Indoor Air Quality on Aircraft

Annyce Mayer, MD, MSPH, FACOEM
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Objectives

• Review what is published about indoor air quality on aircraft
• Describe infectious disease transmission
  – Public Health response
• Discuss areas in need of further research
Workers on Aircraft

- 98,000 flight attendants
- 67,000 pilots, copilots, and flight engineers
- 16% business travel
- 609 million US enplanements (2008)

Aircraft Air Quality

- 15-20 air exchanges per hour
- 10 ft³/min per person
- ~85% of planes have HEPA filters
- Variability in smaller aircraft
  - Virtually no published data

WHO/ Mangili A Lancet 2005

GAO Aviation Safety More Research needed in effects of air quality on airliner cabin occupants. Jan 2004; Mangili A Lancet 2005
Aircraft Air Quality

• Flying altitude: ~ 28,000 - 41,000 feet
• Cabin pressurized to ~ 5,000-8,000 feet
  – Excursions up to 10,000 feet

• Low humidity (10-20%)
  – Frequent cause of irritant symptoms

GAO Aviation Safety More Research needed in effects of air quality on airliner cabin occupants. Jan 2004;
Environmental Tobacco Smoke

US Ban gradually phased in:

- 1988: Domestic flights < 2 hours
- 1990: Domestic flights < 6 hours
- 2000: All US domestic and international flights

- 1991: Flight Attendant Medical Research Institute (FAMRI)
Potential Air Contaminants

• Volatile Organic Compounds
  – Not significant under normal conditions
• CO₂ and CO
  – Not significant under normal conditions
• Ozone, increased with
  – Higher altitudes
  – Northern latitude in winter and spring
  – Controlled by ozone converters

GAO Aviation Safety More Research needed in effects of air quality on airliner cabin occupants. Jan 2004;
Potential Air Contaminants

- Exhaust smoke and fumes
- De-icing fluid
- Pesticides
  - Select foreign countries
- Infectious agents
  - Not significant under normal conditions
- Bleed air contaminants

Infectious Disease Transmission

- **Contact**
  - Droplet (>5 um)
  - Direct
  - Indirect
- **Airborne (< 5 um)**
  - Prolonged suspension
- **Common Vehicle**
  - Food and water
- **Vector-borne**
  - Insects and animals

Source: CDC

Source: Associated Press
Infectious Disease Transmission During Flight

- Risk is low, but real

- Contact transmission
  - Meningococcal disease
  - Measles

- Vector Borne
  - Malaria

- Airborne Transmission
  - Tuberculosis
    - No active TB
    - + Latent infection

- Contact transmission (component airborne)
  - SARS
  - Influenza
Transmission of *M. TB*

- Inhalation of airborne droplet nuclei
- Latent TB Infection (LTBI)
  - Bacilli survive in lymph nodes
  - Immune response detectable in 10-12 weeks
- Many exposed people do not acquire infection (~70%)
Active Tuberculosis

- Chronic cough
  - Hemoptysis
- Fatigue
- Fevers, chills
- Night sweats
- Appetite/weight loss
- Progressive debilitation
- Death

Source: CDC
Screening for TB (Active and LTBI)

- Evidence of immune response to *M. TB*
  - Historically by skin test (TST)
  - Interferon Gamma Release Assays (IGRAs)

- Latent TB infection (LTBI)
  - No active disease
  - Asymptomatic
  - Chest x-ray negative
  - Not infectious

Source: CDC
Low U.S. Incidence of Tuberculosis

- Incidence continues to decline
  - Among native born
  - Stable in foreign born
- Highest prevalence
  - Native Americans
  - Foreign born
  - HIV+ population
  - High risk congregate settings

Source: CDC
Common Disease Worldwide

- ~ 1/3 of world’s population infected
- 9.27 million incident cases in 2007
  - Peak incidence rate 2004
- 1.3 million deaths in HIV-
- 456,000 deaths in HIV+
  - 33% of HIV+ TB cases

Source: WHO

WHO Global Tuberculosis Control Report 2009
Drug Resistant *M. TB*

- Multi-drug resistant (MDR)
  - INH & Rifampin
- Extreme drug resistant (XDR)
  - Second line agents
- Increasing elsewhere
- Former Soviet Republic
- HIV
Infectiousness of the Patient

