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Hospital pathogen transmission What we think we know?

Chapter 1. How we 'see' things

Mental models.

https://jamesclear.com/mental-models



Mental models.

Mental models are the **thinking tools** to **understand** life, make **decisions**, and solve **problems**. They are **imperfect**, fluid, and fuzzy - but useful - even if sometimes wrong. They are **unconscious**, which makes them treacherous.

https://jamesclear.com/mental-models

Transmission?













Colonisation versus infection?







'Micro-transmission'

- 92

Alcal Casta Anning and Patient Gare at Services



'Micro-transmission'

Alical Contra Autoring and Patient Core at Services



How do we imagine infections?



~85% of all healthcare-associated infections







"HAI is a non-transmissible disease."

Where are the 'germs'?

Microbiome / Microbiota



40 trillion bacteria 30 trillion human cells

Ron Sender, Shai Fuchs, Ron Milo: Are We Really Vastly Outnumbered? Revisiting the Ratio of Bacterial to Host Cells in Humans, in: Cell 164, January 28, 2016 | Luckey, T.D.: Am. J. Clin. Nutr. 25, 1292–1294 (1972).



https://en.wikipedia.org/wiki/Microbiota





https://thereader.mitpress.mit.edu/the-invisible-organ-shaping-our-lives-microbiome/



Infected

individual

shedding virus in

respiratory & fecal

discharge,

contaminating

surfaces &

aerosolization

≥5µm, traveling ≤ 1m (social distance)

Infectious virus transmission involving combination of both respiratory and fecal-oral routes



Conclusions of Chapter 1.

- Our brain uses 'mental models' to make sense of 'the world'. They might be wrong.
- We distinguish:
 - Transmission from transfer on mobile surfaces;
 - Colonisation from infection;
 - Endogenous from exogenous infection.
- Healthcare-associated infections are (mostly) endogenous.
- Microorganisms are everywhere useful and/or harmful as microbiota.

Chapter 2. So what do we really know?

The initial idea...



Are HA transmissible?

- 5 ICUs, 18 months, genetic typing of all strains of 10 pathogens, daily chart review
- Definition: within 9-day & same strain between patients => transmission \bullet
- 28,498 patient days, 141 transmissions, 278 infections
- 41 infections = 14.5% infections were associated with transmission.

Table 6. Ascertained transmission episodes and transmission-associated nosocomial infections related to indicator organisms in five intensive care units (Jan 2000 to July 2001)								
Intensive Care Unit	Transmissions, n	Transmissions per 1,000 Patient Days (95% CI)	Average Waiting Time Between Transmission in Days (95% CI)	Nosocomial Infections Caused by Indicator Organisms, n	Proportion of Transmission-Associated Nosocomial Infections (%)			
А	57	5.9 (4.5-7.7)	9.6 (12.6–7.4) ^a	111	21			
В	21	6.8(4.2-10.4)	$26.0 (41.9 - 16.9)^a$	28	3			
С	33	5.0 (2.2-5.3)	16.5 (37.9–15.7) ^a	40	9			
D	12	2.8(1.4-4.9)	$45.4 (90.3 - 25.8)^a$	17	2			
E	18	3.7(2.2-5.8)	$30.3 (50.2 - 19.1)^a$	82	6			
Total	141	5.0 (4.2–5.8)	23.2 (27.3–19.8) ^b	278	41 (14.5)			

Grundmann H, Bärwolff S, Tami A, et al. How many infections are caused by patient-to-patient transmission in intensive care units? Crit Care Med 2005, 33:946– 951. https://journals.lww.com/ccmjournal/fulltext/2005/05000/how_many_infections_are_caused_by.5.aspx





Conclusions

bacteria.

• A minority of healthcare-associated infections are caused by transmitted

A transmission literature review

How and how often do pathogens travel? A systematic literature review 2018

32 of 13,121 articles included

84% examined transfer **from patients/envir.—>HCWs**

Transfer from patient/their environment to:

- —> hands in 33%
- —> gloves in 30%
- —> gowns in 10%

Only two studies investigate transfer **HCW**—>patients.

