REPORT

Inaugural Meeting
Cysticercosis Working Group in Europe

Instituto Gulbenkian de Ciência
Oeiras, Portugal
11-12 March 2008

Organized by:
Instituto Gulbenkian de Ciência, Portugal
College of Medicine and Veterinary Medicine, University of Edinburgh, UK
WHO/FAO Collaborating Center for Research and Training on Emerging and Other Parasitic Zoonoses, Denmark
Inaugural Meeting of the Cysticercosis Working Group in Europe
IGC, Oeiras, Portugal, 11th to 12th March 2008

Report compiled by

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INTRODUCTION
The meeting was organised under the auspices of the Global Campaign for Combating Cysticercosis which gives high priority to establishing and supporting regional cysticercosis working groups responsible for planning, implementing and monitoring activities regarding research, training, surveillance, prevention and control of cysticercosis/taeniosis based on regional needs and priorities. The aim of the meeting was to bring together European research groups, technical agency personnel and representatives of other relevant organizations based in Europe involved in combating cysticercosis (both directly and indirectly) to inform about their various ongoing/anticipated research and other related activities to ensure that everyone is informed of the regional scope of activities. The information was to provide a basis for discussion in appropriate working groups on ways to achieve a more effective, concerted European approach to combating cysticercosis.

While most of the European-based cysticercosis research and control activities are directed at the main endemic areas of Africa, Asia and Latin America there is mounting anecdotal evidence that there are still Taenia solium cysticercosis endemic areas persisting/re-emerging in certain lesser developed areas of Europe (e.g. Iberian Peninsula, southeastern Europe) and Taenia saginata remains a problem throughout Europe. Thus attention needs to be directed to further investigation of the European situation in addition to the focus on the situation in developing countries. Because of their international scope of activities and strong interest in collaboration with Europe-based institutes and agencies, the International Livestock Research Institute (ILRI) and U.S. Centers for Disease Control and Prevention (CDC) were also invited to send representatives to the meeting.

OBJECTIVES
The overall objective of convening the meeting was to promote better communication, collaboration and coordination of integrated research and control activities aimed at combating the burden of cysticercosis which would lead to improved human health and well-being as well as livestock production in endemic countries. The specific objectives were:

1. Bring together representatives from the various European-based institutes and organizations involved in cysticercosis research and control efforts to inform about their various ongoing and anticipated activities.

2. Formulate an action plan for achieving a more effective, concerted European approach to combating cysticercosis in Europe as well as the main cysticercosis endemic areas of Africa, Asia and Latin America

3. Consider the establishment of a Cysticercosis Working Group in Europe.

ACKNOWLEDGEMENTS
Many thanks go to the Instituto Gulbenkian de Ciência (IGC) in Oeiras, Portugal for providing the venue for the meeting. Drs Michael Parkhouse, Leslie Harrison and Lee Willingham served as the Organising Committee representing support from their respective institutes, i.e. IGC, University of Edinburgh and WHO/FAO Collaborating Center for Parasitic Zoonoses based at the University of Copenhagen. Appreciation goes to Dr Eric Fèvre for serving as the meeting rapporteur and assisting in formulating the meeting summary. The constructive comments of Professor Zbigniew Pawlowski and Dr Teresa Gárate were also of great help in finalizing the meeting report. Last but not least, the participants are thanked for their keen interest and enthusiasm during the meeting.
MEETING SUMMARY
The first meeting of the Cysticercosis Working Group in Europe was held 11-12 March 2008 at the Instituto Gulbenkian de Ciência (http://www.igc.gulbenkian.pt), in Oeiras, Portugal with organizational support from the WHO/FAO Collaborating Centre for Parasitic Zoonoses in Denmark and the University of Edinburgh, Scotland. The meeting brought together representatives from various European-based institutes and organizations involved in cysticercosis research and control efforts to inform about their various ongoing and anticipated activities. In total 27 participants of diverse backgrounds and expertise from 13 countries participated. The information provided by the 18 oral presentations served as a basis for discussion sessions aimed at finding ways to achieve a more effective, concerted European approach to combating cysticercosis in Europe as well as the main cysticercosis endemic areas of Africa, Asia and Latin America. The regional working group is being established as part of a larger global campaign for combating cysticercosis aimed at promoting and facilitating advocacy and networking efforts.

The meeting opened with an overarching “situation analysis”: Lee Willingham emphasized that cysticercosis is a neglected disease as it causes disabilities, interferes with work capacity, results in stigma and ostracism and affects poor populations in remote areas, and illustrated a range of current global efforts aiming to control cysticercosis on different continents. An important component of on-going efforts is the development of methods to assess the disease burden of this infection, which has been poorly addressed in the past, and for which global data, as with many neglected diseases, is lacking, in order to secure the political will and financial and technical support necessary to enable effective, cost-effective and sustainable intervention. Demand for pork meat is, however, growing consistently in developing countries, and this supply is mainly met by smallholder farmers who do not/cannot prioritise disease control. A Global Campaign for Combating Cysticercosis is being organised to act as a “driving force” which will help establish and support regional working groups which will be responsible for planning, implementing, monitoring and evaluating activities regarding research, training, surveillance, prevention and control based on regional needs and priorities.

