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Opinion of the Scientific Committee on Veterinary Measures relating to Public Health

on

The control of taeniosis/cysticercosis

in man and animals

(adopted on 27-28 September 2000)

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TERMS OF REFERENCE

Since previous work on cysticercosis (1988), important progress has been made in taeniosis-cysticercosis research.

Immunodiagnostic tests have been developed for the detection of specific antibodies against *T. saginata* cysticerci. Monoclonal antibody based antigen detection ELISA's are now available, which allow the detection of animals harbouring living cysts, as opposed to animals harbouring dead cysts. Antigen detection assays have also been developed with improved sensitivity for the detection of tapeworm carriers and DNA probes have been developed which allow the unequivocal differentiation of specimens of *T. saginata* from *T. solium*.

Data that is currently available, does not suggest a decrease in the prevalence of *T. saginata* in man or cattle.

Therefore, the SCVPH is requested to:

- identify which practices or factors are of importance in maintaining a high prevalence level;
- evaluate if there is a need for better control and surveillance methods and, should this be the case, to assess their value in the reducing risk;
- compare the effectiveness of newly developed diagnostic methods with the currently used technique (i.e. visual inspection).

GENERAL INTRODUCTION

After consideration of the above terms of reference, the Committee pointed at consequences of *Taenia solium* infection to re-occur in Europe. Therefore it was decided to give scientific opinion as requested on *T. saginata* and bovine cysticercosis (Part I) but also on *T. solium* and porcine cysticercosis, as well as human cysticercosis (Part II).

The large tapeworms of man have been known since early times, and probably belong to the oldest medical descriptions of human diseases. *Taenia* are intestinal parasites that have infected human for thousand years. Necessity of control led to the implementation of control measures that have mainly relied upon meat inspection at slaughtering, exemplified by the EU Directive 64/433/EEC as last amended. The number of cases has thus markedly decreased but the residual incidence of *T. saginata*, both in humans and cattle, shows that the parasitic cycle remains active in EU Member States. Although human *T. saginata* taeniosis is not a significant public health issue, its current persistence in developed countries can be considered as an indicator of poor hygiene and as such, its control should be envisaged in a global perspective of public hygiene.

The life cycles of tapeworms were only elucidated halfway through the last century (Küchenmeister, 1860) when human and animal experiments revealed two separate life cycles:

– *Taenia saginata*, with man as final host and cattle as the intermediate host ("beef tapeworm").
– *Taenia solium*, with man as the final host and pigs as the intermediate host ("pork tapeworm").

It took another half a century before Brumpt (1913) recognised similarities between "measles" in swine and similar "worm-like" vesicles ("bladder worms") in the brains of humans. The peculiar characteristic of *T. solium* is that besides the definitive host (man as tapeworm carrier) and the intermediate host (pigs with cysticerci in muscles and various organs) there is risk of man being infected with the larval form of *T. solium* by ingestion of eggs, shed by human tapeworm carriers.

Definitions: Taeniosis is the term for human disease caused by *Taenia* tapeworms. Cysticercosis is the condition of cattle and pigs or humans suffering from cysticerci in their muscles or organs. In humans the condition related to the presence of *T. solium* cysticerci in the brain is called neurocysticercosis.

1. PART I: *TAENIA SAGINATA*

1.1. Hazard identification and characterisation

The life cycle of *Taenia saginata* is schematically presented in figure 1. Typically, the tapeworm life cycle consists of an adult stage (tapeworm) in the final host (human). The worms produce segments (proglottids) containing a considerable number of eggs which are shed on defecation. *Taenia* eggs, containing an embryo (or oncosphere) are spread (through sewage) into the environment and may be orally ingested by the intermediate hosts. For *T. saginata*, that is exclusively cattle. In cattle, the embryos move from the intestine to striated musculature. Here they develop into small vesicles (cysticerci) containing one head (protoscolex) of the future tapeworm.

If man consumes meat (muscle) containing viable cysticerci, a tapeworm may develop. One viable cysticercus can be sufficient, although immunity of the host can alter that. Prevention of human taeniosis and bovine cysticercosis is achieved by interrupting the life cycle at one or more points.

Adult *Taenia saginata* attain a length of several meters in the small intestine, where they attach to the mucosa through suckers. Normally man only bears one *T. saginata* at the time. Patients are frequently asymptomatic, however, gastrointestinal discomfort including diarrhoea, flatulence and abdominal pain is sometimes observed. Adult tapeworms release egg-containing motile distal segments which are shed and excreted with the faeces. These "worms" can actually move independently and be the reason for various disorders such as appendicitis, or biliary tract obstruction. Often the segments (proglottids) move spontaneously through the anal opening and cause pruritus.

Bovine cysticercosis is the consequence of an oral infection with eggs, containing embryos, which are infectious immediately after release. The embryonated eggs may reach cattle by different routes. Clinical signs are related to the numbers and distribution of cysticerci. Usually cattle show no clinical signs at all. Vesicles (cysticerci) in cattle will mainly develop within striated muscles.

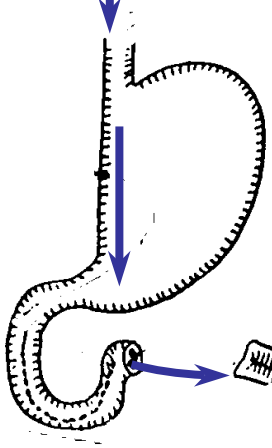
The life cycle is completed when humans consume undercooked beef which contains viable cysticerci. The consequences of taeniosis/cysticercosis in man and animals are summarised in Annex.

