Diagnosis of *Echinococcus granulosus* infection and epidemiology in Europe

Peter Deplazes

Echinococcoses in Europe:

- *Echinococcus multilocularis* (Alveococcus multilocularis)
  - Alveolar Echinococcosis (AE)
  - Alveococcosis
- *Echinococcus granulosus* s.l.
  - Cystic Echinococcosis (CE)
  - Hydatid disease

Approximate Geographical Distribution of *Echinococcus granulosus*

(Status: 1999)

- **Echinococcus granulosus**
  - F: Free
  - PF: Provisionally Free

Approximative distribution of *Echinococcus granulosus* s.l. in Europe

- *E. canadensis* (pig strain, G7)
- *E. ortleppi* (cattle strain, G5)
- *E. equinus* (horse strain, G4)
- *E. granulosus* (s. stricto), (sheep strain, G1/23)
Echinococcus granulosus (sensu lato) strains reported from EU MSs (scientific report, EFSA)

<table>
<thead>
<tr>
<th>Country</th>
<th>Genotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium, Ireland</td>
<td>G4</td>
</tr>
<tr>
<td>Bulgaria, France, Portugal</td>
<td>G1/2/3</td>
</tr>
<tr>
<td>Estonia, Latvia, Lithuania, Slovak Republic</td>
<td>G7</td>
</tr>
<tr>
<td>Finland, Sweden</td>
<td>G10</td>
</tr>
<tr>
<td>Great Britain</td>
<td>G1, G4</td>
</tr>
<tr>
<td>Italy</td>
<td>G1/2/3, G4, G5, G7</td>
</tr>
<tr>
<td>Netherlands</td>
<td>G5</td>
</tr>
<tr>
<td>Poland</td>
<td>G7, G9</td>
</tr>
<tr>
<td>Romania</td>
<td>G1/2/3, G7</td>
</tr>
<tr>
<td>Spain</td>
<td>G1/2/3, G4, G7</td>
</tr>
<tr>
<td>Switzerland</td>
<td>G5 (G1, G4)</td>
</tr>
</tbody>
</table>

Note: From published papers, ( ) imported

Echinococcus ortleppi (slaughtehouse data)
Switzerland

Schlachthof St. Gallen, 1978 - 1993

E. canadensis (G7)

Example: E. granulosus in Lithuania

- The incidence of echinococcosis in slaughtered pigs has increased 2.5 times from 0.4% in 1993 to 1.09% in 1995 (Annual report of SFVS)
- Cystic echinococcosis in humans pigs, cattle (non fertile cysts): all identified as pig strain, G7 (E. canadensis)

Cystic echinococcosis in Lithuania in humans – Hospital of Infectious Diseases, Vilnius

MucinsA A. et al., 2006
Pig production in Lithuania
around 1 million pigs
65% in large industrial farms
(100-10,000 pigs/farm)
35% in small family farms,
predominantly with home slaughtering

Slaughterhouse investigation
- Echinococcus cysts were detected in 81 of 612 pigs (13.2% CI 10.7-16.2) from small family farms and in 4.1% (CI 0.8-11.5) from larger industrial farms.
- 3 of 612 pigs from small farms with atypical liver lesions were identified as *E. multilocularis*.
- Older pigs (> 1 year) had a significantly higher prevalence for *E. granulosus* (fertile cysts already found in one year old pigs)

Sources of cystic echinococcosis in Lithuania
- High number of dogs in villages
- No anthelmintic treatment
- Home pig slaughtering
- Social conditions
- Habits

*E. multilocularis* in a pig liver
Detection of Echinococcus and Taenia spp. in 240 dogs of 12 Lithuanian villages

Taeniid eggs:
- modified McMaster-method: 12 (5.0%, CI 2.6-8.6)
- Flotation/sieving (F/S-method): 33 (14.2%, CI 10.8-19.2)

Taeniid eggs: molecular analyses
- 26 (10.8%) Taenia spp.
- 9 (3.8%) E. granulosus (G7)
- 2 (0.8%) E. multilocularis

(Simultaneous infection: 3 cases E. granulosus and Taenia spp., one case E. multilocularis and Taenia spp.)

