Infectious Disease in Space - Risks, Realities and Remedies

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Canadian Space Agency / Agence spatiale canadienne

Hosted by Paul Webber paul@webbertraining.com
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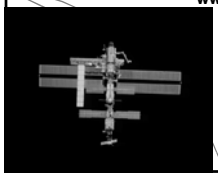
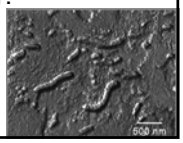


Images courtesy of NASA

Outline of talk

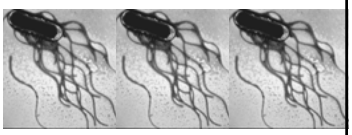
- Reminder of definitions
- Risks – what are the concerns?
- Realities – what information do we have to date?
- Remedies – Based on our knowledge and experience, what are we doing?



Martian bacteria?
(image courtesy NASA)

Disease

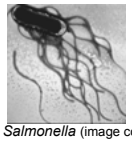
- Human diseases are caused by:
  - Infectious agents
  - Structural or functional genetic defects
  - Environmental factors
  - Combination of the above



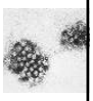
Salmonella (image courtesy PFSE)

Infectious Disease: caused by agents such as

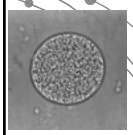
- Bacteria
- Viruses
- Fungi
- Protozoa
- Helminths



Salmonella (image courtesy PFSE)

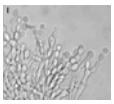


Norovirus (PFSE)



Toxoplasma (PFSE)

http://www.biosci.ohio-state.edu/~parasite/taenia.html



Fungus producing spores
(image courtesy Jim Deacon at

Infectious Disease Continued

- Communicable : spread from one host to another eg. Rubeola (red measles) or influenza
- Non-communicable :
  1. Originate from "normal" flora eg. Thrush by *Candida albicans*
  2. Poisoning following ingestion of toxin (e.g. botulism)
  3. Infections caused by agents found in the environment (e.g. tetanus)

Koch's Postulates

1. Specific causal agent must always be observed in every case of the disease
2. Agent must be isolated from a diseased host and must be grown in pure culture
3. When isolated agent is inoculated into susceptible host, it must cause disease
4. Must then be able to re-isolate the agent from the experimental host and show it is the same

Human Bacterial Load

- 10^{12} bacteria on skin,
- 10^{10} bacteria in mouth,
- 10^{14} bacteria in alimentary canal
- Shed 10^{10} skin scales every 24 hours and these will harbour 4 x 10^{7} bacteria

Image courtesy NASA

Risks in Space

- Conditions ripe for infectious disease
  - Crowded
  - Close
  - Recycled water and air
  - Not just humans to consider!
- Longer the mission duration, the greater the risk

Image courtesy Yellowstone Natl. Park

Images courtesy NASA

Risks continued

- Contamination (air, water, surfaces)
- Food spoilage
- Degradation of critical material
  - Electronics
  - EVA suits

Astronauts in STS-45 enjoy a meal (photos courtesy of NASA)

Risks continued

- Sources of contamination
  - Humans
  - Earth environment
  - Plants or animals
  - Foodstuff
  - Nothing is completely sterile!
  - It came from outer space! Or did it?

Images courtesy of NASA

Risks + Space Environment

- Microgravity
  - Bacteria do not behave as they do on Earth
    - Difference in growth rate and metabolism
    - Differences in antibiotic susceptibility
  - Hygiene and control not as simple as on Earth

Bathing in space

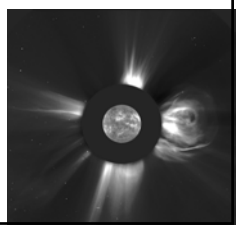
(images courtesy of NASA)

Microgravity environment

- Droplets in air
- Settle quickly on Earth
  - 100 μm diameter spheroid droplet falls 3 m in 10 seconds
  - 10 μm requires 17 minutes
- In microgravity, they stay suspended

Radiation environment

- Can have severe effects on immune system
- Can mutate bacteria



Solar flare
(image courtesy of NASA)

Risks

- Known factors that can impact the immune system

- ✓ Exposure to environmental chemicals
- ✓ Radiation
- ✓ Stress
- ✓ Isolation
- ✓ Nutrition

Image courtesy NASA

Realities

- How serious is the risk to crew health?
- What have we seen to date?

Apollo missions: reported incidents

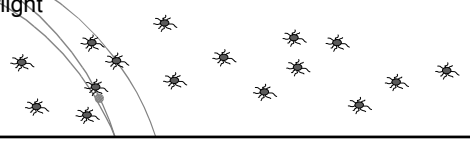
Image courtesy of NASA

- Apollo 7: During flight, crew reported upper respiratory symptoms
- Apollo 9: Launch delayed 3 days because of viral infection
- Apollo 13: Urinary tract infection caused by cold, dehydration and prolonged wearing of urine collection device

1. Taken from Historical Perspectives by Nicogossian et al. in *Space Physiology and Medicine*, third edition, Nicogossian, Hunton and Pool.