François Meslin echoed these issues and presented cysticercosis in the context of the new WHO-led initiative on the Integrated Control of Neglected Zoonotic Diseases (see http://www.who.int/zoonoses/control_neglected_zoonoses/en/index.html). He stressed the challenges in developing a global partnership for neglected zoonotic diseases (NZD) control which include the need for intersectoral collaboration, with an emphasis on the idea of the integrated “One Health” approach (see http://www.who.int/entity/zoonoses/Report_Sept06.pdf) including integration of prevention and control measures at the human/animal interface as well as integrated control packages for multiple diseases with commonalities (e.g. interventions, reservoir species). A recent meeting held in Nairobi in November 2007 considered some of the practical, institutional, political and resources-related issues associated with implementing the NZD initiative in the African context. Cysticercosis and the other neglected zoonotic diseases are being included as a subset of the neglected tropical diseases under WHO’s global plan to combat neglected tropical diseases during the period 2008-2015 (http://whqlibdoc.who.int/hq/2007/WHO_CDS_NTD_2007.3_eng.pdf).

Zbigniew Pawlowski emphasised that *T. solium* cysticercosis/taeniosis is a focal disease, in that it can be present at high prevalence in one location and very rare in a neighbouring location; thus, in designing control activities, much remains to be done towards understanding the reasons for this variation and identifying foci and endemic areas. While the Oeiras
The meeting was well attended by those active with cysticercosis studies and control in Europe, particularly Spain and Portugal. Manuela Vilhena presented the Portuguese situation, which is two-stranded. Cysticercosis in parts of Portugal is most likely driven by immigration of already infected patients of working age from outside of Europe (e.g. from former Portuguese colonies in Africa), while in northern Portugal, there is evidence of endemic transmission between humans and pigs in smallholder production systems. Certainly, there is a need for field studies to elucidate these issues. Teresa Gárate showed that cysticercosis is rare in Spain but is an emerging problem amongst immigrants, mainly from Latin America; 10% of the Spanish population is of non-Spanish origin. There is also anecdotal evidence of endemic transmission in Extremadura Province, one of the country’s least affluent provinces, which borders Portugal. The Instituto de Salud Carlos III in Madrid, in collaboration with colleagues in Portugal, UK, Venezuela and Mexico, developed highly sensitive and specific multiplex, nested and semi-nested PCR based assays for the diagnosis/differentiation of *T. solium* and *T. saginata* and have, sequenced, expressed and characterised several parasite antigens of diagnostic and protective potential (e.g HP6, TEG, TAF, and Ts8B2).

A range of projects are underway in endemic countries with the support of European-based researchers, institutes and agencies to study taeniosis, cysticercosis and NCC in humans. In Tanzania, Erlich Schmutzhard, Joachim Blocher and Andrea Winkler have, in collaboration with local counterparts, been investigating epilepsy and NCC in the northern highlands, which has been enabled by the presence of a new CT-scanner which is the gold-standard diagnostic procedure; 14% of people with epilepsy had scans that were definitive or highly suggestive of NCC (compared to 2% of controls). Pork consumption was found to be a predisposing factor for acquiring NCC infection. A project is now being proposed to expand the research on the epilepsy-NCC association to other African countries. Lorraine Michelet, on behalf of Pierre Marie Preux, informed about French-funded research activities investigating the association between epilepsy and NCC is several countries in Latin America, Africa and Asia and also development of molecular diagnostic tests for cerebrospinal fluid. They are also involved in studies on the phylogenetics of cysticercosis isolates collected from a range of locations using mitochondrial markers including possible differences in clinical manifestations related to the genotype of *T. solium*. Lee Willingham reported on the Danish-funded project “Cross-Disciplinary Risk Assessment of *Taenia solium* Cysticercosis in Eastern and Southern Africa (CESA)” which is promoting a comprehensive approach to porcine and human cysticercosis/taeniosis. The CESA project is promoting an integrated strategy and strengthening research capacity by supporting Masters and PhD studies of students from different disciplines (e.g. medical and veterinary parasitology, neurology, veterinary public health, rural sociology/medical anthropology, pig production, etc.) in Tanzania and Mozambique.
Several studies on porcine cysticercosis, smallholder pig production and neglected zoonoses are also underway globally. Niels Kyvsgaard presented work from Nicaragua on scavenging versus confined pigs that showed scavenging pigs actually gained more weight, highlighting that for many smallholders, pig keeping is a low-input and economically viable activity, and emphasising that preventing scavenging as part of an intervention policy for combating cysticercosis is likely to be met with obstacles in implementation. Vincent Porphyre described French support for research and development in pig farming and pork meat sub-sectors in tropical regions including activities on disease control and food safety, pig husbandry systems analysis, externality management (e.g. waste management, environmental protection) and information sharing through establishment of an internet website devoted to issues in tropical pig production (see http://pigtrop.cirad.fr/). Paulo Duarte informed that the International Livestock Research Institute has recently received funding from the government of Portugal to conduct livestock research in Mozambique including cysticercosis. They intend to focus on investigating economic impact, risk mapping, market access and food safety aspects, evaluation of diagnostics and possibly use of the porcine cysticercosis vaccine for prevention and control strategies. Esther Schelling informed of Swiss involvement in economic impact assessments of cysticercosis and cost-benefit assessments of prevention and control strategies linking with the CESA project, ILRI initiatives and a new study on epilepsy and its causes in Africa being conducted under the auspices of the INDEPTH Working Group on Epilepsy being funded by the Wellcome Trust. Mark Eisler outlined a project proposed to the European Commission aimed at investigating a range of neglected zoonotic diseases in sub-Saharan Africa which would, if funded, collate appropriate data for disease burden calculations and develop integrated control packages that would target multiple neglected zoonoses including taeniosis, cysticercosis and neurocysticercosis.

