expectorated sputum
- Induced sputum
- Tracheal aspirate
- “mini” BAL
- Bronchoscopy with BAL, brushing, biopsy

HAP – other data

- Blood cultures should be sent (rule in/out extra-pulmonary spread of infection)
- Thoracentesis if pleural effusion is present in cases of pneumonia
Early antibiotics are key!

- Every hour in delay of appropriate antibiotics = 7.6% lower survival
- Median time to appropriate antibiotics = 6 hours

Kumar et al. Crit Care Med 2006; 34: 1589-96
Effective Antimicrobial Therapy & Survival in Septic Shock

Empiric antibiotics

- Recommended basic of severity, risk of multi-drug resistant (MDR) pathogens and time of onset
- Empiric coverage while awaiting culture data
- Risk factors (hospitalizations, intubation, immunosuppression, etc) and local resistance patterns

2005 IDSA/ATS HAP, VAP and HCAP Guidelines

Initial Empiric Antibiotics: Hospital Or Ventilator-Acquired With No Risks For Multi-Drug Resistance

<table>
<thead>
<tr>
<th>Potential Pathogens</th>
<th>Recommended Antibiotic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streptococcus pneumoniae</td>
<td>Ceftriaxone OR</td>
</tr>
<tr>
<td>Haemophilus influenzae</td>
<td>Levofloxacin, moxifloxacin, or ciprofloxacin OR</td>
</tr>
<tr>
<td>Methicillin-sensitive Staph aureus</td>
<td>Ampicillin/sulbactam OR</td>
</tr>
<tr>
<td>Antibiotic-sensitive enteric gram-negative bacilli:</td>
<td>Ertapenem</td>
</tr>
<tr>
<td>‒ E. coli</td>
<td></td>
</tr>
<tr>
<td>‒ K. pneumoniae</td>
<td></td>
</tr>
<tr>
<td>‒ Enterobacter species</td>
<td></td>
</tr>
<tr>
<td>‒ Proteus species</td>
<td></td>
</tr>
<tr>
<td>‒ S. Marcescens</td>
<td></td>
</tr>
</tbody>
</table>

2005 IDSA/ATS HAP, VAP and HCAP Guidelines
### Initial empiric therapy for hospital/ventilator/healthcare-associated pneumonia with late onset disease or risks for multidrug-resistance

<table>
<thead>
<tr>
<th>Potential Pathogens</th>
<th>Combination Antibiotic Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>• All previously mentioned pathogens</td>
<td>• Anti-pseudomonal cephalosporin OR anti-pseudomonal carbepenem OR β-lactam/β-lactamase inhibitor</td>
</tr>
<tr>
<td>• Multidrug-resistant pathogens:</td>
<td>• PLUS: anti-pseudomonal fluoroquinolone OR aminoglycoside</td>
</tr>
<tr>
<td>– P. aeruginosa</td>
<td>• PLUS: linezolid OR vancomycin</td>
</tr>
<tr>
<td>– K. pneumonia (ESBL positive)</td>
<td></td>
</tr>
<tr>
<td>– Actinobacter species</td>
<td></td>
</tr>
<tr>
<td>• Methicillin-resistant Staph. Aureus</td>
<td></td>
</tr>
<tr>
<td>• Legionella pneumophila</td>
<td></td>
</tr>
</tbody>
</table>

2005 IDSA/ATS HAP, VAP and HCAP Guidelines  

### Initial intravenous adult doses of antibiotics for empiric therapy

<table>
<thead>
<tr>
<th>Antibiotic</th>
<th>Dosage</th>
</tr>
</thead>
</table>
| Anti-pseudomonal cephalosporin | 1-2 g every 8-12 h  
Cefepime | 2 g every 8 h  
Ceftazidime |
| Carbenems | 500 mg every 6 h OR 1 g every 8 hours  
Imipenem | 1 g every 8 h  
Meropenem |
| B-lactam/B-lactamase inhibitor | 4.5 g every 6 h  
Piperacillin-tazobactam |
| Aminoglycosides | 7 mg/kg per day  
Gentamicin | 7 mg/kg per day  
Tobramycin | 20 mg/kg per day  
Amikacin |
| Anti-pseudomonal quinolone | 750 mg every day  
Levofloxacin | 400 mg every 8 h  
Ciprofloxacin |
| Vancomycin | 15 mg/kg every 12 h |
| Linezolid | 600 mg every 12 h |

