Achieving Daily and Pandemic Surge Capacity

Cairo, Egypt - Jan 19th 2010

Tom Aoki – Mintie Technologies, Inc.
Today’s Agenda

- Review epidemiology of airborne transmissible diseases
- Describe traditional and novel strategies for containment of airborne disease
- Review guidance for natural and mechanical ventilation and scientific support for best practices
- Describe a practical plan for handling a daily or pandemic influx of infectious disease patients
Principles of Disease Transmission

Pathogens:

- Leave original host
- Survive in transit
- Are delivered to a susceptible host
- Reach a susceptible part of the host
- Escape host defenses
- Multiply and cause tissue damage
Modes of Transmission

• **Contact:**
  - **Direct** = microbe transferred directly from patient to caregiver; example: scabies
  - **Indirect** = transfer via intermediate object or person; caregiver picks up germs from contaminated surface and transfers to the patient, example: methicillin-resistant *S. aureus* (MRSA)

• **Droplet**: microbe in respiratory droplets produced by cough or sneeze; droplets travel 3-6 feet; examples: influenza, SARS-CoV, *Bordetella pertussis*

• **Airborne**: microbe in respirable droplet nuclei becomes airborne and can travel long distance and be inhaled deep into lung; examples: *Mycobacterium tuberculosis*, *Aspergillus spp.*, *varicella-zoster virus*, *measles virus*
Re-Examination of the “5 micron” Rule & New Concepts

• Diameter related to unique pathogenesis of pulmonary *Mycobacterium tuberculosis* infection
  – Terminal alveolar deposition
  – “Obligate” inhalational transmission via droplet nuclei

• However, we know that:
  – Much larger particles can float and are inhaled.
  – Most inhaled particles are not infectious.
  – Most respiratory pathogens do not require terminal alveolar deposition, but infect the upper respiratory mucosa.
  – “Opportunistic” inhalational transmission? [e.g. SARS-CoV]

Sources: Michael Bell, MD – Exec. Secretary, Healthcare Infection Control Practices Advisory Committee (HICPAC), CDC

Roy CJ, Milton DK. NEJM 2004;350:1710-12
Coughing and Aerosols

- cough plume may project infectious aerosols into the surrounding air
- maximum airspeed of 8 m per second (18 mph) was observed, averaged during the half-second cough

TB & Ancient Egypt: Case Report

- Lady Irtyersenu, of the 26th Dynasty, ca 600 BC
- Detection: cell-wall mycolic acid biomarkers of the *M. tuberculosis* complex
- *M. tb* complex DNA was detected in the lung tissue, gall bladder and tissues from possible pleura and diaphragm
- Cause of death: terminal disseminated pulmonary tuberculosis

Incidence of TB Disease, Eastern Mediterranean Region, 2007

Number of TB cases, all forms 2008 = 9,760

EMRO, WHO. http://www.emro.who.int/stb/Index.htm
Infection Prevention Strategies
Hierarchy of Controls

Administrative Controls: Respiratory Hygiene + cough etiquette

Environmental Controls: HVAC, AIIR

Personal Protective Equipment
Airborne Infection Isolation Room (AIIR)
Parameters for AIIR

- Pressure Differential $\geq 0.01$ inch (2.5 Pa)
- Air changes per hour (ACH) $\geq 12$
- Airflow volume: exhaust $>$ supply
  - by 10% or 50 cfm (1.42 cmm)
  - aim for 125 cfm (3.55 cmm)
- Sealed room, approx. 0.5sq. Ft. leakage
- Outside or HEPA filtered (99.97% effective @ 0.3 μm) exhaust
CDC Guidance for AIIR

• Air Changes per Hour (ACH)
  – Post 1994 Facility ≥ 12

• Direct Exhaust Outside
  – Air may be returned to the air-handling system or adjacent spaces if all air is directed through HEPA filters

• Whenever an AIIR is in use … monitor air pressure daily with visual indicators

Based on AIA guidelines
Permanent AIIIR associated costs

- Building
- Performance verification
  - Unoccupied, once per month
  - Occupied, Daily
- Annual Air Balancing
- More frequent HVAC system maintenance
Capacity Issues

• **Environmental Controls:**
  - Limited number of private rooms and even fewer true AIIRs
    - U.S. GAO report, 2000: >50% hospitals have ≤ 4 AIIRs/100 staffed beds
    - Smaller facilities may have 1-2, or no AIIRs
    - 38.3% of Hospitals do not have an AIIR (2004 AHA)
  - Existing HVAC - Very limited capability to isolate sections of a facility
AIIR Equivalent Temporary Isolation

