C. difficile and the Environment: Disinfection Practices and Mitigating Risk to Patients

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DISCLOSURES

• Consultation
  – Advanced Sterilization Products, Clorox

• Honoraria (speaking)
  – Advanced Sterilization Products, 3M

• Grants
  – CDC
LECTURE OBJECTIVES

• Understand the impact of *C. difficile*
• Review the role of the environment in disease transmission
• Discuss how to prevent transmission of *C. difficile* via contaminated surfaces
• Identify effective preventive strategies
HAZARDS IN THE HOSPITAL

MRSA, VRE, C. difficile, Acinetobacter spp., norovirus

Endogenous flora 40-60%
Cross-infection (hands): 20-40%
Antibiotic driven: 20-25%
Other (environment): 20%

THE ROLE OF THE ENVIRONMENT IN DISEASE TRANSMISSION

• Over the past decade there has been a growing appreciation that environmental contamination makes a contribution to HAI with MRSA, VRE, Acinetobacter, norovirus and C. difficile

• Surface disinfection practices are currently not effective in eliminating environmental contamination

• Inadequate terminal cleaning of rooms occupied by patients with MDR pathogens places the next patients in these rooms at increased risk of acquiring these organisms
KEY PATHOGENS WHERE ENVIRONMENTAL SURFACES PLAY A ROLE IN TRANSMISSION

- MRSA
- VRE
- *Acinetobacter* spp.
- *Clostridium difficile*
- Norovirus
- Rotavirus
- SARS
**C. difficile:**

**MICROBIOLOGY AND EPIDEMIOLOGY**

- Gram-positive bacillus: Strict anaerobe, spore-former
- Colonizes human GI tract
- Increasing prevalence and incidence
- New epidemic strain that hyperproduces toxins A and B
- Introduction of CDI from the community into hospitals
- High morbidity and mortality in elderly
- Inability to effectively treat fulminant CDI
- Absence of a treatment that will prevent recurrence of CDI
- Inability to prevent CDI
C. difficile

- Linked to more than 30,000 deaths/year among the 347,000 hospitalizations in US
- 75% show symptoms in nursing homes/MD offices/clinics
- At least $1B in extra health care per year
C. difficile: A GROWING THREAT
CDI NOW THE MOST COMMON HEALTHCARE-ASSOCIATED PATHOGEN

- Analysis of 10 community hospitals, 2005-2009, in the Duke DICON system

Miller BA, et al. ICHE 2011;32:387-390
C. difficile PATHOGENESIS

- Handwashing and thorough cleaning of hospital rooms
- Environmental contamination with spores (hands, toilets, bed rails, handles)
- Bacteria and spores in feces
- Pathogenic spores are ingested
- C. difficile spores germinate
- Asymptomatic carrier (if patient is well)
- Patient undergoing antibiotic therapy
- Altered microflora of intestine
- Toxin production
- Protective immune response
- No protective immune response
- CDAD (Diarrhea and/or colitis)
FACTORS LEADING TO ENVIRONMENTAL TRANSMISSION OF CLOSTRIDIUM DIFFICILE

- Stable in the environment
- Low inoculating dose
- Common source of infectious gastroenteritis
- Frequent contamination of the environment
- Susceptible population (limited immunity)
- Relatively resistant to disinfectants
TRANSMISSION MECHANISMS INVOLVING THE SURFACE ENVIRONMENT

ENVIRONMENTAL CONTAMINATION

- 25% (117/466) of cultures positive (<10 CFU) for *C. difficile*. >90% of sites positive with incontinent patients. (Samore et al. AJM 1996;100:32)
- 31.4% of environmental cultures positive for *C. difficile*. (Kaatz et al. AJE 1988;127:1289)
- 9.3% (85/910) of environmental cultures positive (floors, toilets, toilet seats) for *C. difficile*. (Kim et al. JID 1981;143:42)
- 29% (62/216) environmental samples were positive for *C. difficile*. 29% (11/38) positive cultures in rooms occupied by asymptomatic patients and 49% (44/90) in rooms with patients who had CDAD. (NEJM 1989;320:204)
- 10% (110/1086) environmental samples were positive for *C. difficile* in case-associated areas and 2.5% (14/489) in areas with no known cases. (Fekety et al. AJM 1981;70:907)
C. difficile Environmental Contamination