Human
Definitive host

Contamination when **eating undercooked meat** containing viable cysticerci

Human taeniosis

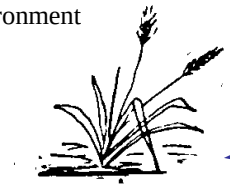
Presence of the **adult worm** (*Taenia*) in the small bowel of humans

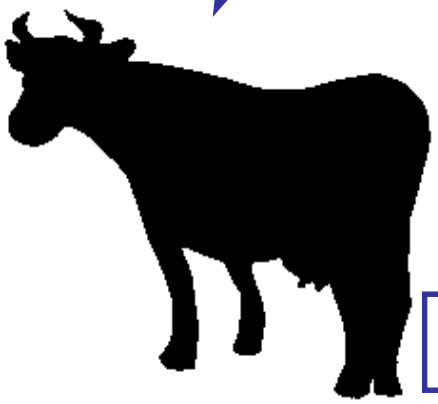


Proglotis

Taenia egg

Humans hosting the adult *Taenia* excrete **eggs** in the environment (through faeces)





Bovine cysticercosis
Presence of the larval stage of the worm (cysticercus) in muscles of cattle

Cattle
Intermediate host

Life cycle of *Taenia saginata*

1.2. Epidemiology

1.2.1. Epidemiology in cattle

Cysticercosis in cattle is screened in EU Member States as a consequence of routine meat inspection procedures.

The reporting in different countries is not standardised and prevalence data are difficult to collate and to compare. Examples of such reporting are presented in Table 1.

Table 1: **Prevalence of bovine cysticersosis and incidence of human taeniosis in various European countries.**

Country	Cysticercosis* Prevalence (%)	Taeniosis** incidence (%)	Reference***
Denmark	0,1-0,7	0,02	Ilsoe *et al*., 1990
Germany:			
former East	4,5-6,8	0,33-0,62	Mobius, 1993
former West	0,4-0,8	0,09	Zimmerman, 1985
Netherlands	1,8-2,2	0,14	Van Knapen & Buys, 1985
Belgium	0,03-0,2	0,26-0,46	Geerts *et al*., 1992
Spain	0,007-0,1	---	Garate, 1999
Poland	0,24	1,64	Pawlowski, 1999
Italy	0,02-2,4	0,02-0,04	Battelli, 1999

* based on abattoir data

** based on sales figures of specific antiparasitic drugs in man

*** studies were of different design and covered different time period

There is insufficient knowledge to determine whether or not *T. saginata* cysticercosis prevalence is similar in the different EU Member States. Detailed studies on infection rates at farms and causative factors are lacking. Only the relatively heavily infected animals are likely to be reported, which results in an overall underestimation of the prevalence. Sometimes overestimation also occurs through misdiagnosing of other pathologies such as eosinophilic granulomas in musculature as cysticercosis. However, the majority of infected cattle in the EU show rather light infections. A case-control study of risk factors in light *T. saginata* cysticercosis cases in Denmark has shown that the major risk factor was the access of cattle to streams carrying the effluent from sewage treatment plants (Kyvsgaard *et al.*, 1991). This is not surprising, since it is well known that most types of sewage treatment plants are not able to eliminate *T. saginata* eggs from the purified water (Arundel & Adolph, 1980). Therefore, it can be anticipated that this transmission route is important in many European countries.

1.2.2. Epidemiology in human

The extent of human *Taenia* carriership is virtually unknown but probably relatively low in European countries. There exists no mandatory notification. Prevalence and incidence figures, if at all available, are based on sales figures of specific drugs (niclosamide, praziquantel) (Table 1). Such figures reveal unexpected levels of infection in our modern society (Van Knapen and Buys, 1985).

1.3. Practices and factors that are of importance in maintaining a high prevalence level of *Taenia saginata* infection in man and cattle

1.3.1. Risk factors for bovine cysticercosis (T. saginata cysticercosis*)*

– Tapeworm carrier on the farm.

– Poor hygiene of farm staff (e.g. handling of bovine feed, or hand milking with egg-contaminated hands).

– Defecation by man in places frequented by cattle, or in cattle feed production areas.

– Application of human sewage slurry on pastures or highly permeable soils with possible contamination of water-bearing surface and drinking water.

– *Taenia* eggs in effluent water from sewage treatment plants.

1.3.2. Risk factors for human taeniosis (T. saginata)

Consumption of undercooked beef containing viable cysticerci (meat not submitted to or not found contaminated by the current meat inspection methods.

Table 2. Effect of processing on bovine cysticerci in meat and meat products

Process	Characteristics	Effect on Cyst
Freezing	<-5ºC for >360 hours <-10ºC for >216 hours <-15ºC for >144 hours	Death of cyst Death of cyst Death of cyst
Heating	>56ºC Core temperature for >1second	Death of cyst
Irradiation	100 K rad 40 K rad	Death cyst Inhibition of development
Pickling	a_w < 0.86 for 3-4 weeks	Death of cyst shown under experimental condition
Cutting / Mincing		No effect on cyst

1.3.3. Other, factors (e.g. social and psychological) that influence a significant prevalence level

Although the overall prevalence of intestinal worms has markedly decreased since the beginning of the century in most of EU Member States. There are no sound epidemiological data on the occurrence of intestinal infections with *T. saginata* in humans in EU Member States. There are several reasons for this, including the usual absence of clinical signs and symptoms in infected humans, but also more subtle sociologic reasons which tend to underestimate parasitic diseases in our developed societies.

– Underestimation by general practitioners of the importance of this kind of infection, maybe due to underdiagnosis (which may be additionally reinforced by inhibition of reporting by patients)

– If diagnosed, therapy might not be sufficient to break the cycle immediately because eggs are not destroyed and are released in the environment (effluent water from sewage treatment plants - see 1.2.1).

1.4. Diagnostic methods

Since there exists a long history in diagnosing taeniosis/cysticercosis in man and animals, ample attention has to be drawn to both historical methods (legislation) and new developments in both methodology and valid interpretation of results.

1.4.1. Routine meat inspection

According to Directive 64/433/EEC as last amended, routine meat inspection include the following procedures: bovines over six months of age are inspected individually at the abattoir by two deep cuts in the external and one deep cut in the internal muscles of mastication. The cut surfaces of the muscle and the tongue are inspected visually. The pericardial surface of the heart is inspected, then the heart muscle incised lengthwise to open the ventricles and to cut through the intraventricular septum.

