THE FREQUENCY AND SEVERITY OF SURGICAL SITE INFECTION: THE UNTOLD STORY

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University of New Mexico School of Medicine
Probability of SSI

- Inoculum of Bacteria
- Virulence of Bacteria
- Advuvant Effects

= Probability of Infection

- Innate and Adaptive Host Defense
- Acute and Chronic Host-Defense Liabilities
Surgical Site Infection
History of Preventive Strategies

Antisepsis (1870s)

↓

Asepsis (1900-10)

↓

Antibiotics (1940s)
Surgical Site Infections
Preventive Strategies

- Reduce the Inoculum
  - Good Skin Preparation
  - Good Surgical Technique
  - Preventive Systemic Antibiotics

- Minimize Adjuvant Effects
  - Hemostasis
  - Minimize Braided Suture
  - Intelligent Use of the Electrocautery

- Augment the Host?
  - Supplemental oxygen
  - Maintenance of core body temperature
  - Glycemic control
• Alexander Fleming discovered Penicillin in 1929.

• The introduction of antibiotics into clinical practice (early 1940s) raised great hopes in the treatment of bacterial infection.

• In surgery, the prospects of using antibiotics for prevention was immediately recognized as a possibility.
Cutaneous injection of bacteria

Inflammation at 24-48 hrs is proportional to the logarithm of the bacterial inoculum.
Timing of Penicillin Administration with Respect to Bacterial Inoculation

Mean 24-Hour Lesion Diameter (mm)

Staphylococcal lesions - no antibiotic

Staphylococcal lesions - antibiotic

Killed staphylococcal lesions

Lesion Age at Time of Penicillin Injection (hr)

Adapted from the American College of Surgeons. 1988-91.
## Prevention of Surgical Site Infection

### Use of Preventive Antibiotics: GI Surgery

<table>
<thead>
<tr>
<th></th>
<th>Cephaloridine</th>
<th>Placebo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>101</td>
<td>98</td>
</tr>
<tr>
<td>Colon Pts</td>
<td>54</td>
<td>50</td>
</tr>
<tr>
<td>Infections</td>
<td>6</td>
<td>29</td>
</tr>
<tr>
<td>Colon Inf</td>
<td>7%</td>
<td>30%*</td>
</tr>
</tbody>
</table>

(P < .05)*

Surgical Care Improvement Project

Performance measures - Process

Surgical Infection Prevention

- Antibiotics
  - Administration within one hour before incision
  - Use of antimicrobial recommended in guideline
  - Discontinuation within 24 hours of surgery end

- Glucose control in cardiac surgery patients

- Proper hair removal

- Normothermia in colorectal surgery patients

- Removal of urinary catheter on Post-operative Day 1 or Day 2.
16 million Inpatient Operations Annually (less than 50% of all operations performed).

31% of Healthcare-Associated Infections among inpatients are SSIs.

157,500 SSIs annually in the U.S. (year 2011).

NHSN overall inpatient SSI rate is 1.9%.
The Current State of Affairs in SSI

CDC: January 1, 2015

- 16 million Inpatient Operations Annually (less than 50% of all operations performed).
- 31% of Healthcare-Associated Infections among inpatients are SSIs.
- 157,500 SSIs annually in the U.S. (year 2011).
- NHSN overall inpatient SSI rate is 1.9%.

NONSENSE!
1. Surveillance is Problematic for SSI.
2. We have no information about ambulatory SSI rates.
3. Shorter hospitalization and shifts to more ambulatory operations have distorted SSI rates over time.
4. SCIP has not changed SSI rates.
5. The deception of Delayed Primary Closure.
6. All Preventive Antibiotics are not equal.
7. One size (dose) does not fit all.
8. SCIP antibiotic recommendations are not valid for patients with recent healthcare exposure.
9. Systemic Antibiotics alone are not enough for Colon Surgery.
10. SSI is a major cause of readmissions: the price of shorter inpatient length-of-stay.
Surveillance for SSI is Inconsistent, Incomplete, and Inaccurate!

