Wildlife Rabies Control -
Latest Achievements and Challenges Ahead

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Introduction
Lyssaviruses

Rhabdoviridae – Mononegavirales

Presence of terrestrial rabies

Bat lyssaviruses

Modified Aréchiga et al., 2013
Terrestrial Rabies
Large Variety of Reservoir Species

Dogs are the main problem!

FLI, 2015
Terrestrial Rabies
Dog-mediated (human) Rabies

Heaviest incidence of human deaths falls on Africa and Asia.
Terrestrial Rabies
Dog-mediated (human) Rabies

THE UNITED AGAINST RABIES COLLABORATION

Dog vaccination can eliminate human rabies
Vaccinating 70% of dogs in high-risk areas breaks rabies transmission cycle

ZERO by 30
SDGs
Public good

PARTNERS
Maximizing resources & impact

UNIFIED AGAINST RABIES
Coordinating, catalytic & country-centric

COUNTRIES
Leading elimination efforts

Global Communities & Practice
Implement & Own
Terrestrial Rabies
Occurrence of Wildlife-mediated Rabies

Source: WHO/FLI 2015
Oral Rabies Vaccination of Wildlife

Only Solution

Susceptible

Immune barrier

Protected
Oral Rabies Vaccines

Attenuated Vaccines

1st generation

- 'sheep'
- RB-71
- RV-97
- KMIEV 94
- VRC-RZ2

2nd generation

- Vnukovo 32
- ERA (Evelyn-Rokitnicki-Abelseth)
- ERA BHK21
- SAD Bern
- SAD B19
- SAD P5/88
- SAD Bern

3rd generation

- rERA
- ERAG3G
- ERA-GS
- ERA-N273/394-G333
- SPBN GAS
- SPBN TrigAS
- SPBN TriGAS
- SPBN GASGAS
- LBNSE-Flagelin
- LBNSE-GM-CSF
- ORA-DPC
- SAD dIND
- SPBN cyto-C(+)
- SPBNGA
- SPBNGA-GA
- LBNSE-IL-15
- LBNSE-GM-CSF

Colored squares indicate:
- Pink = Passaging
- Light Green = Plaque purification/clonal selection
- Blue = Mab selection
- Orange = Reverse genetics
- Red = Licensed
# Oral Rabies Vaccines

## Recombinant Vaccines

<table>
<thead>
<tr>
<th>Virus backbone</th>
<th>Name</th>
<th>Immunogenic component</th>
<th>Target species</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CadV-2 (canine adenovirus)</td>
<td>CAV-2-E3Δ-RGP</td>
<td>G-protein</td>
<td>Wildlife</td>
<td>(Zhao et al., 2014)</td>
</tr>
<tr>
<td>RCN</td>
<td>RCN-G</td>
<td>G-protein</td>
<td>Bats, wildlife</td>
<td>(Stading et al., 2016)</td>
</tr>
<tr>
<td>Vaccinia (poxvirus)</td>
<td>VR-G</td>
<td>G-protein</td>
<td>Dogs, wildlife</td>
<td>(Kieny et al., 1984)</td>
</tr>
<tr>
<td>PIV5 (parainfluenza virus)</td>
<td>PIV5-G</td>
<td>G-protein</td>
<td>Bats, wildlife</td>
<td>(Huanq et al., 2015)</td>
</tr>
</tbody>
</table>
Wildlife Rabies Control – Latest Achievements
Success Stories
Europe (i)
Elimination of fox rabies
Success Stories

Europe (ii)

Elimination of Fox Rabies (1978-2018)

- ORV implementation
- Coherent area: 2.73 Mio km²
  Cumulative area: 38.5 Mio km²
- area ever vaccinated
- 15 countries (by 2018)
- rabies free countries

30 countries
Success Stories
Europe (ii)
N° of vaccine baits used (1978-2018)