- Frequency of sites found contaminated~10->50% from 13 studies-stethoscopes, bed frames/rails, call buttons, sinks, hospital charts, toys, floors, windowsills, commodes, toilets, bedsheets, scales, blood pressure cuffs, phones, door handles, electronic thermometers, flow-control devices for IV catheter, feeding tube equipment, bedpan hoppers

- C. difficile spore load is low-7 studies assessed the spore load and most found <10 colonies on surfaces found to be contaminated. Two studies reported >100; one reported a range of “1->200” and one study sampled several sites with a sponge and found 1,300 colonies C. difficile.
SURVIVAL

*C. difficile*

• Vegetative cells
  – Can survive for at least 24 h on inanimate surfaces

• Spores
  – Spores survive for up to 5 months. $10^6$ CFU of *C. difficile* inoculated onto a floor; marked decline within 2 days. Kim et al. J Inf Dis 1981;143:42.
FREQUENCY OF ACQUISITION OF *C. difficile* ON GLOVED HANDS AFTER CONTACT WITH SKIN AND ENVIRONMENTAL SITES

Risk of hand contamination after contact with skin and commonly touched surfaces was identical (50% vs 50%)

Guerrero et al. AJIC 2012; 40:556-8
FREQUENCY OF ENVIRONMENTAL CONTAMINATION AND RELATION TO HAND CONTAMINATION

- **Study design:** Prospective study, 1992
- **Setting:** Tertiary care hospital
- **Methods:** All patients with CDI assessed with environmental cultures
- **Results**
  - Environmental contamination frequently found (25% of sites) but higher if patients incontinent (>90%)
  - Level of contamination low (<10 colonies per plate)
  - Presence on hands correlated with prevalence of environmental sites

PERCENT OF STOOL, SKIN, AND ENVIRONMENT CULTURES POSITIVE FOR *C. difficile*

Skin (chest and abdomen) and environment (bed rail, bedside table, call button, toilet seat)

Sethi AK, et al. ICHE 2010;31:21-27
Risk of Acquiring MRSA and VRE from Prior Room Occupants

• Admission to a room previously occupied by an MRSA-positive patient or VRE-positive patient significantly increased the odds of acquisition for MRSA and VRE (although this route is a minor contributor to overall transmission). Arch Intern Med 2006;166:1945.

• Prior environmental contamination, whether measured via environmental cultures or prior room occupancy by VRE-colonized patients, increases the risk of acquisition of VRE. Clin Infect Dis 2008;46:678.

• Prior room occupant with CDAD is a significant risk for CDI acquisition. Shaughnessy et al. ICHE 2011;32:201.
EVALUATION OF HOSPITAL ROOM ASSIGNMENT AND ACQUISITION OF CDI

- **Study design:** Retrospective cohort analysis, 2005-2006
- **Setting:** Medical ICU at a tertiary care hospital
- **Methods:** All patients evaluated for diagnosis of CDI 48 hours after ICU admission and within 30 days after ICU discharge
- **Results (acquisition of CDI)**
  - Admission to room previously occupied by CDI = 11.0%
  - Admission to room not previously occupied by CDI = 4.6% (p=0.002)

Shaughnessy MK, et al. ICHE 2011;32:201-206
FACTORS LEADING TO ENVIRONMENTAL TRANSMISSION OF CLOSTRIDIUM DIFFICILE

- Stable in the environment
- Low inoculating dose
- Common source of infectious gastroenteritis
- Frequent contamination of the environment
- Susceptible population (limited immunity)
- Relatively resistant to disinfectants
C. difficile spores
DECREASING ORDER OF RESISTANCE OF MICROORGANISMS TO DISINFECTANTS/STERILANTS

Most Resistant

- Prions
- Spores
- Mycobacteria
- Non-Enveloped Viruses (norovirus)
- Fungi
- Bacteria (MRSA, VRE, Acinetobacter)