When one or more cysts are found there is a requirement for further cuts with specific reference to predilection sites e.g. diaphragm and inspection of offal.

If a carcass has a generalised infestation the carcass and the offal are declared unfit for human consumption.

With a localised infestation there is a requirement to store the carcass at a temperature not exceeding -7°C for not less than 21 days or at a temperature not exceeding -10°C for not less than 14 days before release for human consumption.

1.4.2. Diagnosis in man by direct observation and taxonomic identification of the adult parasite

Wherever possible, direct observation of the parasite and clear taxonomic identification is still the best option. However morphological diagnosis requires skills and training in parasitology and is not always possible,

specifically as in the case of taeniid eggs, which are morphologically identical; or difficult to obtain or to differentiate, as is the case of *T. saginata* and *T. solium* adult proglottids. In practice some carriers may not be aware they are infected as their tapeworm infection may be old in which case the tapeworm may only produce a limited number of proglottids at infrequent times in faeces. Identification of the parasite in biological samples is still a viable goal.

1.4.3. Diagnosis, recent developments

Since 1981 there have been approximately 160 papers published on *T. saginata*. Of these, 32 papers were mainly concerned with diagnosis. Many of these papers do not give sufficient information to allow calculations of sensitivity, specificity, positive and negative predictive values of the methods to be made.

In *T. saginata* cysticercosis the only practical way to assess the cyst burden is to use data from totally dissected cattle. This information is difficult and expensive to obtain and consequently there have been relatively few studies of this nature.

There are three diagnostic tools which may be immediately applied to the epidemiology studies, control and treatment of taeniosis/cysticercosis.

– Robust, sensitive and specific tests for serum antibodies to the parasite. They would indicate exposure and hence outbreaks and endemicity and/or the level of resistance in the host population. In the long term this is best approached using defined recombinant antigens. For example the secreted products of the immature cysticercus of *T. saginata* have been shown to be highly immunogenic in cattle. Presence of circulating antiparasite antibodies, however, whilst indicating exposure to the parasite, cannot be taken as proof of a current viable parasite infection in a particular animal.

– Tests aimed at secretory products of live cysts or tegumental antigen, i.e. serum antigens, from viable cysticerci or adult tapeworms. It offers the advantage of indicating a current infection and thus has a prognostic value in terms of decisions over treatment with drugs.

– Diagnostic tests to distinguish both species on actual samples of the parasites themselves. Differentiating between adult proglottids/eggs of *T. saginata* and *T. solium* as the host ranges of the two parasites overlap in some countries, would be useful, since *Taenia* eggs are morphologically identical and it is currently difficult to identify the taeniids responsible for environmental contamination with eggs unless suitable PCR based assays are employed.

1.4.4. Antibody detection in cattle

Antibody assays although important, unless very carefully designed, can only be expected to indicate exposure to infection and not necessarily current infection with the viable parasites. Although the required levels of sensitivity and specificity are unlikely to be reached through the use of relatively crude

parasite extracts, reasonably useful ELISA assays for the diagnosis of *T. saginata* cysticercosis have been developed and used to monitor experimental and natural infections with the parasites, both in the UK, in Kenya and in Mexico (Harrison, Hammond & Sewell, 1996). Ito *et al*. (1998) have recently described alternative antigen preparations, giving improved levels of sensitivity and specificity. With all these assays, problems with high backgrounds and specificity are obviously likely to occur with the use of crude antigen preparations especially where animals are exposed to other cross reacting infections. For this reason, attempts are being made to identify cDNA sequences encoding for potential diagnostic peptides (Benitez *et al*. 1998a,b; 1996a,b).

1.4.5. Antigen detection

Given the limitations of antibody detection assays, the use of immunoassays to detect the excretory/secretory products of live parasites would be of major advantage. Initial attempts to develop antigen detection assays, based on the use of polyclonal sera, had the disadvantages of high background, resulting in poor signal to background ratios and poor sensitivity (Harrison, Hammond & Sewell, 1996). Subsequently, a more useful antigen detection assay was developed for the diagnosis of viable *T. saginata* cysticercosis of cattle (Harrison, Joshua Wright & Parkhouse, 1989). The assay was based on the use of a monoclonal antibody reactive with a repetitive carbohydrate epitope present on a lentil lectin adherent glycoprotein present on the surface and in the secretions of the parasite.

In cattle

The antigen detection assay has therefore found application in sero-epidemiological studies for *T. saginata* cysticercosis in Swaziland and Kenya (Hughes *et al*., 1993; Onyango-Abuje *et al*., 1996) and the assay has been shown to be at least two to three times more sensitive that the only other current alternative, *post-mortem* examination at meat inspection (Onyango-Abuje *et al*., 1995). These findings have recently been confirmed through a study in naturally infected cattle in South Africa (Williams *et al*., 1997). The assay is also currently being exploited in sero-epidemiological surveys being conducted in Mexico, Venezuela and Peru. A second monoclonal antibody based antigen detection ELISA (Kerckhoven *et al*., 1998) also exists. However, these assays were not tested in comparison.

At the abattoir level introduction of this more sensitive direct detection method would greatly improve the efficacy to prevent human taeniosis (see 1.4.7).

In humans

Current parasite antigen detection assays for taeniosis in faeces use polyclonal antibodies i.e. do not necessarily differentiate between *T. saginata* and *T. solium* (Allan *et al*., 1991; Deplazes *et al*., 1991; Allan *et al*., 1996; Rodriguez-Canul *et al*., 1999). While demonstrating high levels of sensitivity

and specificity, these assays are good examples of the diagnostic problems encountered when, as it happens with taeniosis, the prevalence of infection is very low (and thus predictive value is poor), (see addendum).

