Hand Hygiene in the Biosafety Level-2 Lab: Is it a Matter of Training?

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Microbiological Containment

- Microbiological practices
- Safety equipment
- Facility safeguards

“The most important element of containment is strict adherence to standard microbiological practices and techniques.”

BMBL, 5th ed. (p. 22)
Behaviors and Injury Prevention
Behavior and Injury Prevention

- “At-risk” behaviors
  - Mouth pipetting
  - Recapping needles
  - Hand to face contact
  - Picking up broken glass with hands
- “Safe” behaviors
  - Handwashing
  - Using pipetting devices
  - Safe sharps precautions
  - Using a mechanical device to pick up broken glass
Why Hand Hygiene?

- **Small-diameter Aerosols**
  - Inhalation hazard
    - < 5 µm penetrate to the alveoli
    - < 10 µm penetrate to bronchi

- Large-diameter Aerosols
  - Hand/skin contamination
  - Surface/fomite contamination
    - > 50 µm settle out quickly

- “...the respirable component is relatively small and does not vary widely”
- “...hand and surface contamination is substantial and varies widely”

BMBL, 5th ed. (p. 14)
Primary Routes of Transmission: Inhalation vs. Direct Contact

Comparison of 10 most common symptomatic laboratory-acquired infections (1979 – 2004)

<table>
<thead>
<tr>
<th>Agent</th>
<th>No. of cases</th>
<th>No. of deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Mycobacterium tuberculosis</em></td>
<td>199</td>
<td>0</td>
</tr>
<tr>
<td>Arboviruses</td>
<td>192</td>
<td>3</td>
</tr>
<tr>
<td><em>Coxiella burnetii</em></td>
<td>177</td>
<td>1</td>
</tr>
<tr>
<td>Hantavirus</td>
<td>155</td>
<td>1</td>
</tr>
<tr>
<td><em>Brucella</em> spp.</td>
<td>143</td>
<td>4</td>
</tr>
<tr>
<td>Hepatitis B virus</td>
<td>82</td>
<td>1</td>
</tr>
<tr>
<td><em>Shigella</em> spp.</td>
<td>66</td>
<td>0</td>
</tr>
<tr>
<td><em>Salmonella</em> spp.</td>
<td>64</td>
<td>2</td>
</tr>
<tr>
<td>Hepatitis C virus</td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td><em>Neisseria meningitidis</em></td>
<td>31</td>
<td>11</td>
</tr>
</tbody>
</table>

Adapted from Harding & Byers (2006, p. 55)
Why Hand Hygiene?

- Hand transmission most likely route of infection at BSL-2
  - Fingers, hands, & wrists are easily contaminated during laboratory procedures
  - Hand-to-face contact is common in the lab
  - Generally no barrier between hands and face

Hand Washing & Hand Disinfection

- Effective for removing/inactivating microbes
- Effectiveness varies depending on:
  - Agent used
  - Contact time
  - Surfaces covered
- Antiseptic handwashing & alcohol-based hand sanitizers are superior to traditional soap & water handwashing

CDC, (2002) *MMWR 51(RR-16)*
Behavioral Studies of Lab Workers

• Evans et al. (1990)
  ▫ Observational study of 119 workers in 10 NIH labs
  ▫ Focus: Universal precautions for blood and body fluids
  ▫ Inappropriate behaviors identified in 40% (15/39) areas surveyed
    • At-risk behaviors included:
      • Handling specimens without gloves
      • Mouth pipetting
      • Spills resulting in skin contamination
      • Oral contact with contaminated items
      • Open bench sonicating
      • Hand braking of centrifuge rotors
Behavioral Studies of Lab Workers

- Alp, Haverkate, & Voss (2006)
  - Observational study of clinical lab workers
  - Focus: Hand hygiene behaviors and compliance with a no-jewelry policy (rings, wrist watches, bracelets)
  - Findings:
    - No-jewelry policy: 36.7% compliance rate ($n=49$)
    - Potential pathogens were cultured exclusively from skin underneath the offending accessories
    - End of shift hand hygiene compliance was 100% ($n=37$)
Behavioral Studies of Lab Workers

- Gaps in existing literature
  - Very few studies measure actual behavior
    - Limited to beliefs, perceptions, knowledge, attitudes
  - Intervention studies
    - Focus is primarily on training
    - Studies show change in knowledge over time, but the knowledge-behavior gap is not bridged
    - Studies are short-term (weeks/months vs. years)
  - Limited use/application of behavioral theory
    - Why do people do what they do?
• Why do laboratory workers take risks?

  ▫ “Martyr-to-science” complex?
  • Wedum (1961), Phillips (1969)

  ▫ Perception of risk is low?
  • Blayney & Eijnde (2005)

  ▫ Inadequate training?