Several European institutes are involved in developing immunological and molecular diagnostics for cysticercosis and taeniosis detection. Michael Parkhouse and Leslie Harrison presented work from the collaborative research programme involving institutes in Portugal, Scotland and Spain on use of the secreted metacestode glycoprotein HP10 to monitor treatment of severe neurocysticercosis. They are also involved in vaccine development using the HP6 (~TSA18) oncosphere adhesion molecule that facilitates tissue invasion as it induces a protective immune response in the host possibly blocking further colonization by T. solium parasites thus protecting from excess pathology. Nynke Deckers reported that Belgium is currently supporting multiple epidemiological studies in Africa, Asia and Latin America, a T. solium vaccine trial in northern Cameroon, and development of both antigen and antibody ELISA tests for cysticercosis as well as a PCR-RFLP test for taeniosis. Current focus is on improving the specificity of the antigen-ELISA for detecting porcine cysticercosis using nanobodies developed from heavy chain camel and llama immunoglobulins. Sweden has recently become involved in diagnostic and vaccine work on human T. solium infections in Nicaragua and Mozambique. Johan Lindh described these efforts as being aimed at identifying new immunogenic antigens from T. solium oncospheres for diagnosis and evaluating whether these can be used alone or in combination with known antigens in a “cocktail” as a vaccine. Patricia Wilkins informed about the CDC’s research on development of serum antibody tests (immunoblot) for porcine and human cysticercosis and blood/stool tests for taeniosis. Currently they are working on optimizing the format, sensitivity and specificity of these tests with the goal of producing a serological test using recombinant antigens that combines 2 proteins into a single assay for simultaneous identification of both cysticercosis and taeniosis that can be performed on both serum and fingerstick blood spots. Gilbert Domingue illustrated the approach of the recently formed not-for-profit charity the Global Alliance for Livestock Veterinary Medicines (GALVmed).
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(http://www.galvmed.org/) to help reduce poverty of poor livestock keepers in developing countries through capacity building including enabling development, testing, scaling up and delivery of diagnostics, pharmaceuticals and vaccines. A priority objective of GALVmed is the development, testing and scaling up of a vaccine to prevent porcine cysticercosis (thus blocking taeniosis transmission to humans) and a system for its eventual delivery in endemic communities.

Three working groups were formed to consider priority issues needing attention in relation to both endemic and non-endemic areas (full summary presented in appendix 2):

**Human cysticercosis, taeniosis and epilepsy**

A series of priority issues needing both policy and research attention were identified, and focussed primarily on endemic countries. Firstly, the group recognized that the distribution of taeniosis and human cysticercosis is not well defined, and that baseline mapping of domestic pig distributions and density, capitalizing on existing census data complemented by field surveys, should be a priority as this information would inform about transmission “hotspots”. These data should then form the basis of rapid assessments of the prevalence of cysticercosis in different pig populations, at an appropriate resolution. Ideally, butchered pigs/pork (e.g. at weekly markets) could be used as sentinels for the prevalence in the surrounding landscape. Having identified areas where the parasite circulates in pigs, community-based epidemiological studies should be undertaken using CT-scans (where available) and/or serological tests to assess the scale of human taeniosis and cysticercosis/NCC in the community, while also training a cadre of mental health nurses in the management of epilepsy. CT-scan data, in conjunction with serological results, may validate the latter as a diagnostic for areas where CT scanners may not be available. To address the reservoir of infection in humans, the group proposed that in appropriate areas, treatment for diagnosed cases of taeniosis be made available, and that NCC patients, their families and neighbours should be encouraged to seek testing for taeniosis. Reducing infection rates in the human carriers of adult tapeworms is ultimately the best way to reduce environmental contamination.

**Porcine cysticercosis, veterinary public health and tropical pig husbandry**

The group recognized that poor Veterinary Public Health (VPH) infrastructure and lack of proper meat inspection and control are major factors that enable transmission. Attention should be given to finding novel ways to improve pork inspection especially in rural areas, e.g. developing training material, organizing courses and designing appropriate and acceptable pig slaughtering establishments. However the group also agreed that if infected pig carcasses are totally condemned there will be a strong incentive for people to slaughter their pigs and sell the meat clandestinely thus evading the meat inspection system. A trace-back system would be helpful with regard to securing farmers’ attention to the cysticercosis issue and assist with surveillance, e.g. identifying endemic ‘hot-spots’ since butchered meat in markets can serve as a sentinel of endemicity. Investigating methods for safely processing cyst-infected meat under local conditions with the aim of maintaining a certain value of infected carcasses, decreasing unnecessary losses and thereby suppressing demand for clandestine markets would be very helpful. Sociological studies involving interviews/focus group discussions involving farmers, pig traders, butchers, meat inspectors and pork sellers may also provide information helpful for surveillance and devising prevention and control strategies. More attention should be given to understanding the importance of pigs to rural households and communities and the different management systems being practiced as well as integrating cysticercosis control efforts with those aimed at other important swine diseases, e.g. African Swine Fever.
**Tools for surveillance, prevention and control**

