Workshop on the harmonisation of FMD vaccination strategy in North Africa

Keith Sumption, Chris Bartels, Nick Lyons and Fabrizio Rosso

EuFMD
A vaccination strategy is a process

PLAN – understand risks
  – Outbreak investigation, sero-surveys

APPLY
  – Vaccination strategies

CHECK – monitoring
  – vaccine and vaccination
    • Vaccination coverage
    • Vaccine failure
    • Vaccine quality assessment

ACT – evaluate and redesign
  – Risk-based or targeted
Phases of a vaccination programme

- equally important -

Design

Implement

Evaluate
NOTE: Disease phase of FMD epidemics are naturally short. But circulation does not naturally disappear...
Structure

- Design: what do we want?
- Implementation: how do we deliver it?
- Monitoring: is it working?
- Evaluation: do we need to change anything?
**Strategy:** a plan of action designed to achieve a long-term or overall Goal

An action that managers take to attain one or more of the organization’s goals. Strategy bridges the gap between “where we are” and “where we want to be”.

![Strategy Diagram](Image)
Harmonised strategies

Require a *common vision*: what are the GOALs to achieve

Do NOT mean countries do the same actions

But do require that national actions work towards achieving the same goal

ExCom87
Examples: EuFMD Strategy for the Control of FMD in Europe (1954-):

Common vision: to control FMD in Europe by effective national actions

Members undertake to control foot-and-mouth disease with a view to its ultimate eradication by the institution of suitable quarantine and sanitary measures and by one or more of the following methods:

• a slaughter policy;
• slaughter together with vaccination;
• maintenance of totally immune cattle population by vaccination; other susceptible livestock may be vaccinated.
• vaccination in zones surrounding outbreaks.

NOTE: in the strategy if ““total immunity”” in cattle could not be maintained SLAUGHTER of infected herds (+vaccination) was expected to be rigourously undertaken.

ExCom87
The EuFMD strategy also included special vaccination actions at the borders – Thrace (1962-) and TransCaucasia (1999-2012) funded by member states and EU.
What is the objective of the vaccination – within a framework of limited resources?

The strategy used will depend upon the objective of the campaign:

- Reducing the level or impact of clinical disease
- Reducing the circulation of virus
- Other objectives?
Phases of a vaccination programme

- equally important -

Design

Implement

Evaluate
Designing of the strategy

- Definition of the objectives
- Identification of resources needed
- Identification of short - long term risks
- Definition of timelines
- Identification of interested parties
- Evaluation and selection of suppliers
What is the objective of the vaccination?

The strategy used will depend upon the objective of the campaign – reducing impact (PCP stage 2), or virus circulation (stage 3/4)
Control of disease vs Control over Circulation

1. PCP Stage 2: outcome expected - reduced FMDV impact
   - Focus is on reduced consequence if animal infected
   - National strategies can describe different targets for the subpopulations (risk classifications)

3. PCP Stage 3: outcome expected – control over virus circulation
   - Additional Focus is to achieve reduced probability of transmission
<table>
<thead>
<tr>
<th>PCP Stage</th>
<th>Outcome measure</th>
<th>Vaccination programme design objectives</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>DISEASE burden</td>
<td>Reduced consequence of infection</td>
<td>Dairy/private sector schemes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Public funded cattle-only vaccination</td>
</tr>
<tr>
<td>3</td>
<td>Virus circulation</td>
<td>Reduced transmission rate</td>
<td>Programmes that require vaccination as a condition for movement.</td>
</tr>
<tr>
<td>4</td>
<td>Evidence for non-circulation</td>
<td>Complete interruption to virus circulation</td>
<td>Programmes that aim at CONTINUAL herd immunity levels</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SUFFICIENT TO PREVENT virus circulation</td>
</tr>
</tbody>
</table>
## Tactical Options -1

