Taenia solium Transmission in a Rural Community in Honduras: An Examination of Risk Factors and Knowledge

by

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Abstract

Taenia solium taeniasis and cysticercosis are recognized as a major public health problem in Latin America. *T. solium* transmission not only affects the health of the individual, but also social and economic development, perpetuating the cycle of poverty.

To determine prevalence rates, population knowledge and risk factors associated with transmission, an epidemiological study was undertaken in the rural community of Jalaca. Two standardized questionnaires were used to collect epidemiological and *T. solium* general knowledge data. Kato-Katz technique and an immunoblot assay (EITB) were used to determine taeniasis and seroprevalence, respectively.

In total, 139 individuals belonging to 56 households participated in the study. Household characteristics were consistent with conditions of poverty of rural Honduras: 21.4% had no toilet or latrines, 19.6% had earthen floor, and 51.8% lacked indoor tap water. Pigs were raised in 46.4% of households, of which 70% allowed their pigs roaming freely. A human seroprevalence rate of 18.7% and a taeniasis prevalence rate of 2.4% were found.

Only four persons answered correctly ≥ 6 out of ten *T. solium* knowledge questions, for an average passing score of 2.9%. In general, a serious gap exists in knowledge regarding how humans acquire the infections, especially neurocysticercosis was identified.

After regression analysis, the ability to recognize adult tapeworms and awareness of the clinical importance of taeniasis, were found to be significant risk factors for *T. solium* seropositivity.

These results demonstrate a high level of transmission and a low level of knowledge about *Taenia solium* in Jalaca. Consequently, intervention measures integrated with health education are necessary to decrease the burden caused by this parasite.

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List of Abbreviations

BC	Before Christ
CC	Cysticercosis
CDC	The Centers of Disease Control and Prevention,
CNS	Central Nervous System
CoAg	Coproantigen
CSF	Cerebrospinal Fluid
CT	Computed Tomography
DICU	The Directorate of Scientific Research of UNAH, Honduras
DNA	Deoxyribonucleic Acid
DV	Dependent Variable
EITB	Enzyme-linked Immunoelectrotransfer Blot
ELISA	Enzyme-linked Immunosorbent Assay
g	Gram
GP	Glycoprotein
IgA	Immunoglobulin A
IgG	Immunoglobulin G
ITFDE	The International Task Force for Disease Eradication
IV	Independent Variable
mg	Milligram
ml	Milliliter
mm	Millimeter
m*M*	Millimole

M	Mole
MoAb	Monoclonal Antibodies
MRI	Magnetic Resonance Imaging
NC	Neurocysticercosis
pH	Potential of Hydrogen (Hydrogen ion Concentration)
PAHO	The Pan American Health Organization
PCR	Polymerase Chain Reaction
Q1	General Survey Questionnaire
Q2	Knowledge Questionnaire
RIP	Raised Intracranial Pressure
SDS -PAGE	Sodium Dodecyl Sulphate Polyacrylamide Gel Electrophoresis
SES	Socioeconomic Status
T. solium	*Taenia solium*
***Taenia* sp.**	*Taenia* species
UNAH	The National University of Honduras
USA	The United States of America
VPS	Ventriculoperitoneal Shunt
WHO	The World Health Organization

Glossary of Parasitology Terms

Antibody

(Abbr. Ab.) An immunoglobulin molecule that recognizes a specific antigen

Anthelminthic

Any chemotherapeutic substance directed against a helminthic infection

Anti-convulsant

An agent that prevents or relieves convulsions

Antigen

(Abbr. Ag.) A molecule usually foreign to the host that elicits the production of antibodies

Asymptomatic Infection

The presence of a micro-organism in the body, which presents no signs or symptoms associated with the disease

Autoinfection

Reinfections without exposure to the environment. As in the case of a *T. solium* tapeworm carrier that acquires cysticercosis by self fecal contamination with *T. solium* eggs (Syn. self-infection)

Carrier

An individual who has had the disease and recovered but continue to maintain the pathogen and spread it to others. A host that harbours an infection without particular manifestation of disease

Central Nervous System

(Abbr. CNS) The part of the nervous system which in vertebrates consists of the brain, cranial nerves and spinal cord, to which sensory impulses are transmitted and from which motor impulses pass out, and which coordinates the activity of the entire nervous system

Cestode

Any of various parasitic flatworms of the class Cestoda, having a long flat body equipped with a specialized organ of attachment at the anterior end (the scolex) (Syn. tapeworm)

Chemotherapy

The use of chemical substances or drugs in the treatment or control of disease or mental illness

Coproantigen

(Abbr. CoAg) The presence of parasite's antigens in the intestines and in feces. *T. solium* coproantigen detection is based on the detection of substances excreted or secreted by the adult parasite while in intestine, which can be detected in feces by different immunological techniques, such as an ELISA

Cerebrospinal Fluid

(Abbr. CSF) A clear, colorless liquid that is secreted from the blood into the lateral ventricles of the brain, and serves chiefly to maintain uniform pressure within the brain and spinal cord

Cysticercosis

(Abbr. CC) The presence of larval stages of *Taenia spp* in hosts tissues. *T. solium* causes cysticercosis in humans and pigs