The strong interest and expertise in the European region with regard to diagnostics and vaccines were noted by the group. Improving the antibody and antigen assays and modifying them into more practical formats, *e.g.* dipsticks, lateral flow tests, for field use in endemic areas, as well as standardizing them at the global level were deemed priority issues. In particular large scale evaluations are needed to evaluate the use of antigen detection assays in diagnosing different forms of NCC and monitoring treatment. PCR based assays are potentially important applications for assessing environmental contamination and tracing sources of infection however their application in endemic zones is currently limited primarily due to lack of capacity. The candidate cysticercosis vaccines for pigs based on oncosphere antigens, *e.g.* TSOL18/HP6-Tsol, show great promise for blocking transmission to humans. A vaccine that targets the very early stages of the immature metacestode in the intermediate host as well as the invasive onchosphere would serve as a back-up to kill any invasive oncospheres which evade the initial immune attack. Further research is needed to ensure effective field application of the vaccines with regard to their efficacy, delivery, duration of effect, market acceptability (*e.g.* potential for inclusion in a polyvalent vaccine), etc. Attention also needs to be given to other prevention and control tools such as ensuring chemotherapy is safe for both humans and pigs, designing educational messaging for application from the professional to community level and improving sanitation through novel ways aimed at ending human outdoor defecation.

**The way forward**

The participants found the meeting to be an effective way to enable knowledge sharing and promote a regional concerted effort for combating cysticercosis which should lead to greater research collaboration, academic exchanges, etc. It was decided that the group present as well as those persons invited but unable to attend would constitute the new *Cysticercosis Working Group in Europe* and would continue holding similar meetings on a regular basis every 12-18 months under the auspices of the *Global Campaign for Combating Cysticercosis*. 

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IGC, Oeiras, Portugal, 11th to 12th March 2008
## PROGRAMME

**Tuesday 11 March 2008**

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<td>09:00 – 10:00</td>
<td><strong>Session 1. Opening</strong></td>
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<tr>
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<td>• Welcome (Parkhouse)</td>
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<td>• Overview of current global efforts aimed at combating Cysticercosis</td>
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<td>• WHO Initiative on Integrated Control of Neglected Zoonotic Diseases</td>
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<td>• Open Discussion</td>
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<td>• Chairperson: M. Parkhouse</td>
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<td>10:00 – 10:30</td>
<td>Coffee/tea break</td>
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<td>11:00 – 12:30</td>
<td><strong>Session 2. Presentation of Cysticercosis Research Groups on Current/Planned Activities</strong></td>
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<td>• Cysticercosis in Portugal (Vilhena)</td>
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<td>• Cysticercosis in Spain (Gárate)</td>
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<td>• Austrian/German research programme on Epilepsy/Neurocysticercosis</td>
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<td>• University of Limoges research activities on Epilepsy/Neurocysticercosis</td>
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<td>• Inter-disciplinary Risk Assessment of Cysticercosis Project in Africa</td>
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<td>• Medical aspects of the control of neurocysticercosis (Pawlowski)</td>
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<td>• Discussion</td>
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<td>• Chairperson: E. Schmutzhard</td>
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<td>12:00 – 13:00</td>
<td>Lunch</td>
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<td>13:00 – 14:30</td>
<td><strong>Session 3. Presentations of Cysticercosis Research Groups on Current/Planned Activities (continued)</strong></td>
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<td>• Diagnostics and vaccine research of the Portugese/British/Spanish group</td>
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<td>• Diagnostic and other research at Institute of Tropical Medicine, Belgium</td>
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<td>• Molecular diagnostics research at Karolinska Institute, Sweden</td>
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<td>• Diagnostics research at CDC</td>
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<td>• Global Alliance for Livestock Veterinary Medicines (Domingue)</td>
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<td>• Discussion</td>
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<td>• Chairperson: T. Gárate</td>
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<td>14:30 – 15:00</td>
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<td>15:00 – 16:30</td>
<td><strong>Session 4. Presentations of Cysticercosis Research Groups on Current/Planned Activities (continued)</strong></td>
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<td>• Porcine cysticercosis research capacity building in Latin America</td>
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<td>• ILRI research on pigs and porcine cysticercosis (Duarte)</td>
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<td>• Tropical pig husbandry research at CIRAD (Porphyre)</td>
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<td>• Assessing the economic impact of cysticercosis (Schelling)</td>
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<td>• Discussion</td>
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<td>• Chairperson: M. Vilhena</td>
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<td>16:30 - 18:00</td>
<td><strong>Session 5. Working Group Discussions</strong></td>
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<td>• Human Cysticercosis, Taeniosis and Epilepsy</td>
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<td>• Tools for Surveillance, Prevention &amp; Control</td>
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**Wednesday 12 March 2008**

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<tr>
<td>09:00 – 10:30</td>
<td><strong>Session 6. Working Group Discussions (continued)</strong></td>
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<td>10:30 – 11:00</td>
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<td>11:00 – 12:00</td>
<td><strong>Session 7. The Way Forward</strong></td>
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<td>• Closing</td>
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<td>• Chairperson: M. Eisler</td>
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SUMMARY OF WORKING GROUP DISCUSSIONS

