Taenia solium Transmission Dynamics and the Burden of Neurocysticercosis

ECWG meeting
Institute of Tropical Medicine of Antwerp
Nicolas Praet

April 16th 2012
Presentation Plan

• Introduction

• The burden of NCC

• Why is it important to study the transmission dynamics of *Taenia solium*?
Introduction

• Life cycle

• Distribution and risk factors

• The diagnosis of cysticercosis in pigs and humans
Taeniosis

- Eggs accidentally consumed by humans

Human cysticercosis
- Cysts in raw or undercooked infected meat consumed by humans

Porcine cysticercosis
- Eggs in human faeces consumed by pigs

Life Cycle

Where is *Taenia solium*?

Source: http://www.who.int/en/
Where is *Taenia solium*?

Human to pig transmission: free-roaming pigs
Where is *Taenia solium*?

Human to pig transmission: no sanitations, open-air defecation
Where is *Taenia solium*?

Human to pig transmission: latrines inappropriately built
Where is *Taenia solium*?

**Pig to human transmission:** raw undercooked or pork, culinary habits
Where is *Taenia solium*?

**Human to human transmission:** direct contact or food or water contaminated with eggs

[Link to blog post: http://www.soultek.com/blog/2008/11/cngQcleanQbutQitQleavesQyourQwater.html]
How to diagnose cysticercosis?

Looking for the parasite in pigs

TONGUE INSPECTION

CARCASS INSPECTION
Looking for the parasite in humans

IMAGING

SUB-CUTANEOUS NODULES

http://www.diagnosticimaging.com/brain-mri/content/article/10162/1632814
Looking for antibodies raised against *T. solium* or circulating antigens of the parasite in porcine and human serum

**ANTIBODY DETECTION**
- ELISA (Enzyme-linked immunosorbent assay)
- EITB (Enzyme-linked immunoelectrotransfer blot assay)

**ANTIGEN DETECTION**
- SANDWICH ELISA

EXPOSURE

INFECTION
The disease burden of NCC
1. Setting priorities for public health research, policy and services

2. Comparing the cost-effectiveness of disease control programmes

3. Comparing the importance of a disease between countries/regions of the world
How to estimate the burden of a disease?

Monetary burden

Direct costs: medical doctor, diagnostic tests and treatments

Indirect costs: incapacity to go to work or to get a job

Animal production: carcass condemnation at slaughterhouse and meat price decrease
Health Burden: Disability Adjusted Life Year (DALY)

DALYs = number of years of full health lost due to the disease

= Years of Life Lost due to premature death
  = YLLs

= Years of Life lived with Disability
  = YLDs

DALYs = YLLs + YLDs

Approach used by the World Health Organization to estimate the Global Burden of Diseases
The diagram illustrates the concept of DALYs (Disability-Adjusted Life Years) and its components: YLDs (Years Lost Due to Disability) and YLLs (Years of Life Lost). The vertical axis represents quality of life, with full health at the top and worth health state or death at the bottom.

- **YLDs**: Represented by the pink area, it is the life years lost due to disability. The diagram shows that the onset of the disease typically occurs before the age of 80, and the quality of life is measured across this period.

- **YLLs**: Represented by the blue area, it is the life years lost due to death. The diagram indicates that the age at death due to the disease is also before the age of 80.

- **DALYs**: The total of YLDs and YLLs, represented by the blue + pink area, calculates the overall burden of disease in terms of disability and premature death. The formula for DALYs is:

  \[ \text{DALYs} = \text{YLLs} + \text{YLDs} \]
Estimation of the cost of *Taenia solium* cysticercosis in Eastern Cape Province, South Africa