1.4.6. Identification of eggs in stools

Enzyme electrophoresis has been employed to differentiate various species of taeniid cestodes, including *T. saginata* and *T. solium* (Le Riche & Sewell, 1977), but enzyme zymogram patterns are not so useful for positive diagnosis due to intrinsic handling, transportation and storage difficulties, especially if the goal is to make comparison between samples from different countries. Species identification using nucleic acid probes is a suitable option since DNA samples are relatively stable and so can be transported much more easily. Following the cloning and sequencing of *T. saginata* and *T. solium* DNA probes, suitable primers have now been identified (Harrison, Delgado and Parkhouse, 1990; Gonzalez *et al*., 1999) which will allow the development of Polymerase Chain Reaction (PCR) assays suitable for differential diagnosis of Taeniid eggs from pasture and also to allow the species identification of adult tapeworm proglottids.

1.4.7. Comparison of diagnostic methods and influence of the use of more sensitive tests on reduction of risk

Several studies (Geerts *et al*., 1981; Van Knapen and Buys, 1981; Kyvsgaard *et al*., 1990; De Giovanni *et al*., 1985; Onyango-Abjje *et al*., 1995) have shown that the prevalence of bovine cysticercosis as detected by the classical meat inspection techniques (carried out properly) is underestimated by at least a factor of 3-10. This was confirmed again in a recent survey in Belgium (November 1997-June 1998), in which a random sample of about 1,200 slaughter cattle was examined using the antigen ELISA and a 10 times higher prevalence was found than during meat inspection (Dorny *et al*., in press). In this connection, it should be stressed that in Italy careful investigations on 72 hearts and 89 tongues ready for consumption from inspected cattle showed cysticerci in 24% and 10% of hearts and tongues, respectively (De Giovanni *et al*., 1985). In addition, starting from the early 1990's, modifications were introduced in inspection methods for meat and viscera by EU regulations, in order to reduce time and costs of veterinary control. Some observations (Castoldi, 1994) attribute the decreased cases reported in an industrial abattoir in Northern Italy in 1992-1993 not to a real decrease in cysticercosis but to a reduction in the number of cuts in some organs (e.g. heart) according to the new EU regulations, hence to a reduction in sensitivity of the inspection.

Other disadvantages of the current meat inspection techniques are that they are labour intensive (about 30% of the time spent at meat inspection is involved in making cuts to look for *Taenia saginata* cysts) and that they are very subjective. It depends very much on the skills and on the motivation of the meat inspector whether or not he will detect cysticerci, which results in important differences in the efficacy of the meat inspection from one slaughterhouse to the other.

For these reasons it is clear that there is a need for better and more objective detection methods at the abattoir. Contrary to the meat inspection, which found 0.3% of the animals infected with cysticercosis, the ELISA detected 3.1% positive, i.e. animals carrying living cysts (Dorny *et al*., 2000). Animals with dead cysts are not detected using carefully designed antigen ELISA's (Harrison *et al*., 1989, Brandt *et al*., 1992). Since the detection level of the ELISA's is about 30 and 50 cysticerci respectively per animal, most of the cattle with a cyst burden below 30-50 do escape, which means that 3,1% is certainly an underestimation of the real prevalence.

The use of serological tests (antigen detection ELISA; Van Kerckhoven *et al*., 1998; Harrison *et al*., 1989) should allow veterinary services to reduce the true prevalence of *T. saginata* cysticercosis, to reduce the incidence of tapeworm carriers and to decrease the contamination of the environment with *T. saginata* eggs. Since the sensitivity of the antigen ELISA does not reach 100%, it will not be possible to eradicate *T. saginata* using this method. However, it will allow important progress in controlling the parasite. Importantly cattle in some countries are reared as herd animals and each can be identified by its identification number, so that infection of some animals may be taken to indicate general herd exposure.

Given the fact that serology is at least 3-10 times more effective than the classical meat inspection techniques, it can be predicted that the risk of people getting infected by cysticerci should also decrease by a factor 10, if serological tests are applied on a large scale. Although a good computer simulation model should allow to calculate the risk reduction with more precision, the best method still remains an assessment in the field. Such an assessment should be carried out as follows:

– At the level of the intermediate host (cattle): by comparing the prevalence of cysticercosis in similar cohorts of slaughter cattle before and after the changes in inspection methods (using the antigen ELISA). Special attention should be given to cattle at higher risk of infection, i.e. those kept on free range or periodically on pasture (or farms with a history of infection).

– At the level of the final host (man): by comparing the prevalence of taeniosis in a representative sample of the population before and after the changes in inspection methods (using the copro-antigen technique). Special attention should be given to population groups at higher risk of infection, i.e. those who have a high consumption of raw or undercooked beef.

Attention should be drawn to the fact that an increased prevalence of infection will be seen in cattle during the first years after the introduction of the above mentioned new serodiagnostic methods. It appears therefore appropriate to underline this aspect especially towards public administrations and health authorities with regard to a correct socio-economic evaluation of the new interventions. Except for the increased losses of frozen carcasses it should be realised that freezing capacity likely has to be newly created because the existing freeze houses are not sufficient to cope with larger numbers of carcasses. Moreover, if, as considered by Gemmel (1986), parts

of Europe are hyper-endemic for *T. saginata* cysticercosis, which is based on an assessment of herd-immunity, then a theoretical approach (modelling) is very much needed before intervention is proposed. Due to herd immunity only a certain number of adult animals harbour limited numbers of cysticerci. When the herd immunity disappears by any intervention, it may be calculated or measured how many adult animals will become infected with higher numbers of cysticerci per carcass. This may lead to an actual increase of tapeworm carriers in the initial phase of the intervention programme. It is highly recommended to collect sufficient epidemiological data to reliably conduct mathematical calculations, before intervention studies are introduced.

1.5. Reduction of risk

Notwithstanding the factors identified before which undoubtedly have led to a certain reduction of bovine cysticercosis and human tapeworm carriership (meat inspection, freezing, sewage treatment, etc.) there is ample evidence that the current animal husbandry system and meat inspection as preventive measure have failed to properly control the life cycle of *T. saginata* in most of the EU Member States.