  “Laboratory directors or principal investigators should train and retrain new staff to the point where aseptic techniques and safety precautions become second nature.”

  BMBL, 5th ed. (p. 15)
- **Stimulus-Response Theory (20th century)**
  - B.F. Skinner (1904 – 1990)

**Stimulus** → **Response** → **Stimulus**

*Stimulus*: (Antecedent Cue)  
*Response*: (Operant Behavior)  
*Stimulus*: (Contingent Reinforcement or Punishment)

Theoretical foundation for “Behavior-based Safety”
Theoretical Framework

Social Cognitive Theory (SCT)
Bandura 1986

Person
- Behavioral Capacity
- Self Efficacy Beliefs
- Expectancy-value beliefs
- Perceptions
- Genetics
- Physical Health

Behavior

Environment
1. Physical (resources, equipment, facilities)
2. Social (enforcement practices, social norms, modeling, behavioral reinforcement)
Purpose

1. What is the observed frequency of handwashing (HW) among BSL-2 lab personnel before exiting the lab and before entering “clean” areas?

2. Is there a difference between the observed and self-reported frequency of HW among BSL-2 lab workers?

3. What is the relationship between SCT variables and BSL-2 lab workers’ HW practices, and which of these variables most strongly predict HW?

4. What is the quality of HW among BSL-2 lab workers?
Study Design

• 2-phase, cross-sectional study
  ▫ Phase 1 (May – December 2009)
    • Informed consent
    • Behaviors measured by direct observation
      • Frequency of HW
      • Quality of HW
      • Rate of HFC
    • Situational factors measured
  ▫ Phase 2 (December 2009 – January 2010)
    • Survey of participants beliefs, perceptions, & attitudes related to HH
Subjects & Setting

- Subjects
  - 93 participants (56% male, 44% female)
    - Research professors
    - Post-doctoral students
    - Research associates
    - Graduate students
    - Laboratory technicians
    - Medical doctors
Subjects & Setting

• Participating Labs ($n = 21$)
  ▫ BSL-2 (17)
  ▫ BSL-2+ (4)

• Staffing
  ▫ Range 1 – 9 workers ($mean = 4.4/lab$)

• Approved Agents
  ▫ Viral only (14)
  ▫ Bacterial and viral (4)
  ▫ Bacterial only (2)
  ▫ Bacterial and parasitic (1)
Measurement

• Instrumentation
  - Laboratory behavior observation tool (LBOT)
    • Developed from 2 existing tools
      • Handwashing assessment tool (HAT; Brock, 2002)
      • WHO HH assessment tool (Haas, 2007)
    • Standardized measurement tool
      ▫ Amount of observation time
      ▫ Procedure being performed
      ▫ Agent in use
      ▫ HH behaviors
      ▫ Situational factors within labs
# Measurement

- **Biosafety level 2 behavior survey (BBS)**
  - Demographic characteristics
  - Self-reported rate of HW
  - SCT constructs

<table>
<thead>
<tr>
<th>Scale</th>
<th>Cronbach’s alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expectancy Belief scale 1</td>
<td>.63</td>
</tr>
<tr>
<td>Expectancy Belief scale 2</td>
<td>.79</td>
</tr>
<tr>
<td>Outcome Values</td>
<td>.78</td>
</tr>
<tr>
<td>Modeling</td>
<td>.92</td>
</tr>
<tr>
<td>Self Efficacy</td>
<td>.62</td>
</tr>
<tr>
<td>Behavioral Reinforcement</td>
<td>.93</td>
</tr>
<tr>
<td>Policy Enforcement</td>
<td>.74</td>
</tr>
</tbody>
</table>
Measurement

• Situational Factors
  ▫ Measured at lab level
    ◦ Time since last training
    ◦ Training specifically on HW
    ◦ Exit traffic from lab
    ◦ Soap in lab
    ◦ Paper towels in lab
    ◦ Type of lab
    ◦ HW policies written in SOPs
Measurement

- **Dependent Variables**
  - **HW Compliance**
    - # times washed/# opportunities
    - Attempted to observe 5 opportunities/subject
    - HW Opportunities included:
      - Before exiting BSL-2 lab (96%)
      - Before entering “clean” area within BSL-2 lab (4%)
  - **HW Quality**
    - Duration of scrubbing
    - Use of soap
    - Surfaces covered (dorsal, wrist, palm, interdigital)
    - Rinse
    - Drying (did subject use paper towel to turn off faucet?)
    - Hand sanitizer used
Analysis

- SPSS (version 15.0)
  - Univariate statistics
  - Correlations
  - Significance tests
- Microsoft Excel
  - Linear regression
- HLM 6.08
  - Hierarchical linear modeling of HW predictors
Results