H. Carabin¹, R. C. Krecek²,³, L. D. Cowan¹, L. Michael³, H. Foyaca-Sibat⁴, T. Nash⁵ and A. L. Willingham⁶,⁷

1 Department of Biostatistics and Epidemiology, College of Public Health, Oklahoma University Health Sciences Center, Oklahoma City, OK, USA
2 Ross University School of Veterinary Medicine, Basseterre, St. Kitts, West Indies
3 University of Johannesburg, Department of Zoology, Auckland Park, South Africa
4 Walter Sisulu University Faculty of Health Sciences, Mthatha, Eastern Cape, South Africa
5 Gastrointestinal Parasites Section Laboratory of Parasitic Diseases, National Institute of Allergic and Infectious Diseases, Bethesda, MD, USA
6 International Cysticercosis Coordination Center, Royal Veterinary & Agricultural University, Frederiksberg, Denmark
7 People, Livestock and the Environment Thematic Programme, International Livestock Research Institute, Nairobi, Kenya
The Disease Burden of *Taenia solium* Cysticercosis in Cameroon

Nicolas Praet¹*, Niko Speybroeck¹,², Rafael Manzanedo¹, Dirk Berkvens¹, Denis Nsame Nforninwe³, André Zoli⁴, Fabrice Quet⁵, Pierre-Marie Preux⁵, Hélène Carabin⁶, Stanny Geerts¹

¹ Institute of Tropical Medicine, Antwerp, Belgium, ² Institute of Health and Society, Université Catholique de Louvain, Brussels, Belgium, ³ Batibo District Hospital, Batibo, Cameroon, ⁴ University of Dschang, Dschang, Cameroon, ⁵ Institute of Neuroepidemiology and Tropical Neurology, Limoges, France, ⁶ College of Public Health, The University of Oklahoma Health Sciences Center, Oklahoma City, Oklahoma, United States of America
Neurocysticercosis (NCC) is a major public health problem in many developing countries where health care systems are not optimal. The disease is caused by Taenia solium, a zoonotic cestode whose definitive hosts are pigs. Humans become infected by ingesting undercooked or raw pork containing cysticerci. The infection, however, is not limited to the gastrointestinal tract: the larvae can develop in the brain and other organs, appearing as lesions that can manifest as migraine-type headaches and stroke, among others. The lesions are identified by brain neuroimaging studies.

In Mexico, NCC is considered endemic in Latin American, Asian, and Sub-Saharan African countries. In Mexico, NCC is one of the main causes of epilepsy and severe chronic headaches. A recent meta-analysis of published studies on the frequency of NCC estimated that 29% (95% CI: 23%–36%) of epilepsy cases in NCC-endemic areas exhibit NCC. NCC may also lead to severe chronic headaches, which are considered the equivalent of one year of healthy life lost. In addition, NCC is becoming increasingly recognized as a significant cause of morbidity, with an estimated of 25,341 (95% CI: 12,569–46,640) DALYs lost due to NCC-associated epilepsy.

This is the first estimate of DALYs associated with NCC in Mexico. However, this value is likely to be underestimated since only the clinical manifestations of epilepsy and severe chronic headaches were included. In addition, due to NCC-associated epilepsy, and morbidity due to NCC-associated severe chronic headaches, respectively.

Conclusion: This is the first estimate of DALYs associated with NCC in Mexico. However, this value is likely to be underestimated since only the clinical manifestations of epilepsy and severe chronic headaches were included. In addition, due to NCC-associated epilepsy, and morbidity due to NCC-associated severe chronic headaches, respectively. A total of 25,341 (95% CI: 12,569–46,640) DALYs were estimated to be due to NCC-associated epilepsy.
Burden estimation components

Monetary burden assessment

Direct & indirect costs linked to human health

Costs linked to pig meat production (infected meat price decrease)

Health burden assessment

DALYs lost (YLLs + YLDs)

- Human cysticercosis
  - cysts in raw or undercooked infected meat consumed by humans
  - eggs accidentally consumed by humans

- Taeniosis
  - eggs in human faeces consumed by pigs

- Porcine cysticercosis
  - eggs in human faeces consumed by pigs
Decision tree

Population of West-Cameroon

Epilepsy?

No

Epileptic patients

NCC?

No

Number of epilepsy due to NCC
Number of epilepsy due to NCC

Injuries and hospitalisation?