1.5.1. Cysticercosis free husbandry

The life cycle of *T. saginata* requires contact between man (final host) and cattle. Strict hygiene measures therefore break the life cycle of these parasites (Schantz, 1992 and 1998).

Taenia saginata is frequently observed in cattle at routine meat inspection. The recorded prevalence is even higher whenever special examinations (serology, whole carcass examination) are applied. Apparently, cattle with free access to the environment can easily pick up *T. saginata* cysticercosis.

Cattle kept indoors, and specifically young animals (calves) which are raised for meat production only, are potential populations that can be kept free from cysticercosis. A label could be attributed to meat originating from these farms, which would guarantee the consumers that it is free of cysticerci.

Other aspects such as implication for animal welfare should be kept in mind, but are not within the mandate of this report.

There are a numbers of prerequisites, which would be necessary to be fulfilled in order to ensure cysticercosis-free conditions:

– Keep animals indoor all their lives.

– Feed animals only with feed guaranteed free from *T. saginata* eggs. (This means that no feed from pastures or crops can be used, unless treated.)

– People handling animals should be free from *T. saginata*. The increase of farm visits by non professionals could increase the risk.

– Certification of the herd through sero-surveillance/monitoring as free from cysticercosis.

The background for sampling may be based on the following observation: in a herd (*e.g.* calves) as described above there is virtually no chance for infection. If a direct source of infection is present (*e.g.* the stockmen are infected) this will undoubtedly lead to a "cysticercosis storm" with high prevalence figures in the population after slaughtering. In relatively small samples of such population sero-positivity will alarm the authorities. Such monitoring could be incorporated into systems designed to check for other cattle diseases.

1.5.2. New detection technology

It is clear that the demonstration of the parasite in cattle with more sensitive methods is the only way to prevent human infection and subsequently prevent cattle to get infected through human waste. The mere demonstration of cysticerci at meat inspection may be replaced by antigen detection methods using immunological tools suchs as ELISA. This may enhance the identification of the actual number of cattle which are a risk for the consumer (see 1.4.7). Nevertheless, this still is far from the ideal situation where all cattle infected with viable cysticerci may be identified at slaughter.

1.5.3. Professional and public's awareness

The general ignorance of the public or even professionals such as physicians and veterinarians contributes to the ongoing epidemiological situation. Community-wide education about symptoms of tapeworm carriership and the responsibility to consult the medical profession for therapy should be encouraged. Education on the risk of consuming raw or undercooked meat also may reduce the actual number of infected people.

1.5.4. Future development of vaccination against cysticercosis

Gemmel (1986) pointed out that a vaccine would be useful to immunise naive animals. He also described that immune animals could not be further protected by vaccination, however, they could have their antibodies levels boosted by vaccination. Therefore a vaccine would be of most value in protecting naive animals from sporadic challenge. An integrated approach

would be necessary to ensure control with the general aim being to reduce prevalence in both man and the pig/cattle populations. Many studies would have to be carried out on a vaccine to determine under what circumstances it would work effectively.

Experimental vaccination of livestock against cysticercosis has become possible. *Taenia ovis* research has led to suitable antigens to be used in immunisation procedures. However, this vaccine has never been marketed (Rickard *et al*., 1995). Finally, *T. saginata* vaccination against bovine cysticercosis has been shown to be feasible by Lightowlers *et al*., 1996 and Parkhouse *et al*., 1996, as has *T. solium* cysticercosis in pigs (Plancarte *et al*., 1999). This means that recombinant antigen-candidates for a vaccine production are becoming available, however, it is questionable whether or not vaccines will be commercialised.

1.6. Conclusions

1.6.1. Identification of practices/factors which are of importance in maintaining a high prevalence level

- A wide variety of factors that are important for the maintenance of the infection in man and cattle population are still common practice, thus leading to ongoing infection. These include the spread of *Taenia* eggs through sewage sludge and surface water and ignorance of tapeworm carriers about their spreading capacity by handling feed or taking care of cattle.
- Since there exists no formal notification of tapeworm carriership in humans in any EU Member State, the number of *T. saginata* tapeworm carriers can only be estimated from sales figures of the specific drugs (niclosamide and praziquantel). In our modern society social factors influence the denial of having worms. The virtual lack of severe clinical symptoms when having a tapeworm infection, and the paradigm in the medical profession that parasites are a 'third world problem', lead to underestimation of the actual human *Taenia* carriership.

1.6.2. Is there a need for better control and surveillance and if so, does this reduce the risk as compared to classical meat inspection?

- There is a need to improve the epidemiological knowledge concerning this infection in the EU in man.
- *T. saginata* is abundantly present in most European countries, with up to 5-10% infection rates amongst the intermediate host (bovines). The prevalence figures of bovine cysticercosis (*T. saginata* cysticercosis) that have been published in the various EU Member States vary between 0.01-6.8%.
- These prevalence figures are the results of routine slaughterhouse inspection, which is an underestimation of the real prevalence by at least a 3-10 factor. This is due to the relative low sensitivity of the visual inspection methods prescribed in EU Directives and thus reliable data of prevalence figures in cattle are lacking.

- Current meat inspection technique have limited sensitivity for *T. saginata* infection.

1.6.3. The effectiveness of newly developed diagnostic methods compared to the currently used technique

- New diagnostic tools have been developed for use both in man and animals. In man this is merely contributing to recognition of tapeworm carriership and identification of *Taenia* species by stool examination. Although the specific detection of antibodies or circulating antigen have made diagnosis of (bovine) cysticercosis much more reliable discrepancies between direct visualisation of the parasite at abattoir inspection procedures and these new technologies exist.
- The detection of specific antibodies in cattle has greatly improved in terms of sensitivity and specifity, however, these assays cannot differentiate between past or current infection and hence cannot be used to replace current abattoir procedures. They may be used in epidemiological studies.
- The detection of antigen in serum of cattle is indicating actual infection and could provide considerable improvement of diagnosis at the abattoir level.
- For proper evaluation of these new techniques total carcass examination is needed to assess the diagnostic value of serology. This is only possible for initial comparative assay evaluation. Recent data (Dorny *et al*., 1999) suggest considerable and reliable improvement of diagnosis by introducing the antigen detection, which appears 10 times more sensitive than the current visual method.