• Overall HW Compliance
  ▫ 118 hours of observation
  ▫ 604 HW opportunities
  ▫ 62 HW Events (1 w/hand sanitizer)
  ▫ Overall compliance rate = 10.3%

• Compliance by lab
  ▫ 336 opportunities in 12 labs with zero compliance
  ▫ 268 opportunities in 9 labs: 3 – 85% compliance
Overall % Compliance by Lab

The chart shows the overall % compliance for hand hygiene by laboratory. Each bar represents a laboratory, and the height of the bar indicates the percentage of compliance. Laboratories 10, 11, 13, and 14 have significantly higher compliance rates compared to others.
Observed vs. Self-reported Compliance

- **Mean observed HW rate**
  - Upon exit = 8.8%
  - Before entering clean areas ($n=6$) = 45.8%

- **Mean self-reported HW rate**
  - Upon exit = 39.5%
  - Before entering clean areas = 82%

- **Correlation:** $r = .47, P < .01$
# HW Compliance by Job Title

<table>
<thead>
<tr>
<th></th>
<th>Postdoc/RA</th>
<th>Lab Tech</th>
<th>Prof/MD</th>
<th>Grad student</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 29)</td>
<td>(n = 26)</td>
<td>(n = 8)</td>
<td>(n = 30)</td>
</tr>
<tr>
<td>Years in Lab</td>
<td>8.9</td>
<td>7.1</td>
<td>14.5</td>
<td>4.9</td>
</tr>
<tr>
<td>Compliance Rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>.13</td>
<td>.17</td>
<td>.04</td>
<td>.07</td>
</tr>
<tr>
<td>Upon Exit</td>
<td>.11</td>
<td>.15</td>
<td>.04</td>
<td>.05</td>
</tr>
<tr>
<td>SR Compliance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upon Exit</td>
<td>.38</td>
<td>.49</td>
<td>.36</td>
<td>.34</td>
</tr>
</tbody>
</table>
Observed vs. Self-reported Compliance

![Bar chart showing compliance rates for different laboratories. The x-axis represents the laboratory numbers, and the y-axis represents the compliance rate upon exit. The chart compares observed and self-reported compliance, with bars for each showing the number of observations (n) and the compliance rates (ranging from 0 to 1).]
### Compliance by Agent in use and Type of Lab

<table>
<thead>
<tr>
<th>Agent in Use on Day of Observations</th>
<th>Washed</th>
<th>Did Not Wash</th>
<th>Total</th>
<th>% Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infectious (n = 51)</td>
<td>46</td>
<td>260</td>
<td>306</td>
<td>15.0</td>
</tr>
<tr>
<td>Potentially Infectious (n = 57)</td>
<td>11</td>
<td>217</td>
<td>228</td>
<td>4.8</td>
</tr>
<tr>
<td>Non-Infectious (n = 14)</td>
<td>5</td>
<td>65</td>
<td>70</td>
<td>7.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of Lab</th>
<th>Washed</th>
<th>Did Not Wash</th>
<th>Total</th>
<th>% Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSL-2 (n = 17)</td>
<td>38</td>
<td>466</td>
<td>504</td>
<td>7.5</td>
</tr>
<tr>
<td>BSL-2+ (n = 4)</td>
<td>24</td>
<td>76</td>
<td>100</td>
<td>24.0</td>
</tr>
</tbody>
</table>

* $X^2 (2, N=604) = 15.6, P < .001$

** $X^2 (1, N = 534) = 14.86, P < .001$
## Determinants of HW

- Correlations between HW and SCT predictors

<table>
<thead>
<tr>
<th>Variable</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expectancy Belief Scale 1</td>
<td>.17</td>
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<td>Expectancy Belief Scale 2</td>
<td>.39**</td>
</tr>
<tr>
<td>Modeling</td>
<td>.41**</td>
</tr>
<tr>
<td>Outcome Values</td>
<td>.27**</td>
</tr>
<tr>
<td>Self Efficacy</td>
<td>.28**</td>
</tr>
<tr>
<td>Perception of Safety Policies</td>
<td>.26*</td>
</tr>
<tr>
<td>Reinforcement</td>
<td>.38**</td>
</tr>
</tbody>
</table>

**P < 0.01
* P < 0.05
Determinants of HW

- Correlations between HW and situational factors

<table>
<thead>
<tr>
<th>Variable</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety Training</td>
<td>.18</td>
</tr>
<tr>
<td>Training on HW</td>
<td>.18</td>
</tr>
<tr>
<td>Exit Traffic</td>
<td>-.45*</td>
</tr>
<tr>
<td>Soap in Lab</td>
<td>.22</td>
</tr>
<tr>
<td>Paper Towels in Lab</td>
<td>.03</td>
</tr>
<tr>
<td>Type of Lab</td>
<td>.13</td>
</tr>
<tr>
<td>HW Policy in SOPs</td>
<td>.24</td>
</tr>
</tbody>
</table>