- Inconsistent Definitions and Reporting
- Post-discharge Identification is poor
- We do not know the actual rate of SSI.
When I use a word, it means just what I choose it to mean---neither more nor less.
-Humpty Dumpty

Lewis Carroll: Through the Looking Glass, Chapter 6, 1871.
### Coded Event

<table>
<thead>
<tr>
<th>Event</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. difficile Inf.</em></td>
<td>71 (0.5%)</td>
</tr>
<tr>
<td>Acute MI</td>
<td>115 (0.9%)</td>
</tr>
<tr>
<td>UTI</td>
<td>270 (2%)</td>
</tr>
<tr>
<td>SSI</td>
<td>510 (3.9%)</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>335 (2.5%)</td>
</tr>
<tr>
<td>Pulmonary Dys</td>
<td>631 (4.8%)</td>
</tr>
<tr>
<td>Ileus</td>
<td>2033 (15.4%)</td>
</tr>
</tbody>
</table>

## Colon Surgery SSIs in NHSN

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Cut Point (min)</th>
<th>NHSN Risk Index</th>
<th>0 (%)</th>
<th>1 (%)</th>
<th>2 (%)</th>
<th>3 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colon resection</td>
<td>187</td>
<td></td>
<td>3.99</td>
<td>5.59</td>
<td>7.06</td>
<td>9.47</td>
</tr>
<tr>
<td>Coronary artery bypass with donor incision</td>
<td>301</td>
<td></td>
<td>0.35</td>
<td>2.55</td>
<td>4.26</td>
<td>8.49</td>
</tr>
<tr>
<td>Spinal fusion</td>
<td>239</td>
<td></td>
<td>0.70</td>
<td>1.84</td>
<td>4.15†</td>
<td>–</td>
</tr>
<tr>
<td>Herniorrhaphy</td>
<td>124</td>
<td></td>
<td>0.74</td>
<td>2.42</td>
<td>5.25†</td>
<td>–</td>
</tr>
<tr>
<td>Hip prosthesis</td>
<td>120</td>
<td></td>
<td>0.67</td>
<td>1.44</td>
<td>2.40†</td>
<td>–</td>
</tr>
<tr>
<td>Abdominal hysterectomy</td>
<td>143</td>
<td></td>
<td>1.1</td>
<td>2.2</td>
<td>4.05†</td>
<td>–</td>
</tr>
</tbody>
</table>

*The cut point is identified in minutes. Procedures that exceed the cut point in duration have one risk point added to the NHSN risk index.

†Indicates that risk index groups 2 and 3 have been pooled together because of small total cases.

### Table 3. Unadjusted Analyses of Postoperative Mortality, LOS, and Morbidity

<table>
<thead>
<tr>
<th></th>
<th>Right-Sided Colectomy</th>
<th>Left-Sided Colectomy</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-d mortality</td>
<td>40 (1.8)</td>
<td>32 (1.2)</td>
<td>.08</td>
</tr>
<tr>
<td>Postoperative LOS, mean (SD)</td>
<td>6.9 (5.5)</td>
<td>6.5 (5.2)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Median</td>
<td>6</td>
<td>5</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Patients with &gt;7 d postoperative LOS</td>
<td>804 (36.2)</td>
<td>840 (31.7)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Patients with no medical or surgical complications</td>
<td>1852 (83.4)</td>
<td>2199 (82.9)</td>
<td>.55</td>
</tr>
<tr>
<td>Surgical complications</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superficial SSI</td>
<td>130 (5.9)</td>
<td>217 (8.2)</td>
<td>.002</td>
</tr>
<tr>
<td>Deep SSI</td>
<td>17 (0.8)</td>
<td>25 (0.9)</td>
<td>.50</td>
</tr>
<tr>
<td>Organ space SSI</td>
<td>44 (2.0)</td>
<td>48 (1.8)</td>
<td>.66</td>
</tr>
<tr>
<td>Wound dehiscence</td>
<td>25 (1.1)</td>
<td>26 (0.9)</td>
<td>.62</td>
</tr>
<tr>
<td>Sepsis</td>
<td>102 (4.6)</td>
<td>106 (4.0)</td>
<td>.31</td>
</tr>
<tr>
<td>Reoperation</td>
<td>98 (4.4)</td>
<td>118 (4.5)</td>
<td>.95</td>
</tr>
<tr>
<td>Bleeding requiring ≥5 U</td>
<td>8 (0.4)</td>
<td>7 (0.3)</td>
<td>.55</td>
</tr>
</tbody>
</table>
# Elective Colorectal Surgery: Preventive Antibiotics and SSIs