1.7. Recommendations

- Awareness of taeniosis/cysticercosis among medical doctors, veterinarians, meat animal producers and the public should be developed through appropriate information and education
- An epidemiological surveillance of human cases of taeniosis (including *T. saginata* / *T. solium* species diagnosis) should be undertaken
- Abattoir testing of animal cysticercosis should be improved, through the sensitivity of the use of antigen detection tests
- Reporting of *Taenia saginata* infection should be done in a standardised manner at EU level
- As a part of the table to stable concept animal rearing system should be re-evaluated in order to produce cysticercosis free animals in a qualify controlled system.

2. PART II: *TAENIA SOLIUM*

2.1. Hazard identification and characterisation

The life cycle of *Taenia solium* is schematically presented in figure 2. Typically, the tapeworm life cycle consists of an adult (tapeworm) stage in the final host (human). The worms produce segments (proglottids) containing a considerable number of eggs which are shed on defecation. *Taenia* eggs, containing an embryo (or oncosphere) are spread (directly or through sewage) into the environment and may be orally ingested by the intermediate hosts. For *T. solium* these are normally pigs. However, also man can also act as intermediate host. In the intermediate host, the embryos move from the intestine to organs such as muscles, liver, lungs, brain and sometimes subcutaneous tissues. Here they develop into small vesicles (cysticerci) containing one "head" (protoscolex) of the future tapeworm.

If the definitive host (human) consumes meat (muscle) or organs containing viable cysticerci, the life cycle is completed and a tapeworm may develop. Thus, humans are able to contaminate pigs and humans through *Taenia* eggs (oncospheres) released with their faeces. Adult *Taenia solium* attains lengths of several meters in the small intestine of humans where it attaches to the mucosa through suckers and hooklets. Normally one to a few worms are harboured by a patient. Patients suffering from taeniosis are frequently asymptomatic; however, gastrointestinal discomfort including diarrhoea, flatulence and abdominal pain is sometimes observed. At the distal part of the worm adult tapeworms release egg-containing motile segments which are shed and excreted at the distal part of the worm with the faeces.

Cysticercosis in pigs is the consequence of an oral infection of the intermediate host with eggs, containing embryos, which are infectious immediately after deposition in the environment. Usually pigs show no clinical signs at all. The embryos (oncospheres) in pigs show a wide distribution in muscles (where they can be found at slaughter), nervous tissue of the brain or eye. Cysticerci in lungs and liver tissue usually die early.

Human taeniosis due to *Taenia solium* raises a public health issue quite different from that previously described for *T. saginata*. *T. solium* eggs, if ingested by humans, may lead (like in pigs) to invasion of various organs (including brain), by cysticerci. Human cysticercosis, especially neurocysticercosis, is associated with marked morbidity and mortality. Although swine cysticercosis has virtually disappeared from Europe, analysis of recent epidemiological data from the USA suggest that *T. solium* infection could become a reemerging disease in Europe too.

Eating undercooked pig meat containing viable cysticerci leads to

Human taeniosis

Eating food contaminated by *Taenia solium* **eggs** leads to

Human cysticercosis

Ingestion of *Taenia* larvae (cysticercus)

Ingestion of *Taenia* egg

Human taeniosis

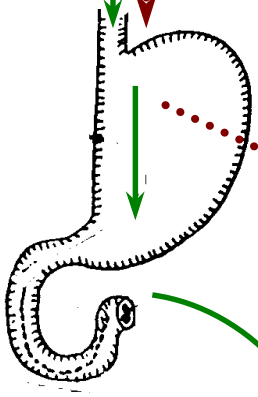
Presence of the **adult worm** (*Taenia*) in the small bowel of humans

Human cysticercosis

Presence of the **cysticercus (larval stage** of the worm) in various organs, following consumption of *Taenia* eggs.

Migration

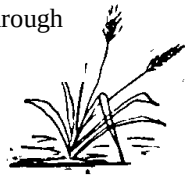
Adult *Taenia* in small bowel



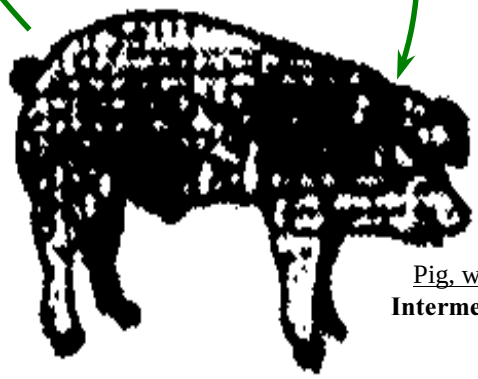
Cysticercus in muscle

Taenia egg

Humans hosting the adult *Taenia* excrete **eggs** in the environment (through faeces)



Food contaminated by *Taenia* eggs for example through dirty hands



Pig, wild boars:
Intermediate hosts

Animal cysticercosis

Presence of the larval stage of the worm (cysticercus) in muscles of pigs, wild boars

Human = Definitive host of the **adult *Taenia solium***

Life cycle of *Taenia solium*

Human = Intermediate host of the ***Taenia solium* larvae**

Usually adult stage in small bowel (= *taeniosis)*; but sometimes eggs originating the small bowel, heavily infect all organs

Humans may act as accidental intermediate hosts usually by ingesting *Taenia solium* eggs. Human are considered epidemiologically a dead end host for cysticerci and infection will not lead to further development of tapeworms in consumers. The infection may be asymptomatic typically when cysticerci are mainly found in muscles and in subcutaneous tissues. However, massive infection often leads to myositis with swellings and weakness. Severe involvement of the myocardium may lead to heart failure. The most severe symptoms are observed when infected individuals develop cysticerci in the brain (neurocysticercocsis). Cerebral locations are the cause of epileptic type seizures, abnormal behaviour, functional losses, acute hydrocephalus, failing vision and other abnormalities. Death or degeneration of cysticerci in the brain may worsen the actual disease because of intensified associated tissue reaction.