No infections in humans found.

E. equinus (G4)
Global burden of cystic echinococcosis

- US $ 4.1 billion (adjusted for underreporting, PPE estimate)
- 54% Human costs
- 46% Animal health costs


Analysis of the economic impact of cystic echinococcosis in Spain

The overall economic loss attributable to CE in humans and animals in 2005 was estimated at €148'964'534 (95% CI: 21'880'446–394'012'706). Human-associated losses were estimated at €133'416'601 (95% CI: 6'658'738–379'273'434) and animal-associated losses at €15'532'242 (95% CI: 13'447'378–17'789'491).


Required properties of tests for diagnosing Echinococcus spp. in definitive hosts

- to measure the actual infection status with intestinal immature and mature stages of Echinococcus with high sensitivity and specificity
- intra vital and post mortem examination of animals
- examination of field faecal samples
- suitable for mass-screening
- safe for laboratory personnel
- to enable quantitative investigations

Diagnosis in definitive hosts

Examination of intestinal infection

Sedimentation and Counting Technique (SCT): Gold Standard, Sensitivity of 96-100%, Specificity >98%
(† During first time of prepatency)
Diagnosis in definitive hosts: post mortem
Examination of intestinal infection: Intestinal Scraping Technique (IST)

Senstivity for *E. multilocularis*: 70-100% (15-24 slides)
Specificity >98% (? In very early infections)

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Diagnosis in definitive hosts: intra vitam

**Arecoline purgation**
Specificity >98% (? In very early infections)
Sensitivity 65-78% ?
Screening of dogs, but inefficient in up to 32% of the dogs

Arecoline hydrobromide is not approved for the use in dogs, serious adverse reactions.

Dog successfully purged of a large Taenia worm

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Diagnostic parameters of arecoline purgation and PCR testing of faecal samples (95% credible intervals) in Kyrgyzstan

<table>
<thead>
<tr>
<th>Arecoline purgation</th>
<th>Sensitivity for intestinal stages</th>
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<tr>
<td><em>E. granulosus</em></td>
<td>38% (27–50)</td>
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<td>21% (11–34%)</td>
</tr>
</tbody>
</table>

Ziadinov et al. 2008, Int J Parasitol 38, 1179

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Alternative intra vitam diagnosis of intestinal *Echinococcus* infection

**Copro-Antigens**
Genus identification
• ELISA

**Taenid eggs**
Species or strain identification
• PCR / sequencing

**Copro-DNA**
Species identification
• PCR

Specific immune reactions
not reliable

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Diagnosis in definitive hosts: intra vitam

**Coproantigen detection by ELISA**
Antibodies: polyclonal, against somatic or excretory/secretory antigens of worms, produced in immunized rabbits or in eggs from immunized chickens

**Antigens:**
- E/S somatic

**Immunization**

**Antibodies**

**Blood**

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An *Echinococcus multilocularis* coproantigen is a surface glycoprotein with unique O-glycosylation

Carbohydrate compositional analyses indicated the presence of N- and O-glycans with the ratio of carbohydrate to protein being 1.5:1 (w/w). N- and O-linked glycans were released by hydrazinolysis and analyzed as 2-aminobenzamide derivatized glycans by mass spectrometry together with HPLC and enzymatic sequencing. Novel linear O-linked saccharides with multiple β-N-acetyl extensions of reducing end Gal were identified. N-Linked glycans were also detected with oligomannose, mono-, bi-, tri- and tetra-antennary type structures, most of which were found to be core-fucosylated.