- Pulmonary or laryngeal TB
- Sputum smear positive for AFB
  - Much lower risk if smear negative
- Cavitation on chest x-ray
- Severity of cough
Airline Transmission of TB

• 9 flights
• ≥ 8 hours duration
• Passenger with infectious TB
  – Cough, AFB smear + and cavitation on x-ray
• 6 flights had no conclusive evidence of transmission
  – 1 flight: 3 conversions without identifiable risk

Evidence of TB Transmission

- **May-July**
  - 39 international flights
  - 233 crew members

- **Aug-Oct**
  - 128 domestic flights
  - 51 crew members

- 266/274 contacts
- 270/355 controls

- Flight attendant
- Minimally symptomatic
- Increasingly symptomatic
- November 1993
  - severe cough and SOB
- Proportion with + TST
- TST conversions

Driver CR JAMA, 1994
Evidence of TB Transmission

Figure 1.—Tuberculin skin test results for contacts by month of exposure to the index case and for comparisons.

Figure 2.—Smoothed and fitted estimates of percentages of tuberculin skin test (TST) results that are positive as a function of flight time with index case, August through October 1992. Percentage of TST results that are positive among crew members who shared no flight time in August through October was 5.8%, denoted by asterisk. These crew members flew in May through July. Boxes represent kernel-smoothed estimates of percentage of TST results that are positive. The solid line represents the logistic regression fit of positive TST results to shared flight time during August through October 1992.

Driver JAMA 1994
Evidence of TB Transmission

- April 1994
  - Honolulu-Chicago
  - Chicago-Baltimore

- May 1994
  - Baltimore-Chicago
  - Chicago-Honolulu

- 32 yo passenger with cough and lethargy
  - Worsening cough, SOB, fever, scant hemoptysis
  - Massive hemoptysis
    - MDR TB
    - Died 5 days later

Kenyon NEJM, 1996
Chicago-Honolulu Flight

- 4 TST conversions and 2 TST+ with no risk factors

Kenyon, NEJM 1996
CDC Legal Authority for Isolation and Quarantine

- Isolation
  - Separation of ill patients with communicable diseases
- Quarantine
  - Separation and restricted movement of well persons who were exposed to a communicable disease

- 2007: US traveler with XDR TB
- 1963: Traveler entering US with suspected small pox
- 1918-1919 flu pandemic
Federal Isolation and Quarantine Authorized

- Plague
- Smallpox
- Yellow fever
- Viral Hemorrhagic fever
- Diphtheria
- Cholera
- Infectious TB
- Pandemic Flu
- SARS
Do Not Board List

- June 2007
- CDC
- Department of Homeland Security
- June 2007-May 2008
- 42 requests for DNB
  - All infectious TB
  - 33 confirmed & added to the list.

MMWR Sept. 19, 2008
Do Not Board List

• Disease likely contagious
  – Serious health risk
• Passenger unaware of or non-adherent to PHS recommendations
• Likely to try to board
• Airline instructed not to issue boarding pass

MMWR Sept. 19, 2008
Border Lookout Record

- CDC
- DHS Customs and Border Protection (CBP)
- Alerts Border authorities
  - Seaport, airport, land borders
- Backup to DNB list
  - 2/33 on DNB list detected by CBP before entry into US.
SARS

- Severe Acute Respiratory Syndrome
  - Coronavirus (SARS-CoV)
- Reported in Asia in 2003
- Incubation: 2-10 days

Fever > 100.4
Cough

Source: CDC
SARS TRANSMISSION

- 40 flights investigated
- 5 had probable transmission of SARS
  - 37 passengers
    - 22 on 1 flight
  - Most within 5 rows of index case
  - Atypical pattern for droplet/contact spread

WHO Global Alert and Response Summary of SARS and air travel
March 15, 2003 Hong Kong-Beijing (3hr)

- 120 passengers
- 16 laboratory confirmed SARS, 2 probable SARS, 4 reported SARS

Figure 2. Schematic Diagram of the Boeing 737-300 Aircraft on Flight 2 from Hong Kong to Beijing.
Two flight attendants and two Chinese officials also reportedly had illness that met the WHO criteria for a probable case of SARS. The flight attendants are shown here as members of the crew. The seat locations of the two Chinese officials are unknown, and they are not included in the diagram.