It is also possible that in some cases of infection with the adult stage (taeniosis), mature eggs coming from the small bowel, heavily infect all organs causing cysticercosis or neurocysticercosis.

The consequences of taeniosis/cysticercosis in man and animals are summarised in the Annex.

2.2. Epidemiology

Cysticercosis in swine is diagnosed in EU Member States as a consequence of routine meat inspection procedures (Council Directive 64/433/EEC). However, swine cysticercosis has virtually disappeared from Europe and consequently the meat inspection does not pay much attention to such control. It is based on visual observation of the muscle surface of pig carcasses only.

Cysticercosis in man seems to be eradicated in most of the EU, although small foci in Spain and formerly Eastern Germany may exist. However, neighbouring countries (Poland) do have significant, albeit low incidence of human *T. solium* and cysticercosis (Schantz *et al*., 1998, Ilsoe *et al*., 1990 and Kyvsgaard *et al*., 1991). As a matter of fact, there is an overlap with the prevalence data in animals: 0.006-0.6% of the pigs in some areas of Spain are infected with cysticercosis (Garate, 1999) and 0.0003% of the pigs in Poland (Pawlowski, 1999).

Because of the frequent location of cysticerci and inflammatory lesions in the brain and occurrence of various symptoms and signs of central nervous system involvements in patients, cysticercosis due to *T. solium* in humans, namely neurocysticercosis, has raised considerable interest in the USA in recent years. Like Europe, the USA was considered as virtually free of *T. solium*. More than 35 years ago this was called "a testimony to under-development" Of 42 cases observed in the USA from 1857 to 1954, only 3 were autochthonous. In non-endemic areas imported cases, i.e. cases acquired in a foreign country, are observed among internationally mobile persons, returning tourists, soldiers or immigrants. These patients may

inadvertedly transmit the infection to another person (or to a pig), and thus "introduce" the disease in an usually "free" country.

More than 900 cases were diagnosed through 1986 in the USA, including 15 well documented locally acquired cases. It was readily apparent that during the late 1970's there was a significant increase in diagnoses of neurocysticercosis. 59% of the patients were Hispanic. A prospective survey in southern California initiated in 1988 has allowed the Centers for Disease Control to estimate more than 1,000 cases were currently diagnosed each year in the USA, with an increasing frequency in children. As in the late 1970's, most cases were diagnosed in patients of Hispanic origin, but increasing proportions of patients (up to 42%) were persons born in the United States, including individuals who lived in particular communities known to avoid pork meat and who were contaminated by infected domestic workers recently emigrated from Mexico or other countries of Central America (Schantz *et al*., 1993, 1998).

2.3. Practices and factors that are of importance in supporting a certain prevalence level of *Taenia solium* in man and animals

2.3.1. Risk factors for human taeniosis (T. solium)

Consumption of undercooked meat containing viable cysticerci (meat not submitted to or not found contaminated by the current meat inspection methods).

The effect of processing pork meat and pork meat products on swine cysticerci is as presented in Table 2.

2.3.2. Risk factors for swine cysticercosis (T. solium cysticercosis*)*

– Application of human slurry over pastures, or direct environmental access by free ranging pigs.

– Presence of a tapeworm carrier on the farm, when swine have access to human faeces.

– Feeding of household scrapes or garbage to swine or swine being allowed access to garbage. This includes wild boars in the same area.

2.3.3. Risk factors for human cysticercosis/neurocysticercosis (T. solium cysticercosis*)*

Poor hygiene of a person with *T. solium* may lead to selfinfection, but also to contamination of food, water, household his direct surrounding. Even direct infection to other persons is possible.

2.3.4. Other factors (e.g. social and psychological) that influence a significant prevalence level

There is no reason to believe that European citizens, or the medical profession will behave differently to *T. solium* as compared to *T. saginata*. However, experience in the USA in the past 10 years (see 2.2) warrants some more discussion.

The USA example emphasises the fact that even infections which could have been considered as virtually eradicated from a given country or area, can be re-introduced because of changes in environmental factors, but also because of behavioural and/or political changes. International exchanges, immigration from countries where the disease remains endemic because of poor hygiene, deficient sanitary facilities and primitive swine husbandry practices, and also international transport of infected pigs and subsequent consumption of their infected meat are the main factors susceptible to introduce the disease in countries which had been nearly free for the last decades.

Neurocysticercosis is an emerging disease, virtually absent in the current EU member states. However, in Central and Eastern Europe countries the prevalence of *T. solium* in man and pigs is substantially higher. The risk of introducing this infection when opening the borders after joining the EU community is real. There too, the poor awareness of the condition by physicians living and trained in non-endemic countries may lead to delayed diagnosis, and, thus delayed alert and delayed measures to control the emerging disease. Because of the severity of neurocysticercosis, surveillance programs could be implemented which could help physicians in diagnosing the disease early, using well evaluated methods such as neuro-imaging procedures (CT scan and MR imaging) and immunoblotting for immunodiagnosis. Early detection of human cases should make the epidemiologic investigations easier and lead to appropriate measures to limit the spread of cysticercosis in the human population.

2.4. Diagnostic methods

2.4.1. Direct recognition of the adult tapeworm in humans

As described in paragraph 1.4.2 & 1.4.6, this appears to be difficult.

2.4.2. Routine post mortem inspection procedures

Even applying current meat inspection procedures, *T. solium* infection may be underdiagnosed.

2.4.3. Recent developments in human diagnosis

More than 260 papers have been published since 1981 on *T. solium*, of which 76 were related to diagnosis. Generally speaking information on the specificity and sensitivity of assays is better for *T. solium* than *T. saginata,* especially for diagnosis of human cysticercosis/taeniosis. This probably is a reflection of the fact that it is easier to obtain this information on humans

where CT scan and MR technologies are available and can act as the 'gold standard'.

