Taenia solium cysticercosis: Life cycle, epidemiology and diagnosis

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INTRODUCTION: *Taenia* Infections in general

- *Taenia* spp. are long, segmented, parasitic tapeworms
- They have an **indirect life cycle**, cycling between a definitive and an intermediate host
- Some *Taenia* species are zoonotic, with humans serving as the definitive host, the intermediate host, or both:
  - Definitive host humans: *Taenia solium, T. saginata, T. asiatica*
  - Definitive hosts animals: *T. ovis*, *T. hydatigena*, *T. multiceps* and others
- Non-zoonotic species of *Taenia* also exist

Beef tapeworm (Taenia saginata) demonstrated by Dr M Ndao, Director of the National Research Laboratory for Parasitology, Montreal General Hospital (http://www.mcgill.ca/reporter/38/07/ 2006)

INTRODUCTION: *Taenia* Infections in general

- Most adult and larval tapeworm infections cause little or no disease (**taeniasis**)
- The larval intermediate stages can cause **cysticercosis**, **neurocysticercosis**, **coenurosis**, or **neurocoenurosis**
- Cysticercosis causes economic loss through condemnation of infected meat and offal

Taenia solium tapeworm . (Image from Bioweb, University of Wisconsin System universities and centers. http://bioweb.uwlax.edu/bio203/s2008/geske_rich/)

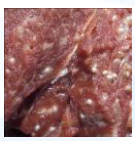
Cysticercosis in porcine skeletal muscle. (Image from: Faculty of Veterinary Science, Section of Veterinary Public Health)

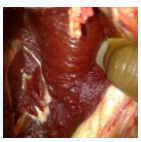
INTRODUCTION: Cysticercosis

- Infection with the larval form of *Taenia solium*, *T. saginata*, *T. ovis*, or *T. hydatigena* (and others) is called **cysticercosis**
  - At one time, the larvae and adult tapeworms were thought to be different species. For this reason, the larval stages are sometimes called by a different name e.g. the larval stage of *T. solium* is sometimes called *Cysticercus cellulosae* and the larval stage of *T. saginata* is sometimes called *Cysticercus bovis* etc.

INTRODUCTION: Cysticercosis

- **Bovine cysticercosis** (primarily in muscle) and **porcine cysticercosis** (primarily in muscle, the CNS and the liver) are caused by the larval stages of the human tapeworms *Taenia saginata* and *Taenia solium,* respectively

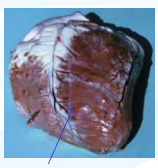




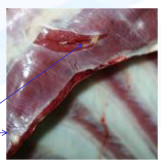
Bovine cysticercosis: Metacestodes (fluid-filled bladder with one or more invaginated protoscoleces) in skeletal muscle. (Images from: Department of Agriculture, Fisheries and Forestry).

INTRODUCTION: Cysticercosis

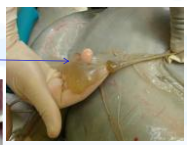
- Cysticercosis of **sheep and goats** (primarily in the muscles, liver and peritoneal cavity) are caused by *T. ovis* and *T. hydatigena*, adults of which occur in the intestines of **canids**.



Parasitic intermediate stages of *Taenia ovis* in heart and diaphragm of a sheep



Parasitic intermediate stage of *Taenia hydatigena*



(Image from: Faculty of Veterinary Science, Section of Veterinary Public Health).

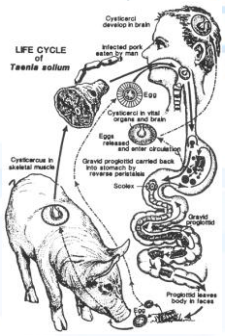
INTRODUCTION: Coenurosis

- Infection with the larval forms of *T. multiceps* (definitive host canids) is called **coenurosis**.
  - (The larval stage of *T. multiceps* is sometimes called *Coenurus cerebralis)*

Parasitic intermediate stage of *Taenia multiceps* *Image courtesy of Dr Rick Last, Vetdiagnostix, Pietermaritzburg, Kwazulu-Natal*

LIFE CYCLE OF *TAENIA SOLIUM*

1. Eggs or gravid proglottids are passed with faeces of humans
2. Pigs become infected by ingesting human faeces or food contaminated with eggs or gravid proglottids
3. In the animal's intestine, the oncospheres hatch, invade the intestinal wall, and migrate to the striated muscles, where they develop into cysticerci.
4. Humans become infected by ingesting raw or undercooked infected meat



Life cycle of *Taenia solium* (Image from: Food and Agriculture Organization (2000) Specific diseases of pigs: Cysticercosis (Cysticercus cellulosae infestation). Manual on meat inspection for developing countries.)