Olsen SJ NEJM 2003
World Health Organization Response

- March 15, 2003 Emergency Travel Advisory
- March 23, 2003 screening measures
- Ill passengers/crew advised postpone travel
- Exit screening checks
  - Symptoms or fever
- Contacts of probable SARS advised not to travel for 10 days post exposure.
World Health Organization
Response

- Cough etiquette
- Frequent hand washing
- Isolation of possible SARS
  - Isolate from other passengers
    - restroom
  - Face mask
- Ill passengers taken to airport health authorities
- Passengers and crew to give contact details for next 14 days

Case Definition
- High fever (>38), and
- Cough, SOB, and
- Close contact with SARS or recent travel history to area with SARS
Cold and Flu

Common Cold
• No difference URI symptoms in aircraft with or without air recirculation.
  – Low humidity

Influenza
• 74% passengers and 40% crew contracted influenza
  – 3-hour ground delay without ventilation
• 20/75 passengers developed flu-like illness
  – Proximity to index case

Zitter JN JAMA 2002
H1N1 Transmission Modeling

- Boeing 747
  - First class
  - Business Class (2)
  - Economy
- Infection risk limited to cabin of source
- Low in first class
- Low-moderate in economy

- Wells-Riley Equation
  - Number exposed
  - Source respiratory rate
  - Length of exposure
    - 5 hour
    - 11 hour
    - 17 hour
  - Concentration
    - Air volume/passenger

Wagner BG  BMC Med 2009
Low Risk of ID Transmission

- May be increased during non-normal operating conditions
- Risk of TB transmission increased:
  - Infectiousness of patient
  - Host factors
  - Flight duration $\geq 8$ hours
  - Proximity to patient
- Likely not increased from comparable public places, with comparable duration
Decreasing Risk of Contact Transmission

Prevention can be Travel-sized.

Do your part to stay healthy this flu season.
For more information, go to cdc.gov/travel

- Travel only when you feel well.
- Get your flu vaccine.
- Wash your hands often.
- Cover your coughs and sneezes.
ETS Exposure

- 61 never-smoking flight attendants
- 51% with DLCO < LLN
  - 75% predicted, unadjusted
  - 84% predicted, corrected
- No association with years of exposure
- No control group

Fig. 1. Box plot distribution of spirometry of the flight attendants as percent predicted values for their sex, age, and height (N = 61). The box represents the interquartile range; the horizontal line inside the box represents the median; and the vertical lines (whiskers) represent the minimum and maximum nonoutlier values. Outlier values are shown by a cross (x).
Areas of Future Research

• Aerotoxic Syndrome
  – Constitutional
  – Neurologic
  – Neuropsychological
  – Gastrointestinal
  – Respiratory

• Bleed Air
  – “Fume Events” likely not common
  – Seem to be increased in certain model aircraft
GAO Aviation Safety More Research needed in effects of air quality on airliner cabin occupants. Jan 2004
Tricresyl Phosphate (TCP)

- Some jet oils (~3%)
- TOCP
  - Tri Ortho-Cresyl Phosphate
  - OSHA PEL
- Organophosphates
- Other toxic isomers
- Other potential neurotoxic compounds

De Nola J Chromatog 2007; Winder C Env Res 2002; Solbu J Chromatog 2007
Toxicity of Organophosphates

- **Acute:** Acetylcholinesterase inhibition
  - Headache, fatigue, confusion
  - Cholinergic Crisis, muscle twitching

- **Delayed:**
  - Organophosphate-Induced delayed neuropathy (OPIDN)
  - Intermediate Syndrome
  - Chronic Organophosphate-Induced Neuropsychological Disorder (COPIND)
Summary

• Airline indoor air quality (IAQ) is generally good
• Additional studies are needed:
  – Ventilation on other aircraft
  – IAQ under nonstandard conditions
  – TCP sampling & analysis
  – Diagnostic clarity of Aerotoxic Syndrome

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