Cysticercosis---Human

The presence of *T. solium* larval stages in human tissues including the central nervous system, eyes, muscles, subcutaneous tissues, other organs

Cysticercosis---Porcine

The presence of *T. solium* larval stages in pigs' tissues and organs

Cysticercus

The hollow fluid-filled (vesicle) larval stage of *Taenia* containing a single invaginated scolex

Diagnosis---Definitive

A final or conclusive determination of the nature of a case of disease

Diagnosis---Probable

A likely determination of the nature of a case of disease

Diagnosis---Presumptive

A determination of the nature of a case of disease, which has a reasonable basis

Egg

In helminths: the spherical thick-shelled product of fecundation. In the case of *T. solium* containing a hexacanth embryo (i.e. oncosphere) and nutrient material, is the infective stage for porcine and human cysticercosis

Enzyme-linked Immunoelectrotransfer Blot

(Abbr. EITB) An immunological technique that transfers proteins from a gel to a paper-like membrane (e.g. nitrocellulose), by capillarity or electric field, preserving spatial arrangement by molecular weight. Proteins are then immobilized and detected (e.g. antibodies) (Syn. western blot)

Elimination of Disease

Reduction to zero of the incidence of a specified disease in a defined geographical area as a result of deliberate efforts; continued intervention measures are required (e.g. neonatal tetanus)

Elimination of Infections

Reduction to zero of the incidence of infection caused by a specific agent in a defined geographical area as a result of deliberate efforts; continued measures to prevent re-establishment of transmission are required (e.g., measles, poliomyelitis)

Enzyme-linked Immunosorbent Assay

(Abbr. ELISA) An immunological technique used to detect antibodies or antigens in a variety of specimens including serum, CSF, feces, tissues, etc. The name of the test derives from its use of enzymes that will link antibodies or antigens reacting with the specimen and give a measurable color signal when the reaction is positive

Embryophore

In tapeworms, the envelope immediately around the oncosphere and derived from it. In genus *Taenia* it forms a thick protective layer composed of a keratin type of protein

Endemic Disease

The constant presence of a disease or infectious agent within a given geographic area or population group; may also refer to the usual prevalence of a given disease within such area or group

Epidemic

The occurrence of more cases of disease than expected in a given area or among a specific group of people over a particular period of time

Epilepsy

A chronic neurological disorder characterized by loss of consciousness and convulsions (from the Greek, "epilepsia" means "a taking hold of or seizing")

Epilepsy---Late Onset

Epilepsy that starts in adulthood, generally accepted as after 20 years of age

Eradication

Permanent reduction to zero of the worldwide incidence of infection caused by a specific agent as a result of deliberate efforts; intervention measures are no longer needed (e.g., smallpox)

Evasion (of the immune response)

Mechanisms by which helminths avoid the immune response of the host either by occupying a privileged site or by covering themselves with host or host-like antigens

Formol-ether Concentration Technique

A stool concentration parasitological technique that combines flotation and sedimentation for increasing sensitivity in obtaining parasite diagnostic stages

Granuloma

Focal lesion resulting from an inflammatory reaction caused, in the case of CC, by *T. solium* cysticerci

Gravid Proglottid

Terminal segment of a tapeworm filled with eggs

Helminths

A group of parasites commonly referred to as worms. The group includes cestodes, trematodes and nematodes. *T. solium* belongs to cestodes

Hermaphroditic

Containing both male and female organs in the same individual (e.g. Cestodes)

Hexacanth Embryo

The motile microscopic embryonic stage that hatches and escapes from eggs of tapeworms. In tapeworms infecting humans (e.g. *T. solium*), the oncosphere is six-hooked (the word "hexacanth" is from Greek: hex, 'six; akantha, hook or thorn) (Syn. oncosphere)

Host

A person or other living organism that can be infected by an infectious agent under natural conditions. There are many types of hosts. Being the main: the definitive host, (usually the natural host) in which final development or sexual reproduction takes place, and the intermediate host which serves as a step in the parasite's life cycle

Host---Definitive

One that harbours the sexually mature stage of a parasite. Humans are the only definitive host of *T. solium*

Host---Intermediate

An obligate host that alternates with the definitive host and harbours the larval stage of the parasite. Pigs are the natural intermediate host for *T. solium*

Humoral Immune Response

An immune response (chiefly against bacterial invasion) that is mediated by B cells

Hyperendemic Disease

A disease that is constantly present at a high incidence and/or prevalence rate. In the case of *T. solium*, a community with taeniasis prevalence > 1% is considered hyperendemic

Immunoglobulin

(Abbr. Ig.) Molecules of the immune system, produced by activated B cells against antigens (i.e. IgM, IgG, IgA, IgE, and IgD) (Syn. antibody)

Kato-Katz ConcentrationTechnique

A stool concentration parasitological technique that requires a large amount of fecal sample, usually around 50 mg (as opposed to the direct examination which usually requires 2 mg) applied to a cellophane strip pre-soaked with glycerine (Syn. cellophane fecal stick smears)