<table>
<thead>
<tr>
<th>Buffer Zone vaccination</th>
<th>Objective</th>
<th>Success requires:</th>
<th>Weakness</th>
</tr>
</thead>
</table>
|                         | Separate two populations of different FMD status | • Control over entry and exit to zone.  
• Targetting of high risk livestock | Insufficient control over borders - livestock pass across zone |

| Pre-movement vaccination | Reduce risk of non-immune animals spreading infection when moved. | • Regulation of movement across internal borders.  
• Passport/ID systems to prove immunised. | • Epidemic strains not matched by vaccine.  
• Effective immunity needs a booster vaccination |

| International pre-movement vaccination | Reduce risk of animals entering the country with infection | Co-operation with neighbouring countries (formal) or traders (informal) | • Risks of inadequate immunisation schedules.  
• Problems with ID of vaccinates |
## Tactical Options - 2

<table>
<thead>
<tr>
<th></th>
<th>Objective</th>
<th>Success requires:</th>
<th>Weakness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency re-vaccination</td>
<td>Address problems in Disease reduction or to control circulation</td>
<td>• Capacity for safe implementation. • Protocols to avoid spreading infection • Existing baseline immunity OR Vaccines capable of high potency or booster 21 days after first. • At least 5 days between vaccination and challenge</td>
<td>• High potential wastage where vaccine used too late. • For new strains, booster vaccination required.</td>
</tr>
<tr>
<td>(Ring, Zone, Risk Group)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Special vaccination programmes for high trasmission risk groups</td>
<td>Reduce risk of non-immune animals spreading infection.</td>
<td>Political and Administrative capacity to target risk groups.</td>
<td>• Targets hard to reach. • Impact hard to measure. • Owners may not co-operate</td>
</tr>
</tbody>
</table>
Vaccination against DISEASE: vaccine potency matters

Expect 20% cases of clinical disease on challenge with a 3 PD50 vaccine and HIGHER when not well antigenically matched

Data taken from Vianna Filho et al, 2003
Vaccination against disease: potential failure issues

Recipient-related
- Immunodeficiency
- Immature immune system (i.e. age)
- Poor health
- Waning immunity
- Immunological interference (e.g. maternal immunity)

Vaccine-related
- Low potency
- Poor match to field strain
- Interference from other vaccines
- Manufacturer problems (i.e. poor quality batch)

Incorrect usage
- Administration error (wrong dose)
- Incorrect schedule (e.g. no booster)
- Poor storage (e.g. cold chain issues)
- Beyond expiry date of product

Programme problems
- Vaccine availability
- Incorrect timing or schedules
Reducing disease: management process

Set targets:
- maximum level of acceptable FMD loss for each husbandry sector - or farm

Design sector vaccination programmes to provide this

Monitor performance (effectiveness)

Evaluate and Act:
- Act/Issue guidance when effectiveness is too low or FMDV risk changes

ExCom87
Reducing virus **circulation**: management process

- Identify key transmission risk groups in livestock population
- Identify options to reduce transmission - Design movement and vaccination programmes to provide this
- Monitor performance (coverage, immunity, impact on circulation)
- Evaluate and Act: Act/Issue guidance when circulation is too high or FMDV risk changes
Vaccination to prevent virus circulation: aim is to reduce $R_0$ to $< 1$

- Basic reproduction number ($R_0$) – average number of secondary cases for each primary case of disease in a naïve population

- Net reproduction number ($R_n$) – $R_n = 1$
  - immune population
  - $< 1 = \text{outbreak will die out}$
What is the Herd immunity required to prevent circulation?

To have a critical proportion protected such that infection will no longer lead to a major outbreak as the proportion of susceptibles becomes too small: \( R_0 < 1 \)

That critical proportion is defined by \( =1 - \frac{1}{R_0} \)

If \( R_0 \) more than 5: critical proportion > 80%

Critical proportion to be protected

- Not vaccinated
- Vaccinated
What herd immunity is required to prevent circulation of a disease?