2005 IDSA/ATS HAP, VAP and HCAP Guidelines  
### What antibiotics?

**The Ohio State University Wexner Medical Center and Ross Heart Hospital Inpatient Antimicrobial Calendar Year 2015**

<table>
<thead>
<tr>
<th><strong>GRAM POSITIVE COCCI % SUSCEPTIBLE</strong></th>
<th>Penicillin</th>
<th>Penillin G</th>
<th>Nalidixic</th>
<th>Amoxicillin</th>
<th>Cephalothin</th>
<th>Chloramphenicol</th>
<th>Vancomycin</th>
<th>Trimethoprim/Sulfamethoxazole</th>
<th>Linezolid</th>
<th>Daptomycin</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRSA (treatment organisms (g/mL))</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
</tr>
<tr>
<td>Staphylococcus aureus (MRSA)</td>
<td>512</td>
<td>35</td>
<td>100</td>
<td>NR</td>
<td>100</td>
<td>76</td>
<td>100</td>
<td>99</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Coagulase Negative Staphylococci</td>
<td>349</td>
<td>15</td>
<td>42</td>
<td>NR</td>
<td>42</td>
<td>45</td>
<td>100</td>
<td>59</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Enterococcus faecalis (β, δ)</td>
<td>695</td>
<td>100</td>
<td>100</td>
<td>95</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Enterococcus faecalis</td>
<td>37</td>
<td>92</td>
<td>92</td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Enterococcus faecium (β, δ)</td>
<td>269</td>
<td>8</td>
<td>8</td>
<td>26</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Enterococcus faecium</td>
<td>194</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>98</td>
<td>97</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

### Appropriate antibiotics

**The Ohio State University Wexner Medical Center and Ross Heart Hospital Inpatient Antimicrobial Calendar Year 2015**

<table>
<thead>
<tr>
<th><strong>GRAM NEGATIVE RODS: NONFERMENTERS % SUSCEPTIBLE</strong></th>
<th>Ampicillin</th>
<th>Spectinomycin</th>
<th>Polymyxin B</th>
<th>Tetracycline</th>
<th>Cefotaxime</th>
<th>Ceftriaxone</th>
<th>Gentamicin</th>
<th>Ceftazidime</th>
<th>Ciprofloxacin</th>
<th>Vancomycin</th>
<th>Tobramycin</th>
<th>Amikacin</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRC breakpoints (µg/mL)</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
<td>≤2</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa (a)</td>
<td>466</td>
<td>63</td>
<td>82</td>
<td>74</td>
<td>90</td>
<td>74</td>
<td>83</td>
<td>90</td>
<td>95</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>
Duration of antibiotic therapy

- Prolonged abx exposure causes MDR pathogens
- No difference in 8 vs 15 days for mortality, ICU LOS and recurrent infections
- Non-fermenting GNR need longer course
- Serial pro-calcitonin levels can help guide duration of therapy

2005 IDSA/ATS HAP, VAP and HCAP Guidelines
Am J Respir Crit Care Med 2005; 171:388-416
**HAP Prevention strategies**

- Hand hygiene
- Standard precautions (gowns, gloves, masks)
- Semi upright or upright positioning
- Incentive spirometry
- Decrease oropharyngeal bacterial colonization
- Subglottic suctioning

**HAP - summary**

- Microbiology includes multi-drug (MDR) organisms
- Guidelines emphasize early, appropriate antibiotics, adequate dosing, broad empiric coverage with de-escalation based on culture data, clinical response, minimal effective duration of therapy
Assessment of Nonresponders

Wrong Organism
- Drug-resistant pathogen
- Inadequate antibiotic therapy

Wrong Diagnosis
- Atelectasis
- Pulmonary embolus
- Pulmonary hemorrhage
- Underlying disease
- Neoplasm
- ARDS

Complication
- Empyema or lung abscess
- Clostridium difficile colitis
- Drug fever

2005 IDSA/ATS HAP, VAP and HCAP Guidelines
## Complications

- Pleural effusion
- Empyema
- Necrotizing pneumonia
- Cavitary pneumonia
- Lung abscess
- Bacteremia
- Pneumatocele
- Hyponatremia

- 65 yo man, 2 weeks of progressive shortness of breath, subjective fevers at home, purulent sputum.
- Presented to ED
• 52 yo woman, asthma, OSA, morbid obesity
• 5-6 days of worsening dyspnea on exertion and non-productive cough.
• Recently diagnosed with pneumonia, only took 4 days of antibiotics
• Exam: appears tired and weak, 76% on RA after walking, 96% RA at rest, lung exam with rhonchi on the right. Vitals stable
• Labs within normal limits
An ounce of prevention\textsuperscript{1,2} …

<table>
<thead>
<tr>
<th>Tobacco Cessation</th>
<th>Smoking is a risk factor for bacteremia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influenza Vaccination</td>
<td>influenza vaccination reduces pneumonia and mortality by 30-50%</td>
</tr>
<tr>
<td></td>
<td>Reduces all cause mortality by 27-54%</td>
</tr>
<tr>
<td>Pneumonia Vaccination</td>
<td>PCV-13</td>
</tr>
<tr>
<td></td>
<td>PPS-23</td>
</tr>
</tbody>
</table>
Pneumococcal Vaccine Schedule:

- No health conditions or risks:
  - Age 65: PCV13
  - After 1 year: PPSV23
- Chronic health condition*, smoker, or long-term care facility:
  - PPSV23
  - After 1 year: PCV13
  - After 5 years: PPSV23

*CHF, chronic lung disease, chronic liver disease, alcoholism, diabetes

Pneumococcal Vaccine Schedule:

- Immunocompromising condition or asplenia:
  - PCV13
  - After 8 weeks: PPSV23
  - After 5 years: PPSV23
- Cerebrospinal fluid leak or cochlear implant:
  - PPSV13
  - After 8 weeks: PPSV23
  - After 5 years: PPSV23


References