- Provide AIIR equivalent performance
- Do not require building modification
- Negligible maintenance costs
- Can be added easily, quickly
- Cost a fraction of permanent AIIR

Provide Economical Protection
Guidance Documents: Airborne Disease Containment

- CDC.
  - TB Guidelines, 2005
  - Environmental Infection Control Guidelines, 2003
- WHO
  - Policy on TB Infection Control in Health-Care Facilities, Congregate Settings and Households
- The European Network for Infectious Diseases (EUNID)
  - Isolation rooms for highly infectious diseases

CDC Guidance for surge isolation

- Place together (cohort) patients who are presumed to have the same infections in areas of the facility that are away from other patients
- Use temporary portable solutions to create a negative pressure environment in the converted area of the facility. Discharge air directly to the outside,… or direct all air through HEPA filters …
WHO Policy on TB ventilation

2009
WHO Policy on TB Infection Control in Health-Care Facilities, Congregate Settings and Households
Measures for TB infection control
WHO, 2009

• Administrative controls
  – 8. Promptly identify people with TB symptoms (triage), separate infectious patients, control the spread of pathogens
  – (cough etiquette and respiratory hygiene) and minimize time spent in health-care facilities.
  – 9. Provide a package of prevention and care interventions for health workers, including HIV prevention, antiretroviral therapy and isoniazid preventive therapy (IPT) for HIV-positive health workers.

• Environmental controls
  – 10. Use ventilation systems.
  – 11. Use ultraviolet germicidal irradiation (UVGI) fixtures, at least when adequate ventilation cannot be achieved.
## Natural vs. Mechanical Ventilation

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<th>Recommendation: Implementation of natural ventilation</th>
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ACH, air changes per hour; TB, tuberculosis
## Natural vs. Mechanical Ventilation

### Summary of advantages and disadvantages of different types of ventilation systems

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<th>Natural ventilation</th>
<th>Hybrid ventilation</th>
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<td><strong>Advantages</strong></td>
<td>Suitable for all climates</td>
<td>Suitable for warm/mild or moderate climates</td>
<td>Suitable for all climates and weather</td>
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<td>More controlled environment</td>
<td>Smaller range of control of environment by occupants</td>
<td>Lower capital, operational and maintenance costs</td>
<td>Energy-saving</td>
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<td>Capable of achieving very high ventilation rate</td>
<td>More flexible</td>
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<td>Large range of control of environment by occupants</td>
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<td><strong>Disadvantages</strong></td>
<td>Expensive to install and maintain</td>
<td>Easily affected by outdoor climate and/or occupant’s behaviour</td>
<td>May be expensive</td>
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<td>Reported failure delivering the required ventilation rate</td>
<td>More difficult to predict, analyse and design</td>
<td>May be more difficult to design</td>
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<td>Potential for noise from equipment</td>
<td>Reduces comfort level of occupants when too hot, humid or cold</td>
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<td>Inability to establish negative pressure in isolation areas, but may be provided by proper design.</td>
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Fungal Loads in Hematology Wards

• Mobile air-decontamination unit used to reduce contamination in immuno-compromised patient room
  – Effective at reducing fungal count
  – Higher CFM = more effective (more ACH)
  – Higher CFM caused noise complaints
    (Negative Air Machine placed in room)
  – Other preventative measures still needed to prevent spores from entering room

• Temporary Anterooms provide missing barrier to entry, relocate NAM outside room

Internal / External Contamination

• Influence of internal and outdoor factors on filamentous fungal flora in hematology wards
  – Administrative preventative measures significantly lower fungal counts
  – Hematology ward had more airborne than surface contamination (surfaces efficient cleaned)
  – Fungal contamination increased when outdoor counts increased

• Airborne contamination was more prevalent than surface. Outdoor contamination directly affects internal contamination

Marie-Pierre Brenier-Pinchart, MD, PhD, “Influence of internal and outdoor factors on filamentous fungal flora in hematology wards” doi:10.1016/j.ajic.2009.03.013
Effective Operating Room Isolation

- Pilot study of directional airflow and containment of airborne particles in the size of *Mycobacterium tuberculosis* in an operating room.
  - Portable combination Ante-Room – HEPA filtration unit
  - Pulled smoke plume down to main entry door
  - No additional noise as HEPA was outside OR

Olmsted RN. Am J Infect Control 2008;36:260-7
Effective Operating Room Isolation

- Submicron particle release
- PAS-HEPA combination Removal Efficiency:
  - Baseline concentration = 6,468 particles / cu. Ft [p/cu.ft] (before particle release)
  - Initial quantity = 500,000 p/cu.ft.
  - 5 min. = 303,701
  - 10 min. = 116,664
  - 20 min = 28,034

- Removal efficiency after 20 minutes = 94.5%

Fig 2. Efficiency of removal of submicron particles (particles/ft³) from operating room with portable anteroom-HEPA unit device.