FMD - Ro

Calves – clinical: 2.52 (Orsel et al., 2008)
Calves – non-clinical: 0.30 (Orsel et al., 2008)
Lactating cows – non-clinical: 177 (Orsel et al., 2008)
Piglets – non clinical: 13.2 (Orsel et al., 2008)
Pigs: 40 (Eblé et al., 2008)
Sheep: 1.1 (Orsel et al., 2007)
Which species to vaccinate? Ro and mixed cattle and sheep systems

- $R = 5.3$
- $R = 4.4$
- $R = 3.7$
- $R = 2.1$
- $R = 1.1$

The higher the proportion of cattle in a mixed cattle-sheep population, the higher the $R$ for the mixed population

100% cattle

78% cattle (NL)

61% cattle (Uruguay)

24% cattle (New Zealand)

0% cattle i.e. 100% sheep

Source: Carla Bravo de Rueda

Vaccination of cattle only will be sufficient to stop transmission in mixed populations of cattle and sheep

C. Bravo de Rueda, A. Dekker, P.L. Eblé, M.C.M. de Jong
Vaccination of both cattle and sheep
Which % of animals needs to be vaccinated

\[ P_c = 1 \rightarrow 83\% \]
\[ P_c = 0.78 \rightarrow 79\% \]
\[ P_c = 0.61 \rightarrow 75\% \]
\[ P_c = 0.24 \rightarrow 56\% \]
\[ P_c = 0 \rightarrow 14\% \]

NB In fully vaccinated populations \( R < 1 \)
Modelling predictions for mixed sheep and cattle populations:

In mixed cattle-sheep populations with at least 14% of cattle, vaccination of cattle only seems to be sufficient to reduce $R<1$.

Acknowledgements:
Dutch Ministry of Economic Affairs
European Community’s Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 226556 (FMD-DISCONVAC)
Herd immunity is NOT the same as vaccination coverage

Herd Immunity wanes after each vaccination

Re-vaccination intervals matter
Why is it difficult to maintain high coverage levels for FMD?

Simple coverage model in Excel

80% coverage level

- 90% vaccinated
- 10% Turnover
- 6m immunity
- Static population size
Why is it difficult to maintain high coverage levels for FMD?

Simple coverage model in Excel

- 80% coverage level
- 90% vaccinated
- 10% Turnover
- 6m immunity
- Static population size
Why is it difficult to maintain high coverage levels for FMD?

Simple coverage model in Excel

80% coverage level

90% vaccinated
10% Turnover
6m immunity
Static population size
As animals are kept in groups, we must consider inter-herd transmission.

Ro (reproductive rate) depends on:
1. Contact structure between epi-units,
2. Duration of contact (infectious) period
   • segregation infectious from susceptible livestock

However, there is large variability of R-epi unit between:
• Species
• Age structure
• Production systems, different contact structure
• Risks exposed
What can be done? How can we use vaccination to prevent circulation?

Either:
Reduce inter-herd transmission (Ro)
➢ Movement management rules

OR
Target vaccination to risk populations
➢ Greater effect of limited resources
➢ % Herd immunity targets differ

OR DO BOTH
Mass vaccination strategies frequently fail if they are not risk based.

- **FMDV is highly contagious (high Ro) - the Herd immunity is insufficient to prevent circulation**
- **The herd immunity required relates to risk of transmission (Ro)**
  - Risk of transmission relates to intra-herd contact (density) and inter-herd contact rate
- **Argues for Risk based vaccination strategies**

ExCom87
Risk-based vaccination - Principles

- Risk-based or “targeted” vaccination
- Certain animals may be at a higher risk of disease (management, age, breed, location)
- In some animals the disease may be more severe with a greater economic impact (dairy cows, young animals)
- Focussing on these animals may be a much more efficient and cost-effective way of using limited resources

Risk is defined by

\[ \text{Risk} = \text{Probability} \times \text{Consequence} \]
Random (mass) compared to Risk based vaccination:

1st campaign

2nd campaign

Random application of vaccine

Risk-based application of vaccine
- Animal markets
- Borders
- Intensive production system
Where is the virus?