Hülsmeier et al. (2010), Glycobiology, 20 127–135, 2010


**Diagnosis in definitive hosts: intra vitam**

**Coproantigen detection by ELISA**

ELISA: Enzyme-Linked ImmunoSorbent Assay

**Sandwich-ELISA**

**Material:** Faeces, intestinal content

**Storage:** Frozen, native or diluted in buffer (egg inactivation by formaline fixation, heating, -80°C)

**Specificity:** High on genus level (80% - 99.5%),

**Sensitivity:** Depending on worm burden

**Test characteristics:** Rapid, easy, cheap

**Method of choice for mass-screening**

**Evaluation of the CHEKIT® ECHINOTEST for detecting Echinococcus granulosus coproantigens in faecal samples of dogs**

<table>
<thead>
<tr>
<th>Dog population</th>
<th>Coproantigen positive / total no. of dogs</th>
<th>Specificity (%)</th>
<th>Sensitivity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dogs from Spain infected with 10 to &gt; 500 Echinococcus granulosus specimens</td>
<td>29/35</td>
<td>---</td>
<td>83</td>
</tr>
<tr>
<td>Dogs from Spain helminth-free</td>
<td>1/52</td>
<td>98</td>
<td>---</td>
</tr>
<tr>
<td>Dogs from Spain with Taenia spp. infection</td>
<td>10/51</td>
<td>80</td>
<td>---</td>
</tr>
<tr>
<td>Dogs from Cyprus, randomly selected</td>
<td>2/97</td>
<td>98</td>
<td>---</td>
</tr>
<tr>
<td>Dogs from Ticino, Switzerland, with intestinal nematodes</td>
<td>4/79</td>
<td>95</td>
<td>---</td>
</tr>
</tbody>
</table>

**Diagnosis in definitive hosts: intra vitam**

**Coproantigen detection in dogs infected with E. multilocularis:**

- detection of infection during prepatency

- disappearance of coproantigens after worm elimination

**Sensitivity of the E. multilocularis coproantigen ELISA in faecal samples of foxes**

- Coproantigens are stable for at least 5 d at room temperature and for years at ~20°C.
- Eggs of Echinococcus are inactivated by deep-freezing (~ 80°C for at least 2-4 days)

**Home made tests required**
**E. multilocularis** coproantigen detection in sampled fox faeces in the city of Zurich

- coproantigen positive
- coproantigen negative

**Baiting and control areas in the city of Zürich**

- Baiting regime: monthly 50 baits / km²
- 1 km² baiting area (6km²)
- 6 small baiting areas (6 x 1km²)
- Control areas

- Hegglin et al., Emerging Infectious Diseases, 2003

**Faeces positive for E. multilocularis coproantigen in baited and in control areas (N=1205)**

<table>
<thead>
<tr>
<th></th>
<th>Winter 99/00</th>
<th>Spring 00</th>
<th>Summer/Autumn 00</th>
<th>Winter 00/01</th>
<th>Summer/Autumn 01</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Coproantigen-positive samples (N)</td>
<td>95% (N=22)</td>
<td>95% (N=22)</td>
<td>95% (N=32)</td>
<td>95% (N=346)</td>
<td>95% (N=605)</td>
</tr>
</tbody>
</table>

**Diagnosis in definitive hosts: intra vitam**

**Coproantigen detection by ELISA**

- Thorough evaluation of test parameters required for each batch of polyclonal antibodies used.
- Due to the heterogeneity of faeces of different animal populations (domestic dogs, stray dogs, cats and foxes), the cut-off values have to be determined for each population.

**Echinococcus multilocularis coproantigen ELISA** (Deplazes et al. 1999)

**Diagnostic parameters**

- Specificity 99.5% (calculated with 600 dog samples)
- Sensitivity 80% (calculated with fox samples)

**Predictive values**

<table>
<thead>
<tr>
<th>Prevalence of E. multilocularis</th>
<th>10%</th>
<th>1%</th>
<th>0.5%</th>
<th>0.1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative predictive value (%)</td>
<td>97.8</td>
<td>99.8</td>
<td>99.9</td>
<td>99.96</td>
</tr>
<tr>
<td>Positive predictive value (%)</td>
<td>94.7</td>
<td>61.4</td>
<td>44.6</td>
<td>13.8</td>
</tr>
</tbody>
</table>