Particles: poly-alpha olefin (PAO); final conc. = 500,000 particles / cubic foot

Olmsted RN. Am J Infect Control 2008;36:260-7
Portable Anteroom Applications

- Single Patient Rooms
  - Isolation, Protective environment
- Bronchoscopy Rooms
- Other procedure room
- Operating Rooms
- Morgue, Etc.
Portable Anteroom Benefits

• Expands isolation surge capacity
  – AllR equivalent isolation
• Suspected cases can be quickly isolated
• Can follow patient throughout continuum of care
• Reduces particulate levels in contained space
• Improves airflow down and away from patient
• Do not require building modifications or constant maintenance

Economically provides mechanical ventilation
Properly Contained Airborne Aspergillus Particulates

- Setting: Children's Hospital, Palo Alto, California
- High concentration of Aspergillus spores [400 conidia equivalents/m³] coincided with demolition activity, Oct. 06
- Concentrations of Aspergillus spores remained low in patient care areas
- Reason for success = Containment strategies for construction zone:
  - Temporary walls
  - Negative pressure anteroom between entry to construction – patient care areas
  - HEPA filter units
- PM$_5$ = particulate matter < 5 micron size

Surge Response & Management
• Orthomyxoviridae family of viruses
• Enveloped virus
• Hemagglutinin (H)
  – Surface protein that attaches to the human host cell membrane
• Neuraminidase (N)
  – Dissolves the human cell so that all the viruses created go on to infect other cells
Influenza virus “Mixing Bowl”: Recipe for a Pandemic Strain Has Arrived

- Transmission of influenza viruses between animals & humans:
  - Viruses are “shared” between wild birds and animals (e.g. chickens and pigs)
- Drift = minor changes in the protein surface
- Shift = new surface protein
CDC. Interim Guidance on Infection Control Measures: 2009 H1N1 Influenza, 10/14/09

• Recommendations:
  – Review and refresh pandemic influenza plans
  – **Hierarchy of Controls**
    • Administrative controls, e.g. vaccine, work restrict ill personnel
    • Eliminate opportunities for exposure, e.g. visitor restrictions and patient triage/management
    • Environmental controls, e.g. spatial separation; AIIR for aerosol-generating procedures
    • Personal Protective Equipment (PPE)
• Environmental Controls:
  – Portable HEPA filtration units may be used to further reduce the concentration of contaminants in the air.
  – Install partitions (e.g., transparent panels/windows/desk enclosures) in triage areas as physical barriers to shield staff from respiratory droplets
  – Ensure effective general ventilation and thorough environmental surface hygiene
Are We Prepared? Gaps Remain

• 2007 Survey of Infection Preventionists, U.S. hospitals; N = 633 respondents
  – 24/7 availability of IP = 78.5%
    • (significantly less; smaller facilities < 99 beds)
  – Airborne infection isolation room capacity
    • 15%; inadequate numbers
    • 71.1%; plans for temporary AIIR or other containment
      – Only 47% have plans/ability for long term activation
  – Surge response staffing plans = 52.6%
  – Medical equipment / supplies:
    • Mech. Ventilators; 50% had < 10 stockpiled
    • N95 respirators; 50% had 7 day supply on hand for emergency
    • Gowns / sheets/ etc.; 18.6% had stockpiled inventory
    • Antimicrobials; 62.6% - in collaboration with SNS
  – Altered standards of care planning; 22.7%

Mass Isolation
Mass Isolation - Droplet

- Physical barrier separation
- Negative pressure at entrances
- Visual alert of contained area
  - Staff PPE Reminder
  - Prevents Patient Wander
Mass Isolation – Airborne

- Physical barrier separation
- Negative pressure separation
- Extended space for gurneys, etc.
- Easily Expanded
Mintie ECU2 Anteroom

- External one piece frame
  - Minimal contaminated area
  - Avoids part loss
- Quick, Easy set up
  - 15 minutes, one person
- Modular units: scalable
- Convenient to
  - Store
  - Move
Conclusions

• Traditional mechanical ventilation
  – Significant benefits
  – Significant cost

• Temporary Anterooms
  – Provide equivalent performance
  – Economically viable

• Applications
  – Daily individual room isolation capacity
  – Pandemic incident mass isolation
Questions?

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