Animal reservoirs in disease control and eradication

J. Segalés
Numerous infectious diseases are shared by animals and humans

### Table 1. Infections shared by animals and humans
(Estimated from McNeill 1991)

<table>
<thead>
<tr>
<th>Animal</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>dog</td>
<td>42</td>
</tr>
<tr>
<td>cattle</td>
<td>35</td>
</tr>
<tr>
<td>sheep, goat</td>
<td>26</td>
</tr>
<tr>
<td>pig</td>
<td>39</td>
</tr>
<tr>
<td>horse</td>
<td>114</td>
</tr>
<tr>
<td>poultry</td>
<td>114</td>
</tr>
<tr>
<td>rats, mice</td>
<td>298</td>
</tr>
<tr>
<td>wild species</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td></td>
</tr>
</tbody>
</table>

*Numbers overlap as some infections are shared among many species.*
... and this is not new!

Table 3. Examples of human infectious diseases of animal origin

<table>
<thead>
<tr>
<th>disease</th>
<th>microbe</th>
<th>animal source</th>
<th>date of crossover</th>
</tr>
</thead>
<tbody>
<tr>
<td>malaria</td>
<td>parasite</td>
<td>chimpanzee</td>
<td>ca. 8000 BCE</td>
</tr>
<tr>
<td>measles</td>
<td>virus</td>
<td>sheep or goat</td>
<td>ca. 6000 BCE</td>
</tr>
<tr>
<td>smallpox</td>
<td>virus</td>
<td>ruminant?</td>
<td>&gt; 2000 BCE</td>
</tr>
<tr>
<td>tuberculosis</td>
<td>mycobacterium</td>
<td>ruminant?</td>
<td>&gt; 1000 BCE</td>
</tr>
<tr>
<td>typhus</td>
<td>rickettsia</td>
<td>rodent</td>
<td>430 BCE</td>
</tr>
<tr>
<td>plague</td>
<td>bacterium</td>
<td>rodent</td>
<td>1492 CE</td>
</tr>
<tr>
<td>Dengue</td>
<td>virus</td>
<td>monkey</td>
<td>ca. 1000 CE</td>
</tr>
<tr>
<td>yellow fever</td>
<td>virus</td>
<td>monkey</td>
<td>1641 CE</td>
</tr>
<tr>
<td>Spanish 'flu</td>
<td>virus</td>
<td>bird, pig</td>
<td>1918 CE</td>
</tr>
<tr>
<td>AIDS/HIV-1</td>
<td>virus</td>
<td>chimpanzee</td>
<td>ca. 1931 CE</td>
</tr>
<tr>
<td>AIDS/HIV-2</td>
<td>virus</td>
<td>monkey</td>
<td>20th century</td>
</tr>
</tbody>
</table>
The interface between animal and human diseases

1821-1902: Rudolf Virchow recognizes the link between human and animal health

1849-1919: William Osler, father of (comparative) veterinary pathology

1947: the Veterinary Public Health division is established at CDC

1927-2006: Calvin Schwabe coins the term “one medicine” and calls for a unified approach against zoonoses that uses both human and veterinary medicine

2004: the Wildlife Conservation Society published the 12 Manhattan principles
12 Manhattan Principles – key words
(http://www.wcs-ahead.org/manhattan_principles.html)
How the concept “one health” was born?

“The One Health concept is a worldwide strategy for expanding interdisciplinary collaborations and communications in all aspects of health care for humans, animals and the environment.”

Emphasis on zoonosis and vector-borne diseases.
Emerging and re-emerging diseases

Emerging and Reemerging infections, 70% vector-borne or animal-borne

Infection Prevention & Control

http://www.onehealthinitiative.com/map.php
Control, prevention and eradication of zoonotic and vector-borne diseases

Focus on breaking the chain of transmission at its epidemiological weakest step

The most susceptible one for intervention
Control at the weakest epidemiological step... options...

- Control or eliminate the agent at the source of transmission
- Protect portals of entry (manner in which a pathogen enters a susceptible host)
- Increase host's defenses
- Others...
Definition of reservoir

“A reservoir is any person, animal, arthropod, plant, soil, or substance (or combination of these) in which an infectious agent normally lives and multiplies, on which it depends primarily for survival, and where it reproduces itself in such manner that it can be transmitted to a susceptible host.”

https://emedia.rmit.edu.au/infection_control/content/1_Reservoir/01_rese_de.htm
Definition of reservoir - complexity (Haydon et al., 2002)

- One or more epidemiologically connected populations or environments in which the pathogen can be permanently maintained and from which infection is transmitted to the defined target population.

- Populations in a reservoir may be the same or different species as the target and may include vector species.
Definition of reservoir (Haydon et al., 2002) - glossary

- **Target population (TP):** population of interest (humans in this case)
- **Non-target populations (NTP):** potentially susceptible host populations epidemiologically connected with the TP (“RESERVOIR”)
- **Critical community size (CCS):** minimum size of a closed population within which a pathogen can persist indefinitely
- **Maintenance populations (MP):** populations larger than the CCS
- **Non-maintenance populations (NMP):** populations smaller than the CCS
- **Maintenance community:** in complex systems, NMPs able to keep pathogen transmission (behaves as a MP)
- **Source population:** population that transmits infection directly to the TP
Definition of reservoir system (Haydon et al., 2002)
Definition of reservoir (Haydon et al., 2002)

Example: potential complexity of rabies reservoir in Zimbabwe and eventual intervention

If jackals with (A) or without (B) other wild carnivore populations constitute a maintenance community independent of dogs, then vaccination of dogs alone will not result in rabies elimination in the target.