**Alternative intra vitam diagnosis of intestinal Echinococcus infection**

<table>
<thead>
<tr>
<th>Copro-Antigens</th>
<th>Genus identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taenid eggs</td>
<td>ELISA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Copro-DNA</th>
<th>Species or strain identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species or strain identification</td>
<td>PCR</td>
</tr>
</tbody>
</table>

| Specific immune reactions | not reliable |
Diagnosis in definitive hosts: intra vitam

**Polymerase chain reaction (PCR)***

**Material:** Faeces, intestinal content  
**Storage:** Frozen, native or in ethanol (no formaldehyde!)  
(egg inactivation: heating, -30°C)  
**Specificity:** very high (96-100%)  
**Sensitivity:** high, but depending on:  
- quality of DNA (e.g. DNA degradation by formaldehyde)  
- presence of PCR-inhibitory substances in faeces/soil  
**Test characteristics:** laborious, technically demanding, expensive  
**PCR:** Method of choice for confirmatory purposes, egg identification

Detection of copro-DNA: sample preparation

1. Total DNA isolation  
   - ‘conventional’ method (phenol/chloroform extraction, DNA adsorbing matrices)  
   - very laborious, up to 4g faeces processible, PCR inhibition!  
   - commercially available kits (PCR-inhibitors adsorbing matrices; DNA adsorbing matrices)  
   - 220 mg faeces processible (up-scaling: DNA lysis with larger amounts of faeces possible, but yield of DNA as with 220 mg starting material)

**Multiplex PCR for Taeniid identification***

- E. multilocularis  
- E. granulosus  
- (all strains/species)  
- Taenia spp.

Trachsel et al., 2007, Parasitology, 134, 911

**Multiplex PCR: Primer design***

Trachsel et al., 2007, Parasitology, 134, 911

**Specificity:**

- E. multilocularis: 100%  
- E. granulosus: 100% (all species/strains)  
- Taenia spp.: cross-reaction with Mesocestoides  
  - Dipylidium, Diphyllobothrium

Detection of mixed infections
**Diagnostic strategy: egg isolation**

- Faecal samples
- Environmental samples

**Sedimentation/Flotation**

Sequential sieving

**Microscopy**

PCR with taeniid egg-positive samples only

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**Prepatent *E. multilocularis* infections in cats: copro-DNA and coproantigen results**

<table>
<thead>
<tr>
<th>Days after experimental infection</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>worm recovery</strong></td>
<td>1) 5720</td>
<td>2) 1475</td>
<td>3) 282</td>
<td>4) 6933</td>
</tr>
<tr>
<td><strong>PCR results</strong></td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td><strong>ELISA A 405 nm</strong></td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td><strong>cut-off</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**PCR results**

- *E. granulosus* 38% (27–50)
- *E. multilocularis* 21% (11–34)

**Ziadinov et al. 2008, Int J Parasitol 38, 1179**

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**Strategy for diagnosis in definitive hosts**

- cELISA
- coproscopy

**DNA isolation from:**
- isolated taeniid eggs
- faecal aliquot

**PCR**

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**Diagnosis in definitive hosts: intra vitam**

**Sensitivity (%) of microscopy, cELISA and PCRs**

<table>
<thead>
<tr>
<th></th>
<th>sieving/ microscopy</th>
<th>cELISA</th>
<th>sieving/ PCR</th>
<th>total DNA/ PCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>prepatency</td>
<td>0</td>
<td>63</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>high patency</td>
<td>100</td>
<td>83</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>low patency</td>
<td>77</td>
<td>40</td>
<td>80</td>
<td>47</td>
</tr>
</tbody>
</table>

**Al-Sabie et al., Parasitol Res, 2007**

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**Diagnostic parameters of arecoline purgation and PCR testing of faecal samples (95% credible intervals) in Kyrgyzstan**