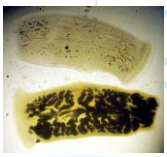
PORCINE CYSTICERCOSIS

- Primarily in skeletal muscle
- Also CNS and the liver

Metacestodes in skeletal muscles of pigs (Images from: Department of Agriculture, Fisheries and Forestry)

LIFE CYCLE OF *TAENIA SOLIUM*

4. In the human small intestine, the cysticercus develops into an adult tapeworm (2-3 months)
   - can survive for years
   - length of adult worms is 2 to 7 m
5. The adults produce proglottids which mature, become gravid, detach from the tapeworm, and are passed in the stool (approximately 6 per day).
6. The eggs contained in the gravid proglottids are released after the proglottids are passed with the faeces. *T. solium* may produce 50,000 eggs per proglottid respectively.



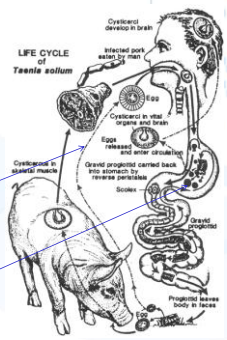
Mature proglottid of T. solium, stained with India ink.

Taenia spp. egg in unstained wet mounts.

(Images from Centers for Disease Control & Prevention, Centre for Global Health, Diagnostic Procedures, Parasites and Parasitic Diseases, Image library)

HUMANS CYSTICERCOSIS: ABERRANT LIFE CYCLE OF *TAENIA SOLIUM*

- Occurs when humans become the intermediate - rather than definitive - hosts when eggs enter the stomach
  - usually as a result of hands contaminated *Taenia solium* eggs,
  - food handlers and child care-givers present a major risk
  - but also due to retroperistalsis



Life cycle of *Taenia solium* (Image from: Food and Agriculture Organization (2000) Specific diseases of pigs: Cysticercosis (Cysticercus cellulosae infestation). Manual on meat inspection for developing countries.)

HUMANS CYSTICERCOSIS

- Can affect any tissue of the body:
  - Skeletal muscle, muscles that control movement of the eye, tongue/cheek
  - Subcutaneous cysts
  - Intraocular cysts
  - Central nervous system

Human cystecercosis: subcutaneous nodules on the chest wall and a few calcified lesions on chest X-ray
From: Foyaca-Sibat H, Ibanez-Valdes LdeF, Mashiyi MK (2004).

HUMAN NEUROCYSTICERCOSIS (AND NEUROCOENUROSIS)

- A severe, potentially fatal outcome of human infection with the paracitic intermediate stages is **neurocysticercosis** caused by *T. solium*
- (occasionally **neurocoenurosis** caused by *T. multiceps)*

Human neurocysticercosis caused by *T. solium.* (Image from Garcia HH, Del Brutto OH, 2000)

EPIDEMIOLOGY: Geographic Distribution

- Infects pigs and humans in Asia, Africa, South America, parts of Southern Europe and pockets of North America
- Usually associated with low social and economic development
- Rapid expansion of pig farming and pork consumption in Africa – may exacerbate the problems with *T. solium* cysticercosis
- Pig population in the countries of Uganda, Tanzania, Kenya, Zambia, Zimbabwe, and Mozambique has increased nearly threefold (in Uganda over sixfold) since 1961

EPIDEMIOLOGY: Risk factors – Poor hygiene and limited use or absence of latrines

- Low economic status, low level of household sanitation and low personal hygiene standards
- Open field defecation
- Those households that have latrines don't always use them
- Tapeworm carriers disseminate the parasite eggs in their environment leading to the contamination of
  - soil,
  - **water** (many homes lack piped water)
  - and food resources
- Eggs may stay alive in the effluent from sewage treatment (shown for *Taenia saginata)* spreading the disease to other areas or villages