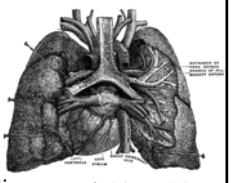
More from Apollo missions

- Apollo 7: all crew experience upper respiratory tract infection in flight
- Apollo 8: all crew experience viral gastroenteritis either before or during flight
- Apollo 9: all crew experience upper respiratory tract infection before flight
- Apollo 12: 2/3 crew report skin infections during flight



How Does Infectious Disease Rate As Risk?(In Decreasing Frequency)

1. Anorexia
2. Space motion sickness
3. Fatigue
4. Insomnia
5. Dehydration
6. Dermatitis
7. Upper respiratory tract infection
11. Urinary tract infection
15. Diarrhea



Gray's Anatomy, 1918

Troublesome Shifts in flora

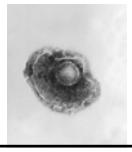
- Russian report looked at 20 cosmonauts before and after 11 missions of up to 96 days
- All showed changes in gut flora
- Changes increased with mission duration
- Increase Enterobacteriaciae, Clostridia and decrease in lactobacilli

Reality: what's been observed in space

- Immune system is depressed
- Changes seen pre-, during and post-flight
- Limited data in-flight because of difficulties in sample processing
- Antibody response appears to be largely unaffected
- Cell-Mediated immunity is decreased
  - May be related to stress and/or isolation

Varicella zoster virus (VZV)

- 1° infection usually chickenpox
- Becomes latent in ganglia
- Can reactivate in immune-compromised, weakened, stress (surgical) = shingles
- One case in astronaut 2 days before spaceflight



Electron micrograph of a VZV virion (CDC)

VZV

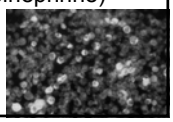
- Saliva taken from 8 astronauts before, during and after mission
- Before flight: one astronaut had VZV DNA in saliva
  (indicator of viral reactivation)
- During flight: VZV DNA detected in 7/8 astronauts
- Post flight: VZV DNA detected in all over 2 weeks
- Controls (astronauts not flying at time of study): VZV DNA undetectable
- Increase in antibody titre over control group but could not test internally

Epstein-Barr Virus (EBV)

- Latent virus present in 90% of human population
- Reactivation (shedding) can occur after physical or social stress
- Cell-mediated immune response controls localized infections that follow reactivation
- EBV is linked to several lymphomas and carcinomas

EBV Reactivation….

- Occurs before flight, but not during or after flight
  (viral DNA in saliva)
- Follow-up study observed EBV-specific antibodies before, during, and post flight
- Viral reactivation was linked to increased levels of stress hormones in astronauts
  (example of stress hormone: norepinephrine)



EBV-infected leukemia cells (green)

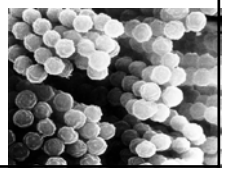
Other aspects of infection or contamination and concern

- Onboard MIR, equipment failure reported due to mold
- Free-floating condensate aboard Mir found behind a service panel (Kvant module-biological and Earth observation, drinking water, shower and washing facilities

Courtesy of Duane Pierson, NASA

What was in the condensate??

- Sampled 3 times over 5 months
- Isolated 13-18 types of bacteria, 8 fungi, protozoa (amoeba) and dust mites
- Greater combination than comparable air, water and surface samples
- Source?



Spores of *Aspergillus*, a fungal genus common in MIR

Remedies - Current

- Health Stabilization Program
  - Instituted with Apollo 14 (1971)
  - Minimize or eliminate adverse health changes in crew before launch
  - Control and reduce locations and contacts for 3 weeks before flight
  - Monitor health status of crew contacts
  - Pre-HSP, 57% of prime crew ill

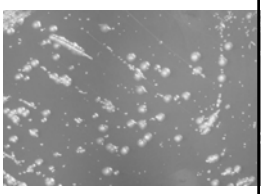
Remedies - Current

- HSP modified
  - Have since added 7 day post-flight quarantine
- Russians have used probiotics

ISS (NASA)

Remedies - current

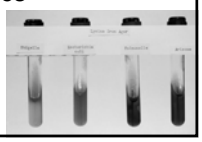
- Microbial monitoring
  - Inconsistent
  - Increasingly difficult
- Disinfection
- Air and water filtration
- Food monitored
- Have antibiotics in case



Mixture of 4 bacterial species (CDC)

Remedies - Future

- Better monitoring
  - Improved sampling
  - Onboard diagnostics
- Improved microbial control
  - More resistant or anti-microbial materials
- Systematic design of probiotics



Traditional microbial identification: too slow and cumbersome! (CDC)

Remedies - Future

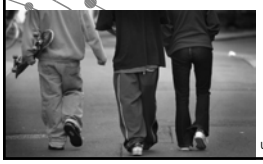
- Improved nutrition
- Know more about changes in micro-organisms in space
- Know more about changes in humans in space

USDA

Remedies -Future

- Mitigate immune effects
  - Probiotics
  - Neutraceuticals
  - Dietary nucleotides
- Mitigate stress

Courtesy of geekphilosopher.com



US Navy

Conclusions

- To date, infectious disease has not been a great risk or obstacle to human space flight
- With increasing mission duration, infectious disease could become more important

NASA

Conclusions

- Better prevention and countermeasures will come with greater knowledge of:
  - Human-microbe interactions
  - Human response to space environment
  - Microbe-material interactions
  - Microbial response to space
  - Microbe-plant interactions
  - Human-plant interactions

Closing

- Critical to any long duration exploration

NASA (Hubble telescope)

September 2004 Teleclasses

Sept 9 – Emerging Zoonoses: The Blurring of Human and Animal Health

Sept 14 – Free UK Teleclass … On-Line Resources for the Infection Control Professional
(live broadcast from the ICNA conference in Belfast)

Sept 29 – Voices of CHICA

Sept 30 – Infection Control in Daycare Settings

www.webbertraining.com/schedule.cfm