Working Groups
1. Human Cysticercosis, Taeniosis and Epilepsy
2. Porcine Cysticercosis, Veterinary Public Health and Tropical Pig Husbandry
3. Tools for Surveillance, Prevention and Control

Considerations for the Working Groups:
1. Priority issues needing attention in relation to:
   1.1. surveillance and control needs in endemic areas
   1.2. imported cases in non-endemic areas
2. Opportunities for more concerted efforts to address these needs
3. Possibilities for mobilising resources to enable these efforts
4. Other relevant issues

GROUP 1: HUMAN CYSTICERCOSIS, TAENIOSIS AND EPILEPSY

The Working Group considered the problem of human cysticercosis, taeniosis and epilepsy by addressing a series of key questions and whether data were available to answer those questions, and if not, what focussed data collection exercises would be necessary.

1. Where is the problem?
The major public health impact of T. solium infections is neurocysticercosis (NCC), sometimes fatal and frequently – if symptomatic – responsible for chronic debilitating illness, including epilepsy. T. solium taeniosis/cysticercosis (t/c) is not a global problem but is an area specific one i.e., regional or even local one. It may even be on the increase, e.g. in Africa, due to increasing pig production and meat consumption trends. Endemicity of t/c depends on an unsanitary environment, mostly in undeveloped countries, where pigs have access to human faeces and where meat hygiene is insufficient. Migrating people infected with T. solium taeniosis play an important role in spreading cysticercosis in the populations of both endemic and non-endemic countries. This is, of course, more visible in non-endemic countries, e.g. in USA, where foci of NCC occur in local populations around some infected immigrants. Focality of human and porcine cysticercosis is very characteristic for T. solium infections (Ref 1) which has important consequences regarding selecting prevention and control strategies.

Noting that human T. solium taeniosis will not occur in the absence of the intermediate host pig and human and pig cysticercosis cases are usually clustered around human tapeworm carriers the location of pigs helps define the problem (though it should kept in mind that migrating T. solium tapeworm carriers can take their infections to non-endemic areas and infect other humans with cysticercosis) ; thus it would be helpful to map pig distributions in order to then target further surveillance in endemic regions:
- Making maximum use of existing data (eg livestock census data; meat inspection records)
- Filling the gaps with small field surveys, where appropriate
- Surveillance in pig populations discussed under WG2 point 4
2. Finding and treating *Taenia* tapeworm carriers

- Eliminating *T. solium* tapeworm infections in humans will block transmission of cysticercosis to both pigs and humans and would thus be crucial in eliminating NCC. Targeted or mass chemotherapy need to be considered for endemic foci as appropriate in rural areas producing pigs and in urban areas, where *T. solium* infected migrant people spread NCC.
- Treatment should be administered for any diagnosed case of taeniosis regardless of the *Taenia* species. (Ref 2).
- Cases of human and porcine cysticercosis have been found to be clustered around tapeworm carriers. Therefore, if someone is found to be infected with NCC they, their families and close neighbours should be tested for t/c infection. Likewise the household’s pigs and those in the vicinity should be checked for cysticercosis infection. A proper medical treatment should be ensured to detect both NCC and taeniosis cases.
- Village-level mapping of t/c may be helpful in conducting investigations of the local foci of transmission.
- Consideration should be given to the availability and cost of taeniocidal drugs (praziquantel, niclosamide) as well as taeniosis diagnostic tests (see WG3 summary) in endemic countries.

3. Mass drug administration

- Is a single dose of 10 mg/kg praziquantel a relevant application for mass drug administration against taeniosis considering possible co-endemicity of other tropical diseases (40mg/kg praziquantel is currently used for mass drug administration against schistosomiasis)?
- A pharmacovigilance study is required to understand the impact of mass anthelmintic drug administration on taeniosis and NCC (e.g. Ref 3).
- Such an investigation could be facilitated by establishing a link with the Schistosomiasis Control Initiative funded by the Gates Foundation to test people in the schistosomiasis endemic areas for *T. solium* infection as well as in the areas where mass treatment of liver fluke infection is conducted.
- Data should be collected and assessed regarding side effects of mass anthelmintic drug administration (praziquantel, albendazole, mebendazole, ivermectin) to determine whether there is any ill effect on *T. solium* infected persons, especially those with NCC.

4. In problem areas, what is the magnitude of the Neurocysticercosis problem?

- To study the epidemiology of neurocysticercosis, there are some resources available from: clinical data from neurological hospitals and outpatient clinics, national register of case reports, data from serological laboratories and imaging centres (archived radiographs and CT-scans). This historical data needs to be reviewed by local radiologists (including the development of capacity through radiography training) as well as experts.
- Community-based epidemiological studies should be carried out in likely endemic areas using CT-scan where possible to assess the NCC prevalence in the population and its association with epilepsy. However the WG recognised that CT scanners may not be available in many endemic areas – consideration should be given to securing mobile CT-scan capacity if available to overcome this limitation.
• These surveys should be combined with education and training of mental health nurses who may be very helpful in providing information about locally suspected patients.