Most Susceptible

- Enveloped Viruses
DISINFECTANTS AND ANTISEPSIS

*C. difficile* spores at 20 min, Rutala et al, 2006

- No measurable activity (1 *C. difficile* strain, J9)
  - CHG
  - Phenolic
  - 70% isopropyl alcohol
  - 95% ethanol
  - 3% hydrogen peroxide
  - Disinfecting spray (65% ethanol, 0.6% QUAT)
  - Disinfecting spray (79% ethanol, 0.1% QUAT)
  - 0.06% QUAT; QUAT may increase sporulation capacity- Lancet 2000;356:1324
  - 10% povidone iodine
  - 0.5% hydrogen peroxide
DISINFECTANTS AND ANTISEPSIS

*C. difficile* spores at 10 and 20 min, Rutala et al, 2006

- ~4 log$_{10}$ reduction (3 *C. difficile* strains including BI-9)
  - Bleach, 1:10, ~6,000 ppm chlorine (but not 1:50)
  - Chlorine, ~19,100 ppm chlorine
  - Chlorine, ~25,000 ppm chlorine
  - 0.35% peracetic acid
  - 2.4% glutaraldehyde
  - OPA, 0.55% OPA
  - 2.65% glutaraldehyde
  - 3.4% glutaraldehyde and 26% alcohol
Fig 1. Times required for the microbicides to inactivate $\geq 6 \log_{10}$ (99.9999%) of the spores tested.
Effective Surface Decontamination

Practice and Product
Environmental Surface Disinfection

Product-5000-6000ppm chlorine effective, other sporicidal products
### SURFACE DISINFECTION

**Effectiveness of Different Methods**

<table>
<thead>
<tr>
<th>Technique (with cotton)</th>
<th>C. difficile Log$_{10}$ Reduction (1:10 Bleach)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturated cloth</td>
<td>3.90</td>
</tr>
<tr>
<td>Spray (10s) and wipe</td>
<td>4.48</td>
</tr>
<tr>
<td>Spray, wipe, spray (1m), wipe</td>
<td>4.48</td>
</tr>
<tr>
<td>Spray</td>
<td>3.44</td>
</tr>
<tr>
<td>Spray, wipe, spray (until dry)</td>
<td>4.48</td>
</tr>
<tr>
<td>5500 ppm chlorine pop-up wipe</td>
<td>3.98</td>
</tr>
<tr>
<td>Non-sporicidal wipe</td>
<td>$&gt;2.9$</td>
</tr>
</tbody>
</table>

Rutala, Gergen, Weber.  ICHE. In press
Thoroughness of Environmental Cleaning
Carling et al. ECCMID, Milan, Italy, May 2011

Mean = 32%

>110,000 Objects
ALL “TOUCHABLE (HAND CONTACT)” SURFACES SHOULD BE WIPED

“High touch” objects only recently defined and “high risk” objects not scientifically defined.
HCWs and visitors must use gloves (AI) and gowns (BIII) on entry to room

- Emphasize compliance with the practice of hand hygiene (AII)

- In a setting in which there is an outbreak or an increased CDI rate, instruct visitors and HCP to wash hands with soap (or antimicrobial soap) and water after caring for or contacting patients with CDI (BIII)

- Accommodate patients with CDI in a private room with contact precautions (BIII)

- Maintain contact precautions for the duration of diarrhea (CIII)

- Identification and removal of environmental sources of *C. difficile*, including replacement of electronic rectal thermometers with disposables, can reduce the incidence of CDI (BII)

- Use chlorine containing cleaning agents or other sporicidal agents in areas with increased rates of CDI (BII)

- Routine environmental screening for *C. difficile* is NOT recommended (CIII)

Cohen SH, et al. ICHE 2010;31:431-435
PROVING THAT ENVIRONMENTAL CONTAMINATION IMPORTANT IN C. difficile TRANSMISSION

• Environmental persistence (Kim et al. JID 1981;14342)
• Frequent environmental contamination (McFarland et al. NEJM 1989;320:204)
• Demonstration of HCW hand contamination (Samore et al. AJM 1996;100:32)
• Environmental $\Rightarrow$ hand contamination (Samore et al. AJM 1996;100:32)
• Person-to-person transmission (Raxach et al. ICHE 2005;26:691))
• Transmission associated with environmental contamination (Samore et al. AJM 1996;100:32)
• CDI room a risk factor (Shaughnessy et al. IDSA/ICAAC. Abstract K-4194)
• Improved disinfection $\Rightarrow \downarrow$ epidemic CDI (Kaatz et al. AJE 1988;127:1289)
• Improved disinfection $\Rightarrow \downarrow$ endemic CDI (Boyce et al. ICHE 2008;29:723)
REDUCTION IN CDI INCIDENCE WITH ENHANCED ROOM DISINFECTION