<table>
<thead>
<tr>
<th>Reason for Failure</th>
<th>Ertapenem (n=346)*</th>
<th>Cefotetan (n=339)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any Failure</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>102</td>
<td>29.5</td>
</tr>
<tr>
<td>Surgical Site Infection</td>
<td>63</td>
<td>18.2</td>
</tr>
<tr>
<td>Unexplained Antibiotic Use</td>
<td>29</td>
<td>8.4</td>
</tr>
<tr>
<td>Anastomotic Leak</td>
<td>10</td>
<td>2.9</td>
</tr>
</tbody>
</table>

*P<0.001

Ambulatory SSI rates?

- Not amenable to conventional surveillance.
- Requires self-reporting which is problematic.
- Patients return to ERs at hospitals other than where the procedure was performed.
- ER visits, readmissions, subsequent ambulatory procedures (e.g., wound drainage or debridement), and antibiotic prescriptions may be necessary metrics: these will require better data systems (e.g., Healthcare Information Exchanges).
Process Measures are not Outcomes: SCIP has failed to improve SSI Rates

- 9,195 elective VA operations (orthopaedic, colon, peripheral vascular)
- 86.4% complied with timely antibiotic administration. (SCIP-1).
- Poor timing of antibiotic administration was not associated with increased SSI rates (Overall SSI rate =4.7%).

- 405,720 cases from Premier Database.
- 68% elective; overall SSI rate = 1%.
- Adherence with individual SCIP measures by hospitals was not associated with reduced SSI rates.
Hospital Process Compliance and Surgical Outcomes in Medicare Beneficiaries

Lauren H. Nicholas, PhD; Nicholas H. Osborne, MD; John D. Birkmeyer, MD; Justin B. Dimick, MD, MPH


- 325,052 surgical patients from national Medicare database undergoing high-risk surgical procedures (aorta, heart, esophagus, pancreas)
- 2,189 hospitals
- Compliance with SCIP criteria at the hospital-level made no difference in SSI infection outcomes.
Surgical Site Infection Prevention

Time to Move Beyond the Surgical Care Improvement Program

Mary T. Hawn, MD, MPH,† Catherine C. Vick, MS,* Joshua Richman, MD, PhD,*† William Holman, MD,*† Rhiannon J. Deierhoi, MPH,* Laura A. Graham, MPH,* William G. Henderson, MPH, PhD,† and Kamal M.F. Itani, MD§

Ann Surg 2011; 254:494-501

• VASQIP Database: 2005-2009
• 60,853 operations of the 5 SCIP procedure groups performed at 112 VA Hospitals
• SSI rates measured against hospital compliance with all 5 SCIP performance measures.
• Overall SSI rate (30 days) of 6.2%
  • Colon surgery= 11.3%
  • Orthopaedic surgery= 1.6%
• Compliance with SCIP measures did not lower the odds of SSI or reduced hospital SSI rates!
- Colectomy and Open/Laparoscopic Cholecystectomy procedures.
- N= 245,974 colectomies ≥ 65 years of age
- N= 196,852 colectomies < 65 years of age
- Mortality rates and length of stay declined over the 6 years.
- SSI rates progressively increased.
Why Have SIP/SCIP Appeared to Fail?

- Are the Performance Measures Invalid?
- Are there not enough measures?
- Are Hospitals and Physicians misrepresenting compliance?
- Are SSIs pre-ordained based upon risk?