5. **Is there an alternative to CT-scanning?**
   • It is necessary to consider alternatives such as serological tests, questionnaires, etc to the gold standard of CT-scanning for detecting NCC cases in regions where CT scanners are rare. (Possibilities for alternative/complimentary ways of detecting NCC considered by WG3.)
   • Test for specific antigens and antibodies may be used for studies and surveys such as community-based studies on epilepsy (*e.g.* about 60 human serum samples from Haydom Lutheran Hospital, Mbulu, Tanzania study on epilepsy and neurocysticercosis were tested).
   • Serological tests detecting antibody and parasitic antigens should be validated using sera from patients already CT-scanned for use in endemic regions.
   • If ok, they could then be used as a “definitive diagnostic test” for NCC, which will enable wider application.

6. **Develop capacity for serological testing in reference labs in endemic areas**
   • Although serological tests have limited value for surveillance of NCC developing capacity for using validated serological tests in reference labs in endemic areas may be useful.
   • Develop regional capacity for diagnostics (*eg* CWGESIA Regional Reference Lab for Immunodiagnosis of *T. solium* infections at University of Zambia, Lusaka, Zambia) including coproantigen assays for detecting *T. solium* tapeworm carriers

7. **Epidemiology of epilepsy**
   • Epilepsy prevalence surveys in selected sites should also be conducted – using reference labs to test sera from known epileptic patients, detect eventual presence of *T. solium* tapeworm carriers around cysticercotic patient (treating any case detected!) and assess the degree to which the epidemiology of epilepsy is related to NCC infection. On occasion professional and community education have to be promoted

8. **Professional education**
   • Medical students should receive more training in parasitology and tropical medicine during regular studies as well as during and after postgraduate courses. This should be provided jointly with veterinary students where possible.
   • Distance learning is increasingly being used for training in especially developing countries. European-based scientists could assist in preparing distance learning materials concerning *T. solium* and the infections it causes for students as well as continuing education programmes for graduated professionals.

**Participants in the discussion group**
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GROUP 2: PORCINE CYSTICERCOSIS, VETERINARY PUBLIC HEALTH AND TROPICAL PIG HUSBANDRY

1. Veterinary Services
We observed that Veterinary Public Health (VPH) and meat inspection is not given high priority within the veterinary authorities in many countries. The justification for improvements of meat inspection should not be on the basis of cysticercosis alone but should also include other zoonotic meatborne diseases.

If infected carcasses are totally condemned there will be a very strong incentive for people to slaughter their pigs and sell the meat on the ‘black market’. A trace-back system is on the other hand helpful with regard to securing farmers’ attention to the issue of cysticercosis and to ensure that information on ‘hot-spots’ can be compiled.

We as European scientists can in close collaboration with local professional may help to:
- make a concerted effort with specialists in other fields or sectors and advocate for the importance of improved meat inspection
- review meat inspection and VPH organization in different countries
- design and conduct experiments on how to deal safely with cyst-infected meat under local conditions. The purpose is to maintain a certain value of infected carcasses and decrease unnecessary losses as well as prevent clandestine market to sustain.
- communicate these finding to authorities eg. through policy briefs, to make them aware of cysticercosis with the expectation that they will institute and enforce appropriate regulations to deal with the issue
- develop training material and organise courses for training of meat inspection personnel, who we assume will be persons with a technical education

2. Awareness Creation
We observed that combating cysticercosis has to be undertaken as part of a larger pig development package and in line with control of *T. solium* taeniosis and NCC as well as with cooperation with epilepsy prevention programs.

We can assist in awareness creation by:
- developing an improved pig management “tool box”, which addresses different problems of concern to the farmer. This can be in the form of a manual for the training of trainers.
- this material should be adapted for local conditions (the illustrations and language should be relevant to area of action) to more encourage behavioural change
- the route of entry to the farmers could be the livestock sector or the health sector

3. Pig Importance and Management
We discussed the lack of structured information about the importance of pigs to rural households and on how pig management changes over time. The occurrence of African Swine Fever (ASF) in Madagascar and other parts of Africa has resulted in some instances in pig management changing from free-range to confinement.

We can help the local professionals to:
- review studies on the importance of pigs to rural households
• review different patterns of management practices. This may be possible by exploiting the many different contacts of the group
• review the farmers priorities and problem ranking with respect to livestock
• integrate efforts for controlling other swine diseases e.g. ASF with actions aimed at cysticercosis control to be more efficient and effective.

4. Surveillance and Control Experience

In areas found to have a pig-keeping component to agriculture, the infection status of the pig population needs to be determined using:
• Rapid pig prevalence assessments (utilising a study design to maximise coverage through quick surveys)
• Use of rural markets as central points, as has been carried out in other disease systems (Ref 4), and in particular targeting butchery operations in rural markets – pork meat for sale in local rural markets is likely to be drawn from the surrounding porcine population (validating this assumption may also be necessary).
• Butchered meat and meat inspection data to serve as a source of basic information and a sentinel for surveys of parasite prevalence.
• Interviews of pig traders, butchers, meat inspectors and pork sellers may also provide helpful information.

We observed that there are some examples of intervention and of farmers’ own initiatives which have led to a reduced burden of cysticercosis in pigs. There are such examples from Mozambique regarding very different pig management systems within the country. Successful intervention has in many cases been driven by other concerns rather than cysticercosis, e.g. to protect crops from pigs, ASF.