736 Mio. baits
Success Stories
North America (iii)

Reservoir Species Dependent Success

Elimination of Arctic Variant Rabies in Red Foxes, Metropolitan Toronto

R. C. Rosatte, M. J. Power, D. Donovan, J. C. Davies, M. Allan, P. Bachmann, B. Stevenson, A. Wandelre, and F. Muldoon

Elimination of Rabies from Red Foxes in Eastern Ontario


Thomas J. Sidwa, DVM; Pamela J. Wilson, MEA; Guy M. Moore, MS; Ernest H. Oertli, DVM, PhD, DACVP; Bradley N. Hicks, BS; Rodney E. Rohde, MS; David H. Johnston, BSc
Wildlife Rabies Control  
Challenges Ahead
Oral Rabies Vaccination of Wildlife

Pillars & Challenges

- Vaccine strain
- Target species
- Bait delivery & distribution system
- Vaccination strategy

Vaccine baits
Challenges

Europe (i)

Maintenance of Freedom

- European Union
- Vaccination Area 2018
- Vaccination belt
Challenges
Europe (ii)
ORV in Eastern Europe - financial & logistical overkill?

ORV 2013
1.22 Mio km²
Challenges
Europe - North America (iii)
Vaccination Strategy in Large Areas?

Alternative vaccination strategies:
- Territorial coverage
  - Gliding window vs. large scale
  - Minimum ORV area
- Vaccination intervals
- Natural barriers
- Bait densities
- Flight line spacing
- Cost-effectiveness
Challenges
Europe (iv)
Prevention of Re-introduction

30 imported rabies cases (1990 - 2018)

Rapid communications
Identification of a rabid dog in France illegally introduced from Morocco
Challenges
Europe (v)

(Re)- Incursions into Rabies Free Areas

raccoon rabies - Canada 2016

fox rabies - Italy 2008

fox rabies - Greece 2012

Source: Stevenson et al. (2016), Tsiodras et al. (2012), de Bendictes et al. (2008)
Challenges
North America (vi)
Multi Reservoir Species

“Living in a sea of rabies”

Source: Richard Chipman, USDA Wildlife Services, REDIPRA 16 - Nov. 2017
Containment rather than Elimination

Focus has been directed toward contingency actions to "hold-the-line"
Challenges
North America (viii)
Bat rabies - Spillovers
Challenges
North America (ix)

Bat rabies - Host Shift Events

- raccoon
  - current raccoon endemic (Rupprecht et al., 2017)

- red fox
  - Price Edward Island (Daoust et al., 1996)

- skunks
  - Flagstaff, Arizona (Leslie et al., 2006)
Challenges
Europe (x)
Host Shift Events - When Rabid Dogs Meet Wildlife
Challenges

Europe (xi)

Multi Reservoir Species?
Challenges
Europe (xii)
Multi Reservoir Species!
Challenges

General issues (xiii)

Minimum Effective Titre of Oral Rabies Vaccines

10^5.0  10^6.0  10^7.0  10^8.0  10^9.0  10^{10.0}

FFU/ml oral

Rabies – Oral Vaccination
Challenges
General Issues (xiv)

Difference in Vaccine Uptake

Palatine Tonsil
Challenges
General Issues (xv)
Bait Development - No Bait fits all Species

Source: Richard Chipman, USDA Wildlife Services, REDIPRA 16 - Nov. 2017; courtesy Ad Vos
Challenges
General Issues (xvii)
Optimal Bait Distribution

Source: http://news.cornell.edu/stories/2011/02/cornell-helps-get-long-island-raccoons-rabies-free, courtesy Ad Vos
Challenges
Europe & North America (xviii)
Understanding Urban-Suburban Challenges
Conclusions

- Wildlife rabies **cannot be eradicated(!)**
- Elimination of rabies feasible for certain wild reservoir species
  - ORV is an effective tool to control rabies in those species
  - Will be a long, stony road and will take decades
- A multitude of challenges ahead & problems to be solved
  - Need for sustained political and financial support
  - Development of alternative, more potent or species-specific oral rabies vaccines
  - Need for more fundamental & applied research needed
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