Increased risk:

- moist body sites (n=7)
- longer duration of care (n=5)
- patients with an invasive device (n=3)



Wolfensberger, A. Clack L, Kuster SP, Passerini S, Mody L Chopra V, Mann J, Sax H. Transfer of pathogens to and from patients, healthcare providers, and medical devices during care activity-a systematic review and meta-analysis. Infect Control Hosp Epidemiology 39, 1–15 (2018). <u>https://doi.org/10.1017/ice.2018.156</u>





Conclusion

- Moisture increases the risk.
- Studies are lacking, especially transmission **TO** the patient.

Transmission of pathogens from patients to healthcare worker is frequent.

Where is the reservoir?



nose

Swabs from the first 2 consecutive patients of the day -> puls field electrophoresis









Swabs from the first 2 consecutive patients of the day -> puls field electrophoresis









Swabs from the first 2 consecutive patients of the day -> puls field electrophoresis





Swabs from the first 2 consecutive patients of the day -> puls field electrophoresis



Contamination

23% stopcock (126/548)

- 30 within patients
- 14 between patients



Swabs from the first 2 consecutive patients of the day -> puls field electrophoresis



infection occurred but





Conclusion

- Transfer of microorganisms in anesthesia is frequent.
- The reservoirs are high-touch surfaces > healthcare workers > patients.
- Stopcock colonisation did not lead to bloodstream infections.



How (far) do pathogen travel?





Scotoni M, Koch J, Clack, L, Pltal AK, Wolfensberger A, Grass R, Sax H. Silica nanoparticles with encapsulated DNA (SPED) – a novel surrogate tracer for microbial transmission in healthcare. Antimicrob Resist Infect Control 9, 152 (2020). https://doi.org/10.1186/s13756-020-00813-7





Scotoni M, Koch J, Clack, L, Pltal AK, Wolfensberger A, Grass R, Sax H. Silica nanoparticles with encapsulated DNA (SPED) – a novel surrogate tracer for microbial transmission in healthcare. Antimicrob Resist Infect Control 9, 152 (2020). https://doi.org/ 10.1186/s13756-020-00813-7







Fig. 1 Floor plan of the 'Patient experiment' ward with room assignments. The floor plan shows the study ward three times (once for each study run) and the localisation of the two-bed patient room, shared restroom, nurses' and doctor's office in the study ward. In Run-1 the doctor's office was situated on another floor and does therefore not appear in the floor plan. The plus signs indicate rooms with one or more positive SPED swabbing results at 8-h follow-up. Detailed swabbing sites s. Table 1. SPED silica nanoparticles with encapsulated DNA

Legend: SPED, silica nanoparticles with encapsulated DNA.

e sequence	Reported activity during eight-hour					Eight hour follow-up								
	Patient A	Patient B	Nurse	Doctor										Ì
	No particular activity reported	Reported the application of hand cream and repetitive use of bedside TV touchscreen	Did not touch the patients; used her mobile phone	Reported not performing any physical examination on any patient during this period	103003000 13003000 1003000 100300 13000 100 1		Ì			1			×	
	No particular activity reported; reported no TV use	Reported frequent hand cleansing with soap and water and alcohol- based hand sanitizer (immuno- compromised patient)	No report	No report	10000000 1000000 1000000 10000 1000 10		ĺ		Í	Ì				
	No particular activity reported	Same patient as in Run-2: Reported frequent hand cleansing with soap and water and alcohol-based hand sanitizer (immuno- compromised patient)	Reported using her mobile phone after prior handwashing with soap and water	Not available for reporting activity	10000000 1000000 100000 10000 10000 1000 1000 100 100 100	18	t A	18	t A	t B	83			
Toliet seat after Patien Flush plate after Patien Tap handle after Patien Tap handle after Patien Door handle after Patien Door handle after Patien			8	no sample available		Hands Patient Hands Patient	Bed control Patient	Bed control Patient	Phone Patient	Phone Patient	Entertainment devi Patient A	Patient B Patient B	Patient A Intravenous pur Patient B	