We can
• review the impact of different intervention programmes and develop strategies for integrated control
• calculate costs of cysticercosis to the farmer and to the community

Participants in the discussion group
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GROUP 3: TOOLS FOR SURVEILLANCE, PREVENTION AND CONTROL

1. Priority issues needing attention in relation to surveillance and control needs in endemic areas and imported cases in non-endemic areas

Guidelines for the surveillance, prevention and control of t/c have recently been revised by WHO, FAO and OIE (Ref 5). The Working Group reviewed the different tools available for surveillance and control noting current needs and opportunities for European assistance on improving the situation.

Diagnostics
For convenience, with respect to diagnosis, porcine cysticercosis, human cysticercosis/ neurocysticercosis and taeniosis were considered separately, as was identification of the
parasite in the environment (e.g. eggs in soil or proglottids in faeces). Human cysticercosis/neurocysticercosis differed in that it does not play a role in transmission of the parasite per se. Figures 1-3 represent flow charts. The diagnostic tools available include:

- Direct observation of the parasite (eg tongue palpation of pigs for cysticercosis, finding cysticerci at meat inspection or in meat prepared for distribution by inspecting local markets, CT/MRI scan for human NCC, morphological identification of tapeworm proglottids, biopsy of subcutaneous nodules)
- Antibody detection assays (function as indicators of exposure but do not necessarily differentiate current from past infection)
- Parasite antigen detection assays (as indicators of current active infection, i.e. potential transmission risk and allow decisions to be made regarding treatment)
- PCR based assays, for the identification of parasite samples or suspect lesions
- All antigen and antibody detection assays, nucleic acid-based tests and copro-antigen testing for humans need further R&D especially if used to monitor therapy
- Standardised testing is required world-wide: ISO 15189 would be the ideal

**Endemic areas:**

- **Porcine cysticercosis**
  - Direct observation – Examination of pigs for cysts using tongue palpation
  - Direct finding of cysticerci at slaughter or in meat being sold on the local markets
  - Antibody detection assays – reagents targeting both oncospheres and metacestodes are available – needed in ELISA and dipstick formats
  - Antigen detection assays (eg HP10 Ag-ELISA and B158/B60 Ag-ELISA) - There is a question assay specificity regarding *T. hydatigena* infection in pigs for the B158/B60 Ag-ELISA (Refs 6 and 7). A recent comparative study indicates that the Ag-recognition pattern in pigs differs between the two assays (Ref 8). Further comparative studies and evaluation/development are indicated.
  - PCR based assays – available but of limited application in endemic zone

- **Human cysticercosis/neurocysticercosis**
  - Direct observation ‘clinical examination’ CT/MRI scan limited availability of facilities
  - Antibody detection assays – reagents targeting both oncospheres and metacestodes are available – needed in ELISA and dipstick formats
  - Antigen detection assays (e.g. HP10 Ag-ELISA and B158/B60 Ag-ELISA) – Possible *T. hydatigena* cross reactivity is not a problem in humans. Further, larger scale, assay evaluation is needed to determine assay efficiency in diagnosing, parenchymal, subarachnoid and racemose cysticercosis and monitoring patients after treatment (Refs 9 and 10).
  - PCR based assays – Currently limited but potentially important applications when there is access to suitable facilities to biopsy patients and conduct PCR assays.

- **Taeniosis**
  - Direct observation, ‘clinical examination’, morphological examination of proglottids
  - Antibody detection assays – reagents are available (Ts33, Ts38)
  - Copro-antigen detection assays – current reagents are polyclonal antibody based, MAb’s are needed for use in ELISA and in dipstick format assays, standardised and fully evaluated reagents are required
  - PCR based assays – available but of limited application in endemic zone
• Environmental contamination (tapeworm proglottids and eggs)
  o Direct observation ‘clinical examination’ morphological examination of proglottids derived from human stools - limited application in endemic zone
  o PCR based assays – Currently limited application in endemic zone, identification of eggs in soil or water samples to trace sources of infection, determine environmental contamination
  o Copro-PCR for identification of tapeworm carriers in epidemiological studies

Low or Non-Endemic areas (eg Europe):

• Porcine cysticercosis
  o Direct observation, i.e. ‘clinical examination’, by tongue palpation is not generally appropriate
  o Antibody detection assays – reagents targeting both oncospheres and metacestodes are available – needed in ELISA and dipstick formats used for monitoring and follow-up studies
  o Antigen detection assays – e.g. HP10 Ag-ELISA and B158/B60 Ag-ELISA - questions over cross reactivity with T. hydatigena used for monitoring and follow up studies need to be resolved (see above).
  o PCR based assays – Slaughter house identification of lesions, differentiation from sarcocystis.
• Human cysticercosis/neurocysticercosis
  o Direct observation, ‘clinical examination’, CT/MRI scan – primary diagnostic tool, post-mortem examination (standard or forensic).
  o Antibody detection assays – potentially very useful reagents targeting both oncospheres and metacestodes are available. These assays are needed in ELISA and dipstick formats
  o Antigen detection assays – e.g. HP10 Ag-ELISA and B158/B60 Ag-ELISA – T. hydatigena cross reactivity not a problem in humans further assay evaluation needed to assess use for monitoring e.g. parenchymal/subarachnoid cysticercosis and racemose patients post-treatment (Refs 9 and 10).
  o PCR based assays – biopsy samples in the clinical setting. Further assay evaluation is required for the identification of parasite DNA in cerebrospinal fluid.
• Taeniosis
  o Direct observation ‘clinical examination’ morphological examination of proglottids, biopsy of subcutaneous nodules (mainly Asian infections though some reports in Africa), autopsy
  o Antibody detection assays – reagents are available (Ts33, Ts38)
  o Copro-antigen detection assays – current reagents are polyclonal need MAb in ELISA and dipstick formats, standardised reagents –
  o PCR based assays – transmission risk differentiation of T. solium from Taenia saginata proglottids
  o Copro-PCR for the identification of tapeworm carriers – screening
• Environmental contamination (tapeworm proglottids and eggs)
  o Direct observation ‘clinical examination’ morphological examination of proglottids derived from human stools – not applicable
  o PCR based assays – Identification of eggs in soil or water samples to trace sources of infection
**Vaccines**