No

Hospitalisation + anti-epileptic treatment?

No

Medical cares?

Consultation and treatment

Traditional healer

Consultation and treatment

Medical doctor

Consultation and treatment

Both

Number of individuals in terminal nodes (red) X costs by individual
number of epilepsy due to NCC

Loss of job

No

Loss of working time

No

Job lost

No

Loss of working time

Population of pigs

Cysticercosis (tongue palpation)?

No

30% price reduction

Number of individuals in terminal nodes (red) X costs by individual
Retrospective study

Collection of existing data to estimate
1. how many individuals are suffering from NCC
2. How many pigs are infected with *T. solium*

Searching for the necessary information:
1. National and international health statistics
2. Scientific publications
3. Expert opinion

Consider the uncertainty around this information by using probability distributions for almost each of above-mentioned parameters
Monetary burden comparison

Table 8. Comparison of the monetary burden of *T. solium* cysticercosis in West Cameroon and Eastern Cape Province (ECP), South Africa.

<table>
<thead>
<tr>
<th></th>
<th>West Cameroon (This study)</th>
<th>ECP, South Africa [3]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population</strong></td>
<td>5,065,382</td>
<td>7,088,000</td>
</tr>
<tr>
<td><strong>No. (%) of NCC-associated cases of epilepsy</strong></td>
<td>50,326* (1.0)</td>
<td>34,662 (0.5)</td>
</tr>
<tr>
<td><strong>Overall monetary burden (×10^6 Euro)</strong></td>
<td>10.3</td>
<td>15.0–27.5°</td>
</tr>
<tr>
<td>○ % due to human cysticercosis</td>
<td>95.3</td>
<td>73.1–85.4</td>
</tr>
<tr>
<td>○ % due to porcine cysticercosis</td>
<td>4.7</td>
<td>14.6–26.9</td>
</tr>
<tr>
<td><strong>Monetary burden per capita (Euro)</strong></td>
<td>2.0</td>
<td>2.1–3.9</td>
</tr>
</tbody>
</table>

*based on a prevalence of epilepsy of 3.6%.

Different calculation methods were used (based on 2004 exchange rate of 1US$ = 0.805 Euro).

doi:10.1371/journal.pntd.0000406.t008

More cases in Cameroon but lower monetary burden: mainly due to difference in indirect costs (lower salary)
## DALY studies comparison

<table>
<thead>
<tr>
<th></th>
<th>Cameroon</th>
<th>Mexico</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 DALYs lost per 1,000 person-years*</td>
<td>0.25 DALYs lost per 1,000 person-years*</td>
<td></td>
</tr>
</tbody>
</table>

*years of life in perfect health yearly lost per 1000 inhabitants of the area

Higher health burden in Cameroon mainly due to higher mortality rate.
Conclusions

1. Burden of human and porcine CC may be non negligible and deserves a more global assessment

2. Identification and description of disease data gaps (epidemiological and clinical)
3. Comparison Monetary and Health burden approaches

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Monetary Burden</th>
<th>Health (DALY) Burden</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Indicator</strong></td>
<td>monetary costs related to morbidity</td>
<td>years lost due to morbidity AND mortality</td>
</tr>
<tr>
<td>Zoonotic infections</td>
<td>cost of animal production losses may be included</td>
<td>cost of animal production losses can NOT be included</td>
</tr>
<tr>
<td>Social impact</td>
<td>not taken into account</td>
<td>not taken into account</td>
</tr>
<tr>
<td>Economic impact</td>
<td>taken into account</td>
<td>not taken into account</td>
</tr>
<tr>
<td>Comparison between world regions</td>
<td>depends on time- and region-specific economical factors (difficulties in comparing poor and rich countries)</td>
<td>possible throughout the whole world</td>
</tr>
<tr>
<td>Interpretation for decision-makers</td>
<td>accessible</td>
<td>needs a certain background</td>
</tr>
<tr>
<td>Identification of decision-tree end component</td>
<td>sometimes difficult to identify for each cost</td>
<td>only mortality rate and incidence of each symptom to be identified</td>
</tr>
<tr>
<td>Disability weighting</td>
<td>not necessary</td>
<td>disability weights rather subjective and not context specific</td>
</tr>
</tbody>
</table>
GBD of NCC considered by WHO in the framework of the Foodborne Disease Burden Epidemiology Group (FERG) initiative:

- **Systematic review conducted**
- % of NCC-associated epilepsy available: 29%
- DALY calculations ongoing (estimates expected in 2013)
Why is it important to study the transmission dynamics of *T. solium*?