1st campaign

2nd campaign

3rd campaign

Could be anywhere

Unlikely in the vaccinated epi-units
## Issues to address in the vaccination plan

<table>
<thead>
<tr>
<th>Animal</th>
<th>Vaccine</th>
<th>Delivery</th>
<th>Programme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact structure</td>
<td>Potency</td>
<td>Biosecurity applied by vaccinators</td>
<td>Planning</td>
</tr>
<tr>
<td>Within epi-unit and between epi-units</td>
<td>Self-life</td>
<td>Correct application</td>
<td>- Season</td>
</tr>
<tr>
<td>Livestock turn-over</td>
<td>Matching</td>
<td>Coverage within and between epi-units</td>
<td>- Production systems</td>
</tr>
<tr>
<td>Species difference</td>
<td></td>
<td></td>
<td>Risk assessment</td>
</tr>
<tr>
<td>Age differences - Maternal Ab - Risks</td>
<td></td>
<td>Making farmers understand</td>
<td>Stakeholder consultation</td>
</tr>
<tr>
<td>Risk exposure: - Production systems - Management - Region</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Implementation of the strategy

- Role and responsibilities
- Stakeholder participation
- Training and Standard Operational Procedures
- Legislation and enforcement
- Evaluation and selection of suppliers
- Other control measures: Movement restrictions, Biosecurity, Informing livestock owners
- Data collection and analysis
Role and responsibility

Vaccine attributes
- Safety
- Shelf life
- Match with field virus
- Potency
- Duration of protection

Quality assessment
- Complete
- Accurate
- Regular
- Independent

Distribution
- Cold chain
- Planning
- Coverage

Central supervision
- Data format
- Collection
- Analysis
- Reporting

Application
- Injection and dose
- Age category
- Biosecurity

Local supervision
- Training
- Evaluation
- Vaccination card
- Data recording

Immune protection
- Health status

Vaccinator’s assessment
Implementation of the strategy

- Legislation framework: Regulatory requirements
- Training and Standard Operational Procedures: Biosecurity, vaccination, cold chain, safety
- Definition of responsibilities: Authority and responsibility
- Analysis of other simultaneous programmes: Optimization of the efforts
- Analysis of problems occurred in the past: Root cause analysis
- Data collection and analysis: Monitoring system
Why is it difficult to achieve high coverage levels for FMD?

You start with the target of 100% coverage...

<table>
<thead>
<tr>
<th>Condition</th>
<th>Coverage Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not at home</td>
<td>10%</td>
</tr>
<tr>
<td>No participation</td>
<td>10%</td>
</tr>
<tr>
<td>Cows late preg</td>
<td>10%</td>
</tr>
<tr>
<td>Calf too young</td>
<td>10%</td>
</tr>
<tr>
<td>Insufficient dose</td>
<td>10%</td>
</tr>
<tr>
<td>No immunity</td>
<td>10%</td>
</tr>
<tr>
<td>Home</td>
<td>100%</td>
</tr>
<tr>
<td>Participation</td>
<td>90%</td>
</tr>
<tr>
<td>Cows not late preg</td>
<td>90%</td>
</tr>
<tr>
<td>Calves</td>
<td>90%</td>
</tr>
<tr>
<td>Sufficient dose</td>
<td>90%</td>
</tr>
<tr>
<td>Immune/Protected</td>
<td>90%</td>
</tr>
</tbody>
</table>

Total effect: 47%

And no vaccine is perfectly effective....
Chapter 5 of the Risk Based Strategic Plan

1. Situation analysis
2. Benefits of FMD Control
3. Goal, objectives, tactics and activities
4. Monitoring and evaluation
5. Operational plan
6. Technical assistance
Phases of a vaccination programme

- equally important -

Design

Implement

Monitoring and Evaluation
Monitoring is different from Evaluation

**Monitoring:**
- A continuing function providing management with indications of progress
- Routine data collection and reporting to management
- Triggers actions if performance indicators not achieved e.g. in vaccination coverage or excessive disease