The accumulated evidence suggests that vaccination to prevent porcine (and also bovine cysticercosis) is technically feasible and that very high levels of protection can be anticipated. Candidate vaccines exist (*e.g.* the major oncospheral 18kDa secreted protein TSOL18/HP6-Tsol) and HP6-Tsol reagents can be made freely available. The primary vaccine target is the invasive oncosphere, however, a vaccine that also targets the very early stages of the parasite in the intermediate host would serve as a back-up to kill any invasive oncospheres which evade the initial immune attack (*e.g.* TEG or other conserved and otherwise suitable antigens from immature (early stage) metacestodes.

Vaccines would find utility primarily in the endemic zones. For effective field application, the requirements for the vaccination of pigs include:

- Affordable and suitable for mass vaccination
- Market acceptability (*e.g.* possible inclusion in a polyvalent vaccine, for example incorporation into a vaccine against hog cholera)
- Single shot/dose vaccine
- Delivery (neonatal/sows)
- Determine earliest age at which pigs or cattle can first develop antibody to candidate vaccines
- Vaccine conferring lifelong immunity
- Further laboratory based trials/vaccination and release trials
- Efficacy all breeds of pigs
- Marker vaccine (*e.g.* BVD)

**Chemotherapy**

- Porcine cysticercosis
  - oxfendazole
  - ensure safe at dose given for treating infection (*i.e.* 30 mg/kg)
  - medicated feeds
- Human cysticercosis/neurocysticercosis
  - albendazole/praziquantel
  - some patients refractory to treatment
  - more work into side effects
- Taeniosis
  - cheap and effective drugs available (praziquantel/niclosamide)
  - efficacy of purgatives questioned
  - more work into environmental and long term impact is indicated

**Information, Educational interventions**

- Education messaging designed for application from the professional to community level
- Intervention packages
- Information packages
- Integrated pig development packages, messaging aimed at improving pig husbandry practices
- Monitoring - early warning systems in particular for *T. solium* prevalence in low-endemic/non-endemic zones
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- Surveillance around any detected case of human cysticercosis/neurocysticercosis in an attempt to find the possible source of infection, i.e. *T. solium* tapeworm carrier, as well as other human cysticercosis and/or porcine cysticercosis cases.

*Sanitation*
- Improvements needed in endemic areas integrated with other initiatives *(eg CLTS)*

2. Opportunities for more concerted efforts to address these needs
- Establish reference laboratories
- Standardisation of reagents
- Meeting to discuss assay development, standardisation and other R&D needs *(suggested by GALVmed)*

3. Possibilities for mobilising resources to enable these efforts
- Funding initiatives described at the meeting *(eg ICONZ, GALVmed, BMGF)*
- Improve communications to funding and technical agencies

4. Other relevant issues
- Epidemiological studies
- Determination of sources of infection
- Geographical overlaps between *T. solium/T.saginata/T. asiatica*
- Higher resolution genotyping tools
- Molecular epidemiology
- Social epidemiology
- Projected increases in the pig population and the overall consumption of pig meat
- Migration from rural areas to urban/peri-urban environment
- Medicated pig feed
- Herd accreditation *(screening for parasite exposure)*

**Participants in the discussion group**
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**References**
Figure 1: Flow diagram of assay types and requirements for porcine cysticercosis. The areas with most immediate scope for development are indicated by grey shading.

Figure 2: Flow diagram of assay types and requirements for human cysticercosis/neurocysticercosis. Regarding *neurocysticercosis (NCC), cases can be classified into confirmed, probable and suspect cases on clinical findings (Ref 8). Biopsy samples can be used for diagnosis of cases of subcutaneous (**SC) or dermal cysts. The areas with most immediate scope for development are indicated by grey shading.
Figure 3: Flow diagram of assay types and requirements for human taeniosis. The areas with most immediate scope for development are indicated by grey shading. *NB There are limitations to reliance on morphological differentiation since tapeworm eggs are morphologically identical and there is reported to be a degree of morphological overlap between proglottids of T. solium and T. saginata.
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IGC, Oeiras, Portugal, 11th to 12th March 2008

APPENDIX 3:

**LIST OF PARTICIPANTS**

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## Inaugural Meeting of the Cysticercosis Working Group in Europe
IGC, Oeiras, Portugal, 11\textsuperscript{th} to 12\textsuperscript{th} March 2008

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