- Before-after study of CDI incidence rates in two hyperendemic wards at a 1,249 bed hospital
- Intervention: Change from cleaning rooms with QUAT to bleach wipes (0.55% Cl) for both daily and terminal disinfection
- Results: CDI incidence dropped 85% from 24.2 to 3.6 cases per 10,000 pt-days (p<0.001); prolonged median time between HA CDI from 8 to 80 days

Orenstein R, et al
ICHE 2011;32:1137
Daily disinfection of high-touch surfaces (vs cleaned when soiled) with sporicidal disinfectant in rooms of patients with CDI and MRSA reduced acquisition of pathogens on hands after contact with surfaces and of hands caring for the patient.
Effect of Hypochlorite on Environmental Contamination and Incidence of *C. difficile*

- Use of chlorine (500-1600 ppm) decreased surface contamination and the outbreak ended. Mean CFU/positive culture in outbreak 5.1, reduced to 2.0 with chlorine. (Kaatz et al. Am J Epid 1988;127:1289)

- In an intervention study, the incidence of CDAD for bone marrow transplant patients decreased significantly, from 8.6 to 3.3 cases per 1000 patient days after the environmental disinfection was switched from QUAT to 1:10 hypochlorite solution in the rooms of patients with CDAD. No reduction in CDAD rates was seen among NS-ICU and medicine patients for whom baseline rates were 3.0 and 1.3 cases per 1000-patient days. (Mayfield et al. Clin Inf Dis 2000;31:995)
Effect of Hypochlorite on Environmental Contamination and Incidence of *C. difficile*

- 35% of 1128 environmental cultures were positive for *C. difficile*. To determine how best to decontaminate, a cross-over study conducted. There was a significant decrease of *C. difficile* on one of two medicine wards (8.9 to 5.3 per 100 admissions) using hypochlorite (1,000 ppm) vs. detergent. (Wilcox et al. J Hosp Infect 2003;54:109)

- Acidified bleach (5,000 ppm) and the highest concentration of regular bleach tested (5,000 ppm) could inactivate all the spores in <10 minutes. (Perez et al. AJIC 2005;33:320)
CONTROL MEASURES

C. difficile Disinfection

• In units with high endemic C. difficile infection rates or in an outbreak setting, use dilute solutions of 5.25-6.15% sodium hypochlorite (e.g., 1:10 dilution of bleach) for routine disinfection. (Category II).

• We now use chlorine solution in all CDI rooms for routine daily and terminal cleaning (formerly used QUAT in patient rooms with sporadic CDI). One application of an effective product covering all surfaces to allow a sufficient wetness for > 1 minute contact time. Chlorine solution normally takes 1-3 minutes to dry.

• For semicritical equipment, glutaraldehyde (20m), OPA (12m) and peracetic acid (12m) reliably kills C. difficile spores using normal exposure times.
ALL “TOUCHABLE (HAND CONTACT)” SURFACES SHOULD BE WIPED

“High touch” objects only recently defined and “high risk” objects not scientifically defined.
### TABLE. Rates of Cleaning for 14 Types of High-Risk Objects