- Accurate burden estimates/filling data gaps on:
  - Age-related prevalence/incidence/mortality estimates (pigs and human)
  - Disease duration

- Cost-effective intervention programmes
Why is it important to study the transmission dynamics of *T. solium*?

Simulating transmission and control of *Taenia solium* infections using a Reed-Frost stochastic model

Niels C. Kyvsgaard a,c,* , Maria Vang Johansen b,c, Hélène Carabin d

a Department of Veterinary Pathobiology, Faculty of Life Sciences, University of Copenhagen, Stigbojen 4, DK-1870 Frederiksberg C, Denmark
b DBL-Institute for Health Research and Development, Charlottenlund, Denmark
c WHO/FAO Collaborating Centre for Emerging and Other Parasitic Zoonoses, Danish Centre for Experimental Parasitology, Department of Veterinary Pathobiology, Faculty of Life Sciences, University of Copenhagen, Frederiksberg C, Denmark
d Department of Biostatistics and Epidemiology, College of Public Health, University of Oklahoma Health Sciences Center, OK, USA

Received 18 September 2006; received in revised form 24 November 2006; accepted 28 November 2006
Study of the effect of age on the proportion of infected and exposed individuals

International Journal for Parasitology 40 (2010) 85–90

Age-related infection and transmission patterns of human cysticercosis

N. Praet a,e,*, N. Speybroeck a,b, R. Rodriguez-Hidalgo c, W. Benitez-Ortiz c, D. Berkvens a,d, J. Brandt a, C. Saegerman e, P. Dorny a

a Institute of Tropical Medicine, Animal Health Department, Antwerp, Belgium
b Institute of Health and Society, Université Catholique de Louvain, Brussels, Belgium
c Centro Internacional de Zoonosis, Quito, Ecuador
d Department of Animal Production, Faculty of Bioscience Engineering, Ghent University, Ghent, Belgium
e Department of Infectious and Parasitic Diseases, Epidemiology and Risk Analysis Applied to Veterinary Sciences, Faculty of Veterinary Medicine, University of Liege, Liege, Belgium
Modelling as a tool

• Available data and expert opinion on the transmission dynamics and control of *T. solium* need to be objectively synthesize in order to be objectively interpreted

• Large scale and multifactorial studies are expensive and difficult to implement

Modelling allows to use available information to estimate the prevalence/incidence and effect of control strategies on an objective manner and in different settings

Modelling may include several techniques suc as:
- Bayesian approach
- Rule-based modelling
- Expert elicitation
- Stochastic approach (uncertainty)
Conclusions

1. Burden of human and porcine CC may be non negligible and deserves a more global assessment

2. Identification and description of disease data gaps (epidemiological and clinical)

3. Transmission dynamics studies are essential to assess the burden of *T. solium*
Assessment of the global burden of cysticercosis

How to obtain these estimates when only fragmentary data are available?

2 approaches

Prospective approach
- more accurate diagnostic tools
- standardise data collection

Longitudinal age-related immuno-epidemiological and clinical data to estimate:
- the incidence of the disease
- the proportion of CC-associate symptoms

Retrospective approach
- using existing data in innovative ways

Systematic literature reviews
Meta-analyses
Simulation models
Bayesian modeling
Expert elicitation
Stochastic models
Cost-effectiveness of prevention and control programs can be tested and help national and international policy- and decision- makers in setting priorities in public health and veterinary public health policies, services and research.