**Evaluation**
- Periodic event
- Objective assessment of ongoing or completed programme
- Assesses impact and efficiency
- Provides basis for major changes to programmes
- Reports to funding body/stakeholders
Chapter 4 of the Risk Based Strategic Plan

1. Situation analysis
2. Benefits of FMD Control
3. Goal, objectives, tactics and activities
4. Monitoring and evaluation
5. Operational plan
6. Technical assistance

→ Focus of EuFMD support is to assist VS to establish capacity for Monitoring and Evaluation (PCP Stage 2-3)
Monitoring principles

1. Identify indicators for measures that are critical to success
2. Identify targets to reach and levels that are not acceptable (triggers)
3. Programme the routine collection of data required and routine reporting of the achievement of indicators
4. Monitoring vaccination programmes:
   1. Coverage: monitoring for evidence targets reached - did animals receive intended level of vaccines?
   2. Immunity: monitoring for herd immunity following vaccination
   3. Impact: monitor for evidence that disease or circulation of virus is within acceptable limits
   4. Include Other critical issues such as cold chain if critical to success
Why Monitor more than coverage?

- Because good coverage does not always result in immunity or protection against disease
- Because the management and stakeholders increasingly want evidence that vaccination leads to less disease or less circulation
- Guidelines: OIE/FAO (2016, expected release mid year). Training can be provided

<table>
<thead>
<tr>
<th>Types of impact indicator</th>
<th>How measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disease</td>
<td>Herd or village studies: Vaccine Effectiveness (VE) at preventing cases</td>
</tr>
<tr>
<td>Virus Circulation</td>
<td>Surveys: Sero-conversion (NSP antibodies), usually 6-12 month age cohort</td>
</tr>
</tbody>
</table>
Monitoring impact on disease: field vaccination effectiveness studied in herds recently affected

Vaccination effectiveness (VE)
- Level of protection after vaccination

\[ VE = \frac{\text{incidence of disease in Vx}}{\text{incidence of disease in non Vx}} \]

<table>
<thead>
<tr>
<th></th>
<th>Clinical FMD</th>
<th>No clinical FMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaccinated</td>
<td>3 30%</td>
<td>7</td>
</tr>
<tr>
<td>Non vaccinated</td>
<td>7 70%</td>
<td>3</td>
</tr>
</tbody>
</table>

\[ VE = 1 - \frac{0.3}{0.7} = 57\% \]

Outbreak after vaccination?
Evaluation of the strategy

- Animal and epidemiological population immunity induced
- Consistency of the results
- Effective protection
  Comparison of clinical FMD in Vx and Non-Vx
- Customer satisfaction
- Duration of immunity
Overview of evaluation

Vaccine effectiveness

- Clinical protection
- Immune protection

Evaluation vaccine and vaccination

- Distribution and application
- Field immune response

Vaccine quality

- Correlation
- Potency
- Matching

In population
- Animal
- Epi-unit

After VX

M & E - Implementation

- Application
- Cold chain

Local VS to demonstrate to central VS

Vaccination coverage

M & E – impact

Central VS to demonstrate local VS

Veterinary services to demonstrate to livestock owners

M & E – implementation

Vaccine producer to demonstrate to veterinary services
National Risk Based Strategic Plans (RBSP)

Excellent Basis for effective, sustainable national control plans

1. Situation analysis
2. Benefits of FMD Control
3. Goal, objectives, tactics and activities
4. Monitoring and evaluation
5. Operational plan
6. Technical assistance
Control of FMD by vaccination is complex: every situation is different

It's not baking a cake...

No recipe book

Ingredients change frequently

So no standard formula works

FMDV: Every new epidemic strain will differ from the previous

It's more like managing a vegetable garden in a desert

Failure is likely... so

Identify the key risks

Monitor the key indicators as often as needed to detect problems early

Evaluate every season
Thank you
Merci beaucoup