<table>
<thead>
<tr>
<th>Object</th>
<th>Mean ± SD</th>
<th>Range</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sink</td>
<td>82 ± 12</td>
<td>57-97</td>
<td>77-88</td>
</tr>
<tr>
<td>Toilet seat</td>
<td>76 ± 18</td>
<td>40-98</td>
<td>68-84</td>
</tr>
<tr>
<td>Tray table</td>
<td>77 ± 15</td>
<td>53-100</td>
<td>71-84</td>
</tr>
<tr>
<td>Bedside table</td>
<td>64 ± 22</td>
<td>23-100</td>
<td>54-73</td>
</tr>
<tr>
<td>Toilet handle</td>
<td>60 ± 22</td>
<td>23-89</td>
<td>50-69</td>
</tr>
<tr>
<td>Side rail</td>
<td>60 ± 21</td>
<td>25-96</td>
<td>51-69</td>
</tr>
<tr>
<td>Call box</td>
<td>50 ± 19</td>
<td>9-90</td>
<td>42-58</td>
</tr>
<tr>
<td>Telephone</td>
<td>49 ± 16</td>
<td>18-86</td>
<td>42-56</td>
</tr>
<tr>
<td>Chair</td>
<td>48 ± 28</td>
<td>11-100</td>
<td>35-61</td>
</tr>
<tr>
<td>Toilet door knobs</td>
<td>28 ± 22</td>
<td>0-82</td>
<td>18-37</td>
</tr>
<tr>
<td>Toilet hand hold</td>
<td>28 ± 23</td>
<td>0-90</td>
<td>18-38</td>
</tr>
<tr>
<td>Bedpan cleaner</td>
<td>25 ± 18</td>
<td>0-79</td>
<td>17-33</td>
</tr>
<tr>
<td>Room door knobs</td>
<td>23 ± 19</td>
<td>2-73</td>
<td>15-31</td>
</tr>
<tr>
<td>Bathroom light switch</td>
<td>20 ± 21</td>
<td>0-81</td>
<td>11-30</td>
</tr>
</tbody>
</table>

**Note.** CI, confidence interval.
DEFINING HIGH TOUCH SURFACES


No correlation between touch frequency and microbial contamination

<table>
<thead>
<tr>
<th>Surface</th>
<th>Before Cleaning Mean CFU/Rodac</th>
<th>After Cleaning Mean CFU/Rodac</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>71.9 (CI 46.5-97.3)</td>
<td>9.6</td>
<td>High=Low&lt;br&gt;High=Medium</td>
</tr>
<tr>
<td>Medium</td>
<td>44.2 (CI 28.1-60.2)</td>
<td>9.3</td>
<td>Medium=Low</td>
</tr>
<tr>
<td>Low</td>
<td>56.7 (CI 34.2-79.2)</td>
<td>5.7</td>
<td></td>
</tr>
</tbody>
</table>
UNC HEALTH CARE ISOLATION SIGN FOR PATIENTS WITH NOROVIRUS OR C. difficile

• Use term Contact-Enteric Precautions
• Requires gloves and gown when entering room
• Recommends hand hygiene with soap and water (instead of alcohol-based antiseptic)
• Information in English and Spanish
ANTISEPSIS TO PREVENT *C. difficile* INFECTIONS

**Yes**

Either soap or CHG works as a handwash for removal of *C. difficile*.


**No**

70% isopropyl showed no inactivation of *C. difficile* spores at exposure times of 5m, 15m, and 30m.

Wullt et al. ICHE 2003;24:765.
What are the data for soap and water versus alcohol-based hand rubs for *C. difficile* spores?
Hand Hygiene with Soap and Water Is Superior to Alcohol Rub and Antiseptic Wipes for Removal of C. difficile

(Oughton et al. Infect Control Hosp Epidemiol 2009; 30:939)

Objective: Evaluate HH methods for efficacy in removing C. difficile

Design: Randomized crossover comparison among 10 volunteers experimentally contaminated by $1.4 \times 10^5$ C. difficile (62% spores)

Methods: Interventions were evaluated for mean reduction

Conclusion: Handwashing with soap and water showed the greatest efficacy in removing C. difficile and should be performed preferentially over the use of alcohol-based hand rubs when contact with C. difficile is suspected or likely
C. difficile after Hand Hygiene Interventions
(Oughton et al. Infect Control Hosp Epidemiol 2009; 30:939)

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Mean Count, log_{10} CFU/ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm water and plain soap, 10s</td>
<td>1.99</td>
</tr>
<tr>
<td>Cold water and plain soap, 10s</td>
<td>1.90</td>
</tr>
<tr>
<td>Warm water and antibacterial (CHG) soap, 10s</td>
<td>2.31</td>
</tr>
<tr>
<td>Antiseptic (PCMX) hand wipe, 15s</td>
<td>3.25</td>
</tr>
<tr>
<td>Alcohol-based handrub, 15s</td>
<td>3.74</td>
</tr>
<tr>
<td>No intervention</td>
<td>3.82</td>
</tr>
</tbody>
</table>
The Role of the Environment in Disease Transmission