<table>
<thead>
<tr>
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<th>PCR</th>
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<tr>
<td>Sensitivity for intestinal stages</td>
<td>Sensitivity for eggs in faeces</td>
</tr>
<tr>
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<td>21% (11–34)</td>
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</tbody>
</table>

**Ziadinov et al. 2008, Int J Parasitol 38, 1179**

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**Echinococcus infections in definitive hosts: diagnostic strategy using a cELISA screening test and confirmation of positive results by PCR**

1. **Fecal sample**
2. **Centrifugation**
3. **Isolation of taeniid egg**
4. **PCR**

*environmental fecal samples or collected ante or post mortem, inactivated (-80°C / 3 days)*
Test systems for diagnosis of *E. multilocularis* in definitive hosts

<table>
<thead>
<tr>
<th>technique</th>
<th>work intensity*</th>
</tr>
</thead>
<tbody>
<tr>
<td>sedimentation and counting technique</td>
<td>10 animals / day</td>
</tr>
<tr>
<td>intestinal scraping technique</td>
<td>20 animals / day</td>
</tr>
<tr>
<td>microscopy</td>
<td>40 samples / day</td>
</tr>
<tr>
<td>coproantigen ELISA</td>
<td>100 samples / day</td>
</tr>
<tr>
<td>PCR (total DNA isolation)</td>
<td>20 samples / day</td>
</tr>
<tr>
<td>PCR (sieving procedure)</td>
<td>10-30 samples / day</td>
</tr>
</tbody>
</table>

*Number of animals/samples that can be investigated per person and day

Diagnosis in sheep:

**Post mortem: meat inspection and necropsy: Sensitivity?**

In vivo: Ultrasound for liver infections only, serology

### Cystic echinococcosis in sheep: ultrasound for liver infections

<table>
<thead>
<tr>
<th>Study</th>
<th>Number autopsied</th>
<th>Sens</th>
<th>Spec</th>
<th>Localisation liver and lung (liver and lung, bilateral)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sage et al. 1997</td>
<td>10 (Kenya)</td>
<td>3/5 (60%)</td>
<td>10/11 (91%)</td>
<td>Liver and lung (liver and lung)</td>
</tr>
<tr>
<td>Masson et al. 1996</td>
<td>20 (Kenya)</td>
<td>Liver: ND</td>
<td>Lung: 1/6 (16.7%)</td>
<td>Lung (1/6)</td>
</tr>
<tr>
<td>Lahmar et al. 2007</td>
<td>18 (Tunisia)</td>
<td>Detected: 89/248 (36%)</td>
<td>ND</td>
<td>No faeto-positive</td>
</tr>
</tbody>
</table>

### Cystic echinococcosis in sheep: serology

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of positive sheep</th>
<th>Negative Control</th>
<th>Antigen Type of test</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Cross reactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ibrahem et al. 1996</td>
<td>59 (natural infection; Libya; UK)</td>
<td>139</td>
<td>Native AgB (Camel)</td>
<td>90</td>
<td>99</td>
<td>Th/Fh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>EGHF (Camel)</td>
<td>71</td>
<td>96</td>
<td>24/0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>EGHF (sheep)</td>
<td>36</td>
<td>93</td>
<td>48/0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rec AgB</td>
<td>25</td>
<td>99</td>
<td>0/0</td>
</tr>
<tr>
<td>Moro et al. 1997</td>
<td>94 (nat; Peru)</td>
<td>79</td>
<td>AgB (EITB; any or all bands 8, 16, 21)</td>
<td>73</td>
<td>98.7</td>
<td>Th</td>
</tr>
<tr>
<td>Kittelberger et al. 2002</td>
<td>249 (226 nat, 23 exp; Australia, Peru, Libya, UK)</td>
<td>1012</td>
<td>EgP ELISA</td>
<td>62.7</td>
<td>95.8</td>
<td>Th 12.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8kDa HcF AgELISA</td>
<td>11.2</td>
<td>96.7</td>
<td>Th 5.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>recOnco ELISA</td>
<td>5.2</td>
<td>95.8</td>
<td>Th 0</td>
</tr>
</tbody>
</table>