EPIDEMIOLOGY: Risk factors - Management systems used by pig farmers

- A **scavenging/free-range production system** with open field defecation by humans allowing pigs to scavenge and eat human faeces (sanitary policeman)
- **Semi-intensive and intensive systems** where the majority of the food consists of domestic kitchen waste
- **Intensive pig production systems** do not always eliminate *T. solium* transmission
  - Human carriers involved in pig rearing and care
  - Water contaminated with eggs
- Use of sewage effluent to irrigate and/or fertilize pig pastures and food crops.
- Deliberate use of human faeces as pig feed or connecting pigpens to human latrines (pigsty privies)

EPIDEMIOLOGY: Risk factors - Education and no official inspection of the pig carcasses

- Farmers in endemic areas **recognize the cysts** in infected pigs. **Also aware of epileptics and tapeworm carriers** but are not aware of:
  - the mode of transmission (does not associate disease with pigs that are allowed to scavenge for food)
  - the zoonotic potential of the disease
- Limited or no **formal meat inspection** and/or ignorance of consequences of selling/consuming infected meat
- Infected pig carcasses (esp. those with a mild infestation) identified on meat inspection **not frozen** as per regulations prior to marketing
- Often cysticerci are not killed by meat preparation methods such as grilling, frying or baking in a oven

EPIDEMIOLOGY: South Africa

- South Africa is the country with the highest number of pigs in Southern Africa with a estimated 25% of these pigs kept in scavenging/free range systems
- Human cysticercosis appears to be most prevalent in **Eastern Cape Province** particularly in the poor rural areas
- Previous prevalence estimates ranged between 0% and 25% - however, were based on the results of a single test, namely the routine carcass inspection, known as a rather insensitive diagnostic method
- Estimation of the true **prevalence** of in the Eastern Cape Province **56.7%** - used a Bayesian analysis framework and utilizing four tests (Krecek R.C. et. al. 2003)

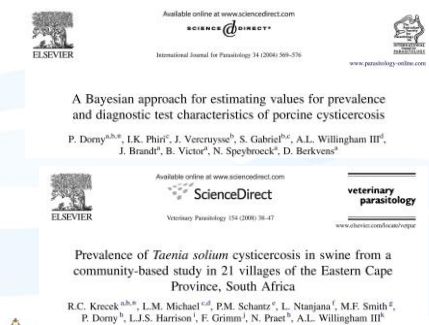
EPIDEMIOLOGY: Why the Eastern Cape?

- Province challenged in terms of infrastructure, unemployment and the economy.
- **Unemployment** is higher (55% vs. 42% for national statistics)
- Homes with **piped water** (i.e. purifies) lower (62% vs. 84%)
- Fewer homes with **latrines** (14% vs. 31%).
- Situation in other Provinces? Adequately studied?

DIAGNOSTIC TECHNIQUES: Available methods

- Gold standard: Enumeration of cysticerci by complete dissection of pig carcasses – slices from muscles, heart, lungs, kidneys and liver of less than 0.5cm – Impractical
- Tongue palpation
- Routine carcass inspection
- Tests for assessment of serum antibodies
- Detection of secretory products of live cysts or tegumental antigen (i.e. serum antigens)

DIAGNOSTIC TECHNIQUES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A Bayesian approach for estimating values for prevalence and diagnostic test characteristics of porcine cysticercosis

P. Dorny[a,b,*], I.K. Phiri[c], J. Vercruysse[b], S. Gabriel[b,c], A.L. Willingham III[d], J. Brandt[a], B. Victor[a], N. Speybroeck[a], D. Berkvens[a]

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Prevalence of *Taenia solium* cysticercosis in swine from a community-based study in 21 villages of the Eastern Cape Province, South Africa

R.C. Krecek[a,b,*], L.M. Michael[c,d], P.M. Schantz[e], L. Ntanjana[f], M.F. Smith[g], P. Dorny[h], L.J.S. Harrison[i], F. Grimm[j], N. Praet[h], A.L. Willingham III[h]

DIAGNOSTIC TECHNIQUES: Tongue palpation

- Tongue, examined and palpated throughout the base.
- A pig is considered positive for cysticercosis if cyst-like nodules are either seen or felt
  - Estimated sensitivity: **7.3% to 21%**
  - Estimated specificity: 80.8% to 100%
- Does not detect light infections and only about half of heavy to moderate infections
- Depends heavily on method used