Ullrich, C., Luescher, A. M., Koch, J., Grass, R. N. & Sax, H. Silica Nanoparticles With Encapsulated DNA (SPED) to Trace the Spread of Pathogens in Healthcare. (2021) doi:10.21203/rs.3.rs-870804/v1







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Conclusions

- Surrogate tracers help to investigate transmission pathways.
- Pathogens can 'travel' far and quick.
- The 'last inch' of transmission -> transmission by fingers versus palms. Introducing cell phones can create new transmission pathways. •

Microbiota - an enlarged view

Distinct ecological niches define dynamic architecture of hospital resistome and mobilome.

Methods

- Repeated sampling of patient environment, 1 hospital, 45 beds.
- Combination of:
 - short-read shotgun metagenomics with
 - nanopore sequencing
 - of antibiotic-resistant mixed cultures.
- Antibiotic resistance genes in:
 - microbial genomes and
 - closed plasmid sequences.

Conclusions

- MDROs **persist** in the hospital environment for >8 years and infect patients opportunistically
- ► >60% novel sequences



Chng, K. R. et al. Cartography of opportunistic pathogens and antibiotic resistance genes in a tertiary hospital environment. Nat Med 26, 941-951 (2020).

















Conclusion

- Modern analytical methods allow to hospital environment and patients.
- Colonisation & infection of patients from the hospital up to 8 years.
- What is going on under the hood can be surprising...
- This will help to understand and upgrade our mental models on transmission and infection.

Modern analytical methods allow to 'see' the microbial life (and survival) in

Transmission network analysis

Social network analysis [Wikipedia]



Social network analysis characterises **network structures** in terms of **nodes** (individual actors, people, or things within the network) and the ties, **edges**, or links (relationships or interactions) that connect them.

Centrality assigns numbers or rankings to nodes within a graph corresponding to their network position. Applications include identifying the **most 'influential' person(s)** in a social network.

Network analysis by patient based on EMR data.

Simulation of transmission of influenza virus and Staphylococcus aureus MRSA **@Stanford Medical Center**

70-day period, 4891 patient days



Model of transmission based on probabilities (literature)

Patients' healthcare worker sharing Patients' room sharing

Cusumano-Towner, M., Li, D. Y., Tuo, S., Krishnan, G. & Maslove, D. M. A social network of hospital acquired infection built from electronic medical record data. J Am Med Inform Assn 20. 427-434 (2013).







Network analysis by patient based on EMR data.



Matrix showing the probabilities for spread of influenza between wards.

A. One infected patient in step down unit.

B. Same with 50% increase in hand hygiene.



Results of methicillin-resistant Staphylococcus aureus (MRSA) simulations conducted using a social network of hospital inpatients.

> Cusumano-Towner, M., Li, D. Y., Tuo, S., Krishnan, G. & Maslove, D. M. A social network of hospital acquired infection built from electronic medical record data. J Am Med Inform Assn 20, 427-434 (2013).



Individual hand hygiene behaviour matters. The PROHIBIT European central-line prevention study.



Kooi, T. van der et al. Hand hygiene improvement of individual healthcare workers: results of the multicentre PROHIBIT study. Antimicrob Resist Infect Control 11, 123 (2022).

Conclusions

- Network analysis/graph theory can augment our understanding \bullet
- Simulations can create hypotheses about:
 - transfer pathways
 - the effect of interventions.
- Individual hand hygiene might have a disproportional impact.

Mental models matter:

Infection or colonisation?

Exogenous or endogenous infection?

Transmission or transfer?

The last inch: micro-transmission

Microbiota become visible.

Tracers detect potential pathways.

Network analysis empowers analysis.



Please join the discussion: <u>saxhealthdesign.com</u> <u>hugo.sax@saxhealthdesign.com</u>