Diagnosis by Western Blot (EITB) or Enzyme-Linked Immunotransfer Blot based on parasite glycoproteins has found wider application in the diagnosis of human *T. solium* neurocysticercosis infections than for the diagnosis of either porcine or bovine cysticercosis (Parkhouse and Harrison, 1989, Tsang, Brand & Boyer; 1989, Tsang & Garcia, 1996, Schantz, 1998). As in *T. saginata* (see paragraph 1.4) three diagnostic tools which may be applied in epidemiology studies and control of taeniosis/cysticercosis:

(a) Tests for assessment of serum antibodies.

(b) Detection of secretory products of live cysts or tegumental antigen (i.e. serum antigens) from viable cysticerci or adult tapeworms (i.e. copro antigens) in humans (Correa, Sandoval, Harrison & Parkhouse, 1989, Harrison, Parkhouse, Correa & Flisser, 1990, Garcia, *et al*., 1998) and pigs (Rodriguez del Rosal, Correa & Flisser, 1989; Sciutto *et al*., 1998).

(c) Differential diagnosis methods between adult proglottids/eggs of *T. saginata* and *T. solium* as the host ranges of the two parasites overlap in some countries.

2.4.4. Conclusion

In an emerging situation these technologies can also be applied in pigs. Again, like in *T. saginata*, the detection of circulating antigen is the most appropriate technology.

2.5. Reduction of risk

2.5.1. Present status in EU Member States

There is a reason for vigilance because of experciences in the USA and the nearby membership of endemic East European countries to the EU community.

In the rare endemic foci the theoretical possibility of a future vaccination (see also paragraph 1.5.4) should be considered. For the time being extra-alertness at meat inspection procedures in such areas is necessary. In modern husbandry practices in the EU the parasite life cycle cannot persist, and this may be the main reason for its absence. Cysticercosis-free husbandry, as proposed for cattle (see 1.5.1) may very well be applied to get rid of swine cysticercosis in endemic foci in the EU.

2.5.2. Early warning system

Because of the severity of (neuro)cysticercosis in man and because *T. solium* infection is currently absent in most parts of the EU, an early warning system is required. Travel of people from and to endemic areas is increasing. The risk of importing infected pigs is much less than the chance of introducing the infection by tapeworm carriers. Many factors such as hygiene, toilet use,

waste treatment, animal husbandry practices like free ranging, and public education may have major impact on re-establishment of a *T. solium* cycle in Europe. In addition current trends in rearing pigs outside, in small settings, could bring new opportunities to pigs to become infected via human parasite carriers. Therefore it is suggested that a reporting system is established to identify this potentially re-emerging zoonosis as early as possible.

The following suggestions are made:

At the human level:

- Diagnosis or suspicion for human taeniosis could be followed by adequate identification methods of the tapeworm involved (microscopy, PCR analysis).
- The public, physicians and veterinarians should be informed about *T. solium*.
- People coming or returning from endemic areas should voluntarily be examined by copro-antigen testing or treated with specific anthelminthics, in particular food handlers, cooks, etc.
- Cases of human cysticercosis as well as tapeworm carriers should be notifiable.
- Whenever a case of cysticercosis in man is diagnosed, epidemiological examinations should be carried out to trace the source of infection (auto infection) and to examine relatives or other contacts for cysticercosis (serology) or tapeworm carriership (copro-antigen test).

At the pig (pork) level:

- Extensively reared (free-roaming) pigs should be examined individually for cysticercosis with the antigen detection method, in addition to post mortem inspection.
- Sero-surveillance at the farm level conducted for other diseases (such as swine vesicular disease or Aujeszky disease) should include specific *T. solium* antibodie detection (or a surogate marker: antibodies).
- Swine cysticercosis should be a notifiable disease.

2.6. Conclusions

Though, at present, *T. solium* does not constitute a public health problem in the EU, neither as human tapeworm, nor as swine cysticercosis.

Ignorance of the public, the medical profession and inadequate veterinary control in non-endemic EU Member States may lead to significant consequences. This has been clearly demonstrated in the USA, where *T. solium* and human cysticercosis were reintroduced during the past 20 years.

There exists a risk of importing *T. solium* by tourism, migration of tapeworm carriers or indirectly by importation of infected pigs, or pig meat.

An early warning system reporting cases in man and pigs would play a key role.

2.7. Recommendations

- An early warning system should be set up at EU level to be able to take adequate measures as soon as such infection in man and/or pigs is observed.
- Cysticercosis-free husbandry should be encouraged.
- *T. solium*/taeniosis/cysticercosis cases should become notifiable to enable investigations at the farm/production level and favour interruption of the parasitic cycle.
- Inclusion of the larval cestode infections among the diseases of public health importance in the European programme of surveillance of communicable diseases would fulfil this requirement.

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4. ANNEX

Consequences of taeniosis/cysticercosis in man and animals in short

Man *1) T. saginata* and *T. solium*	Adult tapeworm in the intestinal tract (**taeniosis**) shedding of proglottids and/or eggs with the faeces. *Mild clinical symptoms.*
2) T. solium only	**Cysticercosis** in organs, subcutaneous tissues. The larval stage of the tapeworm (cysticercus) is embedded in muscles, liver/lung, or directly under the skin. *Depending on the number and localisation of cysticerci moderate to severe symptoms.* **Neurocysticercosis.** The larval stage of the tapeworm is embedded in brains and/or eye. *Severe clinical symptoms.*
Cattle (*T. saginata)*	**Cysticercosis** in muscle. The larval stage of the tapeworm (cysticercus) is embedded in musculature of cattle throughout the body. No clinical symptoms, however abattoir diagnosis is made by (the rather insensitive) routine meat inspection procedures.
Pigs *(T. solium)*	**Cysticercosis** in muscles and subcutaenous tissues, sometimes in liver, lungs and brain *No clinical symptoms, however abattoir diagnosis is based on visual inspection of the carcass only.*