### Cystic echinococcosis in humans: serology

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Cross reactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immunofluorescence (E. granulosus protoscolex)</td>
<td>95% liver</td>
</tr>
<tr>
<td>Crude antigen ELISA</td>
<td>95% adult, 92% E. granulosus</td>
</tr>
<tr>
<td>Crude antigen EITB</td>
<td>98%</td>
</tr>
<tr>
<td>Affinity purified (ELISA and EITB)</td>
<td>60-92</td>
</tr>
</tbody>
</table>

Estimated sensitivity of screening procedures in humans

- Ultrasound: 69% (95% CI: 42-89.2)
- Ultrasound + EGHF-ELISA + AgB EITB: 83.2% (CI: 65.7-97.6)

### Control of Cystic Echinococcosis

- Long-term measures of public health education with primary health care
- Veterinary public health activities, such as the improvement of slaughter hygiene and meat inspection, dog registration and sanitation measures

Experience from several countries has shown that this option alone may not be sufficient and too slow for effective *E. granulosus* control
Control of Cystic Echinococcosis “attack phase”

- Elimination of definitive hosts (not feasible)
- Public health education of farmers
- Improvement of slaughter hygiene and meat inspection (especially private sector)
- Intensive praziquantel treatment of dogs
- Monitoring of the epidemiological situation
- Vaccination of sheep (new approach under investigation) (no vaccine for dogs available)
- Culling of infected (old) sheep

Control experiment in Lithuania: Praziquantel treatment of dogs with baits (4x/year, autumn, winter, spring)

The prevalence of *E. granulosus*, *Taenia* and *E. multilocularis* in control dogs (300 untreated dogs)

Diagnosis: egg isolation and PCR, Trachsel et al. 2007

The prevalence of *E. granulosus*, *Taenia* and *E. multilocularis* in Praziquantel treated dogs (Treated group 4x/year) (data of 300 dogs per year).

Control program in Cyprus

Prevalence in humans: 1972: 5 / 100'000, 1983: <0,1 / 100'000

Prevalence in sheep

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Number sheep</th>
<th>Number infected</th>
<th>% Sheep infected (exact binomial confidence intervals)</th>
<th>Mean abundance of cysts</th>
<th>Mean numbers of protoscoleces per sheep</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>205</td>
<td>92</td>
<td>44.9 (37.9–52.0)</td>
<td>2.6</td>
<td>21</td>
</tr>
<tr>
<td>2</td>
<td>264</td>
<td>140</td>
<td>53.0 (46.8–59.2)</td>
<td>3.11</td>
<td>99</td>
</tr>
<tr>
<td>3</td>
<td>280</td>
<td>165</td>
<td>58.9 (52.9–64.8)</td>
<td>2.5</td>
<td>711</td>
</tr>
<tr>
<td>4</td>
<td>188</td>
<td>155</td>
<td>82.5 (76.2–87.6)</td>
<td>4.61</td>
<td>1726</td>
</tr>
<tr>
<td>5</td>
<td>95</td>
<td>93</td>
<td>97.9 (92.6–97.7)</td>
<td>7.1</td>
<td>6899</td>
</tr>
<tr>
<td>6</td>
<td>49</td>
<td>49</td>
<td>100 (92.8–100)</td>
<td>10.28</td>
<td>9774</td>
</tr>
</tbody>
</table>

The prevalence and abundance of hydatid cysts and abundance of protoscoleces stratified according to age for sheep from Naryn Oblast, Kyrgyzstan.

Torgerson et al., 2009
The mean number of protoscoleces observed in each age class of sheep (solid bars). The open bars show the fitted model results together with their 95% Credible Intervals.

Control strategies against *E. granulosus* (sheep strain) in continental areas (Torgerson et al. unpublished)

- Combined anthelmintic treatment of dogs and vaccination of sheep
- Anthelmintic treatment of dogs
- Vaccination, anthelmintics and removal of old sheep

• Thank you for your attention!