- Over the past decade there has been a growing appreciation that environmental contamination makes a contribution to HAI with MRSA, VRE, *Acinetobacter*, norovirus and *C. difficile*

- Inadequate terminal cleaning of rooms occupied by patients with MDR pathogens places the next patients in these rooms at increased risk of acquiring these organisms
Thoroughness of Environmental Cleaning
Carling et al. ECCMID, Milan, Italy, May 2011

Mean = 32%

>110,000 Objects

Mean = 32%

95% CI
NEW APPROACHES TO ROOM DECONTAMINATION
Supplements Surface Disinfection
## ROOM DECONTAMINATION UNITS

Rutala, Weber. ICHE. 2011;32:743

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Steris</th>
<th>Steris</th>
<th>Bioquell</th>
<th>Tru-D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active agent</td>
<td>DMHP (dry mist HP)</td>
<td>VHP (vaporized HP)</td>
<td>HPV (HP vapor)</td>
<td>UV-C</td>
</tr>
<tr>
<td>Stenul (5% HR, &lt;50 ppm silver cations)</td>
<td>Vaprox (35% HP)</td>
<td>35% HP</td>
<td>UV-C irradiation at 254 nm</td>
<td></td>
</tr>
<tr>
<td>Application</td>
<td>Aerosol of active solution</td>
<td>Vapor, noncondensing</td>
<td>Vapor, condensing</td>
<td>UV irradiation, direct and reflected</td>
</tr>
<tr>
<td>Aeration (removal of active agent from enclosure)</td>
<td>Passive decomposition</td>
<td>Active catalytic conversion</td>
<td>Active catalytic conversion</td>
<td>Not necessary</td>
</tr>
</tbody>
</table>

### Sporicidal efficacy
- Single cycle does not inactivate *Bacillus atrophaeus* BIs; ~4-log_{10} reduction in *Clostridium difficile* and incomplete inactivation in situ
- Inactivation of *Geobacillus stearothermophilus* BIs
- Inactivation of *G. stearothermophilus* BIs; >6-log_{10} reduction in *C. difficile* in vitro and complete inactivation in situ
- 1.7–4-log_{10} reduction in *C. difficile* in situ

### Evidence of clinical impact
- None published
- None published
- Significant reduction in the incidence of *C. difficile*
- None published

**Note.** Adapted from Otter and Yezli. BIs, biological indicators; VRE, vancomycin-resistant Enterococcus. *C. difficile* experiments were done with *C. difficile* spores.
LECTURE OBJECTIVES

• Understand the impact of *C. difficile*
• Review the role of the environment in disease transmission
• Discuss how to prevent transmission of *C. difficile* via contaminated surfaces
• Identify effective preventive strategies
C. difficile: Prevention Measures

- New Enteric Contact Isolation sign-promote soap and water and sporicidal disinfectant
- Enhanced nursing education-ICLs
- Daily/terminal bleach disinfection of all C. difficile patient rooms
- Bleach wipes-shared equipment
- Monitoring thoroughness of cleaning
- Isolation until no symptoms and end of treatment
C. difficile: Prevention Measures

• Use fidaxomicin in selected CDI patients to reduce recurrences
• Prescribe and use antibiotics carefully
• Follow surgical prophylaxis guidelines (max 24h)
• Test for C. difficile when patients have diarrhea while on antibiotics or recent antibiotics (60d)
• Use new PCR test as part of diagnostic algorithm (which increases sensitivity of diagnosis)
CONCLUSIONS

• Contaminated environment likely important for *C. difficile*
• Some disinfectants are effective but surfaces must be thoroughly wiped to eliminate environmental contamination
• Inadequate terminal cleaning of rooms occupied by patients with *C. difficile* pathogens places the next patients in these rooms at increased risk of acquiring these organisms
• Eliminating the environment as a source for transmission of nosocomial pathogens requires: adherence to proper room cleaning and disinfection protocols (thoroughness), effective product, hand hygiene, and institution of Isolation Precautions
THANK YOU!