* P < 0.05
Relationship between HW compliance and exit traffic

Compliance Rate

Foot Traffic Through BSL-2 Lab (exits/hr.)

\[ y = -0.0343x + 0.3538 \]

\[ R^2 = 0.2025 \]
Quality of HW

- 61 soap and water HW performed by 23 subjects (24.7%) from 9 labs
- 49 HW scored, 12 not scored (n=22)
- Average score = 11.3 (range = 2 – 18 points)
- Scrubbing 9 seconds or less (84% of cases)
- Soap use (92%)
- Lathering not visible to observer (51% of cases)
- Turned off faucet with bare hands (59% of cases)
- Foot operated (27%)
- Turned off with paper towel (14%)
## Quality of HW by Gender and Job Title

<table>
<thead>
<tr>
<th></th>
<th>Time Scrubbing</th>
<th>Soap</th>
<th>Surfaces Covered</th>
<th>Rinse</th>
<th>Dry</th>
<th>Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female (n=8)</td>
<td>1.0</td>
<td>2.3</td>
<td>1.9</td>
<td>1.4</td>
<td>2.7</td>
<td>9.3</td>
</tr>
<tr>
<td>Male (n=14)</td>
<td>2.1</td>
<td>2.5</td>
<td>2.0</td>
<td>1.6</td>
<td>2.8</td>
<td>11.0</td>
</tr>
<tr>
<td><strong>Job Title</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PostDoc/RA (n=10)</td>
<td>1.7</td>
<td>2.4</td>
<td>2.0</td>
<td>1.3</td>
<td>2.4</td>
<td>9.7</td>
</tr>
<tr>
<td>Lab Tech (n=6)</td>
<td>1.9</td>
<td>2.4</td>
<td>2.3</td>
<td>1.7</td>
<td>3.1</td>
<td>11.4</td>
</tr>
<tr>
<td>PI/MD (n=2)</td>
<td>1.0</td>
<td>2.0</td>
<td>1.0</td>
<td>1.5</td>
<td>3.0</td>
<td>8.5</td>
</tr>
<tr>
<td>GradStudent (n=4)</td>
<td>2.0</td>
<td>2.8</td>
<td>1.9</td>
<td>1.9</td>
<td>3.0</td>
<td>11.5</td>
</tr>
</tbody>
</table>

Duration of Scrubbing: < 5 sec. = 0; 5-9 sec. = 2; 10-14 sec. = 4; ≥ 15 sec. = 6
Soap: Soap not used = 0; Soap (lather not visible) = 2; Soap (lather visible) = 4
Surfaces Covered: One surface only = 0; Two surfaces = 2; Dorsal, wrist, palm, interdigital areas = 4
Rinse: No rinsing = 0; Partial = 1; All surfaces = 2
Drying: Did not dry = 0; Dried, turned off faucet with hands = 2; Dried, used paper towel to turn off faucet or foot operated = 4
*Maximum score = 20
Conclusions

- Rate and quality of HW is suboptimal
- BSL-2 containment may be routinely and pervasively violated by poor HW behaviors
- This study supports the need for research on the behavioral aspects of biological safety
Conclusions

• Self-reported compliance is not a reliable metric for use in future studies

• Direct observation is the “gold standard” for measuring hand hygiene in the healthcare setting, and should be used in the laboratory setting
Conclusions

• Space utilization and occupancy rates in BSL-2 labs may significantly influence workers’ HW behaviors

• Risk assessments should consider the location of equipment and the number of workers in the lab

• Alcohol-based hand sanitizers may be appropriate for routine hand decontamination when supported by risk assessment
Future Research

• Apply lessons learned in the healthcare setting to the laboratory
  ▫ Intervention studies are needed, but time should not be wasted on duplicating failed experiments
  ▫ Multi-faceted rather than single-shot approaches
    • Top-down management support
    • Performance feedback
    • Interdisciplinary support
    • Participation by lab workers in program development
    • Alcohol-based hand sanitizer if supported by risk assessment
Future Research

• Need for studies focused on the development of valid and reliable instruments for measuring psychosocial variables

• Development of novel methods for measuring HH compliance

• Measurement of biological indicators of worker exposure
“Equipping a laboratory with the finest safety devices does not insure against all possible laboratory infections. Equipment is no substitute for safe technique...”

Reitman & Wedum, 1956