Performance Measures are not Outcomes

Surgery is not Synchronized Swimming
Fifty Ways to Cause Surgical Site Infections

Donald E. Fry

“...it’s really not my habit to intrude. Furthermore, I hope my meaning won’t be lost or misconstrued. But I’ll repeat myself, at the risk of being crude. There must be fifty ways…”

Paul Simon
The Deception of Delayed Primary Closure

- In high risk cases, the skin and subcutaneous tissues are left open for topical management.
- This leaves the open wound vulnerable to continued environmental contamination.
- In theory, the wound is to have delayed closure at day 3-5; in reality, this does not happen.
- Hospitals can report all non-closed wounds as not infected.
- Patient morbidity of the non-closed wound is the same as a superficial SSI where the wound is opened: All patients sustain open wound morbidity, not just the infected ones!
SSIs: The Untold Story

In Surgical Prophylaxis, All Antibiotics are not created equally!
- Cephalothin is gone from the wound in 90 min from time of administration.
- Cefazolin in therapeutic concentrations beyond 2½ hours.
SSIs: The Untold Story

Colorectal Antibiotic Recommendations:

- Cefoxitin
- Cefotetan
- Ampicillin/Sulbactam
- Ertapenem
- Cefazolin + Metronidazole
• Randomized trial in cardiovascular procedures.
• An environment with high rates of MRSA infection
• Randomization of vancomycin vs. cefazolin
• Overall SSI rates were the same.
• Cefazolin-associated infections had high frequency of MRSA
• Vancomycin-associated infections had high frequency of MSSA

Finkelstein et al: JTCVS, 2002;123:326

### TABLE 2. Outcomes of 885 patients receiving vancomycin or cefazolin prophylaxis for cardiovascular operations

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Vancomycin (n = 452)</th>
<th>Cefazolin (n = 433)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Superficial incisional SSI (No.)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>25 (5.5%)</td>
<td>20 (4.6%)</td>
</tr>
<tr>
<td>Donor site</td>
<td>7 (1.5%)</td>
<td>10 (2.3%)</td>
</tr>
<tr>
<td>Chest</td>
<td>18 (4%)</td>
<td>10 (2.3%)</td>
</tr>
<tr>
<td><strong>Deep incisional SSI (No.)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>12 (2.6%)</td>
<td>7 (1.6%)</td>
</tr>
<tr>
<td>Donor site</td>
<td>2 (0.4%)</td>
<td>2 (0.4%)</td>
</tr>
<tr>
<td>Chest</td>
<td>10 (2.2%)</td>
<td>5 (1.2%)</td>
</tr>
<tr>
<td><strong>Organ-space SSI (No.)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>6 (1.3%)</td>
<td>12 (2.7%)</td>
</tr>
<tr>
<td>Mediastinitis</td>
<td>5 (1.1%)</td>
<td>7 (1.6%)</td>
</tr>
<tr>
<td>Osteomyelitis</td>
<td>0</td>
<td>3 (0.7%)</td>
</tr>
<tr>
<td>Endocarditis</td>
<td>1 (0.2%)</td>
<td>2 (0.4%)</td>
</tr>
<tr>
<td>Pericarditis</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Any SSI (No.)</strong></td>
<td>43 (9.5%)</td>
<td>39 (9.0%)</td>
</tr>
<tr>
<td>Duration of postoperative hospitalization (d, mean ± SD)</td>
<td>8.7 ± 8</td>
<td>9.3 ± 11</td>
</tr>
<tr>
<td>Deaths (No.)</td>
<td>13 (2.9%)</td>
<td>14 (3.2%)</td>
</tr>
</tbody>
</table>

No differences were significant at $P \leq .05$. 
SSIs: The Untold Story

With Preventive Antibiotics, one size (dose) does not fit all!

- Dose adjustment for patient BMI?
- Dose adjustment for duration of operation?
Adipose Cefazolin concentrations at opening of C-sections

SCIP antibiotic recommendations are not valid for patients with recent healthcare exposure.
Hospital and/or Antibiotic Exposure increases colonization with gram-positive and gram-negative resistant bacteria.