If jackals do not constitute a maintenance community independent of dogs (C), then dog vaccination should clear rabies from the reservoir.
Identification of the reservoir is not an easy task sometimes…

A reservoir needs to maintain the pathogen and have a feasible transmission route

High-genetic similarity of the pathogen found in the reservoir system
High degree of functional similarity (infectivity and viability)
Spatial and temporal connectivity
Maintaining pathogen viability

Hallmaier-Wacker et al., 2017
Examples of NTP as maintenance populations (Hallmaier-Wacker et al., 2017)

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Target</th>
<th>Non-target</th>
<th>Main transmission route</th>
<th>High-genetic similarity</th>
<th>Functional similarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influenza A virus (H1N1)</td>
<td>Human</td>
<td>Swine</td>
<td>Aerosol</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>MERS-Coronavirus</td>
<td>Human</td>
<td>Camel</td>
<td>Direct contact</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Brucella melitensis</em> (localized brucellosis)</td>
<td>Human</td>
<td>Sheep</td>
<td>Food-borne</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Immunodeficiency virus</td>
<td>Human</td>
<td>NHP</td>
<td>Direct contact</td>
<td>(X)</td>
<td>NP</td>
</tr>
<tr>
<td><em>Treponema pallidum pertenue</em> (yaws)</td>
<td>Human</td>
<td>NHP</td>
<td>Direct contact/vector</td>
<td>X</td>
<td>(X)</td>
</tr>
<tr>
<td><em>Mycobacterium bovis</em> (bovine tuberculosis)</td>
<td>Human</td>
<td>Cattle</td>
<td>Food-borne/aerosol</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Rabies virus</td>
<td>Human</td>
<td>Fox</td>
<td>Bite</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><em>Echinococcus multilocularis</em> (alveolar echinococcosis)</td>
<td>Human</td>
<td>Fox</td>
<td>Oral/fecal</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Hantavirus</td>
<td>Human</td>
<td>Rodent</td>
<td>Aerosol</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ebola virus</td>
<td>Human</td>
<td>Bats</td>
<td>Contact/aerosol</td>
<td>X</td>
<td>NP</td>
</tr>
<tr>
<td>Zika virus</td>
<td>Human</td>
<td>NHP</td>
<td>Vector</td>
<td>(X)</td>
<td>NP</td>
</tr>
<tr>
<td><em>Borrelia burgdorferi</em> (borreliosis)</td>
<td>Human</td>
<td>Wildlife</td>
<td>Vector</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Yellow fever virus</td>
<td>Human</td>
<td>NHP</td>
<td>Vector</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Identification of the reservoir is not an easy task sometimes… It may require years of field and experimental work, limiting an early and timely intervention.

**Epidemiology**

**Predicting reservoir hosts and arthropod vectors from evolutionary signatures in RNA virus genomes**

Simon A. Babayan¹,², Richard J. Orton³, Daniel G. Streicker¹,³*
Identification of the reservoir is not an easy task sometimes…

Advantages:
• decrease the time between virus discovery and targeted research
• surveillance and management, mostly focused on disease control (and eventual eradication) at the origin

Disadvantages:
• limitations in accuracy (prediction of vector type of 91% and host type of 72%)

Woolhouse et al., 2018
Once the reservoir system has been identified, control or elimination at the source will depend on a number of factors:

- Policy (region, country) – culling policies, quarantine, vaccination
- Diagnostic capabilities
- Treatment/prevention measures available
- Likelihood of intervention (wildlife)
Examples of pathogen control at the source: avian influenza

Efficacy of Two H5N9-Inactivated Vaccines Against Challenge with a Recent H5N1 Highly Pathogenic Avian Influenza Isolate from a Chicken in Thailand

Michel Bublot, François-Xavier Le Gros, Daniela Nieddu, Nikki Pritchard

Vaccine protection of chickens against antigenically diverse H5 highly pathogenic avian influenza isolates with a live HVT vector vaccine expressing the influenza hemagglutinin gene derived from a clade 2.2 avian influenza virus

Darrell R. Kapczynski, Motoyuki Esaki, Kristi M. Dorsey, Haijun Jiang
Examples of pathogen control at the source: Nipah virus infection

1998-99: Infected zones of 2 km radius and buffer zones of 10 km radius were imposed around infected premises. All pigs within the buffer zone were culled over a 2-month period (a total of 901,228 pigs from 896 farms) (source: FAO)
Examples of pathogen control at the source: rabies

The elimination of fox rabies from Europe: determinants of success and lessons for the future

Conrad M. Freuling\textsuperscript{1,\dagger}, Katie Hampson\textsuperscript{2,\dagger}, Thomas Selhorst\textsuperscript{3,\dagger}, Ronald Schröder\textsuperscript{3}, Francois X. Meslin\textsuperscript{4}, Thomas C. Mettenleiter\textsuperscript{1} and Thomas Müller\textsuperscript{1}
Examples of pathogen control at the source: MERS-CoV

VIROLOGY

An orthopoxvirus-based vaccine reduces virus excretion after MERS-CoV infection in dromedary camels

Take home messages

• Most emerging and re-emerging diseases are of zoonotic or vector-borne origin
• A reservoir is a complex network of populations in which the pathogen is maintained and from which infection is transmitted to the target population
• Animal and vector reservoirs might be potentially predicted based on signatures of RNA viral genomes
• Most of the control measures at reservoir level, when feasible, imply culling or immunization; eventually, action can be taken on wildlife
Acknowledgements
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www.virologia2019.com
Thank you very much for your attention!!!