Cyst like nodule (arrows) on the tongue of a pig (Image from Singh A.K. et. al. 2013)

DIAGNOSTIC TECHNIQUES: Routine meat inspection

- Following slaughter the presence of *T. solium* cysticerci in the carcass are assessed by examining the:
  - external and internal masseters, tongue, diaphragm, heart and *M triceps brachii*
  - (also liver and peritoneum for other taeniid species e.g. *T. hydatigena)*
- Estimated sensitivity and specificity respectively **38.7%** and 100%
- Sensitivity decreases with light infestations – serious **underestimation of prevalence** if only test used

DIAGNOSTIC TECHNIQUES: Serological tests

- Blood samples can be taken at slaughter or during routine surveys for other diseases (e.g. classical swine fever or PRRS)
- Ag-ELISA based on monoclonal antibodies produced against the excretory-secretory products of *T. saginata* metacestodes
  - Sensitivity: **64.5% to 86.7%**
  - Specificity: 91.2 to 94.7%
- Ag-ELISA reactive with a repetitive carbohydrate epitope on lentil-lectin adherent glycoproteins present on the surface and in the secretions of *Taenia saginata* cysticerci
  - Sensitivity: **70.4%**
  - Specificity: 66.1%

DIAGNOSTIC TECHNIQUES: Serological tests

- Enzyme-linked immunosorbent assay for the detection of circulating antigen based on affinity purified glycoproteins from *T. solium* cysticerci
  - Sensitivity: **49**%
  - Specificity: 84%
- Enzyme-linked immunosorbent assay for the detection of specific antibodies (Ab-ELISA) based on crude metacestode antigen of *Taenia crassiceps*
  - Sensitivity: **35.8% to 45.2%**
  - Specificity: 88.2% to 91.7%

DIAGNOSTIC TECHNIQUES: Serological tests

- General trend: **Improved sensitivity** compared to meat inspection but still inadequate
- These assays **cannot differentiate between past or current infection**
- Also cross-reactions with *T. hygatigena*
- Sensitivity and specificity vary depending on time of infection and severity of infection – likely to be lower with light or early infections
- Value in diagnosis and control questionable. At most tools for epidemiological studies

TOOLS FOR THE CONTROL OF *T. SOLIUM* CYSTICERCOSIS


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Review

Taenia solium taeniosis/cysticercosis in Africa: Risk factors, epidemiology and prospects for control using vaccination

Emmanuel Assana[a,c,*], Marshall W. Lightowlers[b], André P. Zoli[a], Stanny Geerts[d]

TOOLS FOR THE CONTROL OF *T. SOLIUM* CYSTICERCOSIS

- Most effective: General improvement of the economic situation of the endemic areas and improvements in public sanitation and pig husbandry
  - Largely eradicated in high income areas without special interventions
- **Confinement of the pigs** to avoiding access to human faeces - however free roaming system offers an economic advantage to pig breeders
- **Meat inspection** - however lack of slaughterhouse facilities and inspection of pork is poorly implemented

TOOLS FOR THE CONTROL OF *T. SOLIUM* CYSTICERCOSIS

- **Intensive educational intervention** - significant decrease in the level of consumption of measled pork but no significant changes in the knowledge about the transmission of cysticercosis
- **Chemotherapy against human taeniosis** - but effect is partial; cannot eliminate taeniosis/cysticercosis complex if the entire targeted population is not treated repeatedly
- **Oxfendazole (OFZ) for treatment for porcine cysticercosis** - kills the muscle cysts within 4 weeks but it takes between 8 and 26 weeks before the cysticerci are cleared

TOOLS FOR THE CONTROL OF *T. SOLIUM* CYSTICERCOSIS: Vaccination combined with OFZ treatment

- **Novel disease control tool** that might reduce human neurocysticercosis in endemic areas in Africa
- Most effective immunogen is the recombinant antigen designated TSOL18
- Also a TSOL16 vaccine
- Combined with OFZ treatment to kill any parasite that may have established in pigs prior to vaccination
- The drawback of using the TSOL18 is the need of at least two doses to achieve the protection
- Field trial - combination of TSOL16 and TSOL18 vaccines without OFZ treatment reduced 99.9% the number of viable cysts

Thank you.

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