- 1.5 million U.S. people are in nursing homes.
- 500,000 people are on chronic hemodialysis
- 3,000,000 people are within 30 days of inpatient care.
- Millions are within 30 days of a course of antibiotics.
- SCIP Antibiotic choices are not appropriate for these patients.
Preoperative Stay and SSIs
Vogel et al: JACS, Dec 2010

[Graph showing the rate of Pneumonia, Sepsis, UTI, and SSI over time (Day 0 to Day 6-10).]
SSIs: The Untold Story

Preventive Systemic Antibiotics do not prevent organ/space SSIs!
Mechanical Bowel Preparation? Elective Colon Surgery

Nichols et al., *Clinical Medicine*, April, 1974.
# Preventive Oral Antibiotics for Colon Surgery

<table>
<thead>
<tr>
<th>SSIs/Patients</th>
<th>Infection Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placebo</td>
<td>21/60 35%</td>
</tr>
<tr>
<td>Neomycin/Erythromycin</td>
<td>5/56 9%*</td>
</tr>
</tbody>
</table>
# Mechanical Bowel Preparation vs. No Bowel Preparation

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Without Mechanical Preparation</th>
<th>With Mechanical Preparation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miettinen, 2000</td>
<td>129</td>
<td>10</td>
</tr>
<tr>
<td>Bucher, 2005</td>
<td>75</td>
<td>6</td>
</tr>
<tr>
<td>Fa-Si-Oen, 2005</td>
<td>125</td>
<td>13</td>
</tr>
<tr>
<td>Ram, 2005</td>
<td>165</td>
<td>13</td>
</tr>
<tr>
<td>Zmora, 2006</td>
<td>129</td>
<td>17</td>
</tr>
<tr>
<td>Jung, 2007</td>
<td>657</td>
<td>106</td>
</tr>
<tr>
<td>Contant, 2007</td>
<td>684</td>
<td>96</td>
</tr>
<tr>
<td>Pena-Soria, 2008</td>
<td>64</td>
<td>11</td>
</tr>
</tbody>
</table>
All patients received systemic preoperative amikacin and metronidazole

Oral neomycin and metronidazole were randomized

<table>
<thead>
<tr>
<th>Oral Drugs</th>
<th>No Oral Drugs</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSIs/Patients</td>
<td>5/109</td>
</tr>
<tr>
<td>Infection Rate</td>
<td>5%</td>
</tr>
</tbody>
</table>

(P<0.01)

Preventive Antibiotics in Colon Surgery: Systemic vs. Systemic + Oral Antibiotics

Preventive Antibiotics in Colon Surgery: Systemic vs. Systemic + Oral Antibiotics

Oral Antibiotics v. No Oral Antibiotics
Michigan Surgical Quality Collaborative

16 month study; n=2011 patients; all received systemic antibiotics

Bowel Preparation and SSIs

## Mechanical Bowel Preparation

<table>
<thead>
<tr>
<th></th>
<th>Polyethylene Glycol</th>
<th>Sodium Phosphate</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=</td>
<td>303</td>
<td>367</td>
</tr>
<tr>
<td>SSIs</td>
<td>103 (34%)</td>
<td>87 (24%)</td>
</tr>
</tbody>
</table>

P = 0.03 (Univariant analysis)
P = 0.065 (Multi-variant analysis)

SSI is a major cause of readmissions: the price of shorter inpatient length-of-stay.
Readmissions After Colon Surgery
90 Day Live Discharges = 107,459
21,407 Patient; 28,073 Readmit Events

Medicare Elective Colon Surgery

- 11.9% in 1-30 Days
- 4.3% in 31-60 Days
- 3.8% in 61-90 Days
- 19.9% in Total

Readmissions After Colon Surgery

Total Infections N=7,454 (26.6%)
Conclusions:

- Many effective preventive strategies have been defined for prevention of SSI in controlled trials.
- Consistent surveillance of SSI remains a problem.
- Government programs have not reduced SSI rates.
- Antibiotic choice needs to be individualized to the patient’s weight, and healthcare exposure.
SSIs: The Untold Story

Conclusions:

- Mechanical bowel preparation and oral antibiotics need to be consistently used for the prevention of organ/space infections in colon surgery.
- Readmission and Emergency Department visits need to be evaluated as a measure of SSIs following discharge from the hospital.