Life Cycle

The course of developmental changes through which an organism passes from its inception to the mature state with the ability to reproduce. *T. solium* has three stages: egg, larva or cysticercus and adult worm, and it requires two hosts to complete its cycle, the human and the pig

Metacestode

A collective term for any of the larval stages of cestodes which are found in the intermediate host (e.g. cysticercus in pig and human tissues)

Neurocognitive Deficit

A reduction or impairment of cognitive function in one of these areas, but particularly when physical changes can be seen to have occurred in the brain, such as after neurological illness, mental illness, and drug use or brain injury

Neurocysticercosis

(Abbr. NC) The presence of *T. solium* larval stages in the human central nervous system

Oncosphere

See hexacanth embryo

Pathognomonic

Characteristic or indicative of a disease; denoting especially one or more typical symptoms, findings, or pattern of abnormalities specific for a given disease and not found in any other condition

Polymerase Chain Reaction

(Abbr. PCR) The first practical system for in vitro amplification of DNA and as such one of the most important recent developments in molecular biology

Prepatent Period

The period between the onset of infection and the moment in which there is parasitological evidence of its presence (e.g., in helminthic infections, eggs in feces are the parasitological evidence of infection, but occurs when worms are mature enough to produce them)

Proglottid

One complete unit of the segmented body of tapeworms, commonly called a segment

Reinfection

A second infection by the same pathogenic agent

Rostellum

A protuberant apical portion of the scolex in certain tapeworms, frequently bearing a circle of hooks as in *T. solium*

Sanitation

Facilities for safe disposal of human excreta and for the provision of safe drinking-water

Scolex

Anterior end of a tapeworm, which often bears suckers and hooks for attachment. In *T. solium*, it measures one mm in diameter and presents a conspicuous rostellum bearing two rows of alternating large and small hooks

Sensitivity

The probability that a test will diagnose a true positive reaction (a person with the infection or disease). A test with high sensitivity will have few false negatives. It is expressed as a percentage

Seroprevalence

The rate at which a given population tests positive on the serological test for particular antibodies

Sign

A measurable evidence of disease noted by an observer

Specificity

The probability that a real negative reaction (a person without the infection or disease) is recognized by the test to be negative. A test with high specificity will have few false positives. It is expressed as a percentage

Strobila

The chain of proglottids in a cestode. From anterior end: immature, mature and gravid. *T. solium*

Taenia solium

(Abbr. *T. solium*) A cestode parasite of humans and pigs

Taenia saginata

(Abbr. *T. saginata*) A cestode parasite of humans and cattle

Taeniasis

The infection with adult tapeworms in the human small intestine

Tapeworm

The adult *T. solium* that can inhabit the human small intestine; measuring 4-6 meters long, flat and ribbon-shaped. The tapeworm body consists of a scolex, a neck and a chain of segments called strobila

Trichina (or Trichinosis)

Infection by a nematode parasite of the genus *Trichinella*. Some *Trichinella* species can infect pigs and larval stages locate in their muscles from where they can be transmitted to humans via undercooked pork meat. In some countries cysticercosis is incorrectly called trichina or trichinosis probably due to life cycle similarities

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CHAPTER ONE: INTRODUCTION

The cestode parasite, *Taenia solium*, is increasingly being recognized as a major public health problem.[1] It has been estimated that some 50 million people are infected globally, and roughly 50,000 humans die of *T. solium* infection annually.[2] *T. solium* causes two different presentations depending on the host it is infecting, namely taeniasis and cysticercosis (CC). Taeniasis occurs when adult *T. solium* tapeworms localize in the small intestine of humans, the only definitive hosts, and is acquired by ingestion of raw or undercooked pork containing the parasite's larval stages. Cysticercosis, on the other hand, is acquired by fecal-oral contamination with infectious *T. solium* eggs from infected humans. Pigs are the only relevant intermediate hosts, but humans can also be infected accidentally and become both intermediate and definitive hosts.[3] Neurocysticercosis (NC) is a major form of CC caused by the presence of *T. solium* larvae in the human central nervous system (CNS).[4] Due to its sensitive localization, NC may cause serious morbidity, especially as it relates to seizure disorders and epilepsy. Several studies have confirmed that NC is a major contributor to the etiology of epilepsy in *T. solium*-endemic countries.[5-10] Clinical studies in Latin America have demonstrated that 50-70% of all patients with NC present with seizures.[11] Conversely, hospital-based studies have revealed that up to 50% of epilepsy cases are due to NC.[5,12]

A variety of demographic, economic and cultural factors makes taeniasis and CC significant public health problems. The parasite is principally distributed in pork-consuming countries, and is widely endemic in rural areas of developing countries, especially in Central and South America, southeast Asia and most of Africa with the exception of the strictly Muslim area of North and sub-Saharan Africa.[1,13] However, some developed countries (i.e., the United States, Canada, Argentina, the United Kingdom, etc.), which appear to be free of *T. solium* transmission, are observing an emergence in imported and introduced infections.[1] This emerging awareness is the result of the immigration of persons from *T. solium*-endemic countries, improved diagnostic technology and new options for treatment.[1,14]

A review of more than 50 cross-sectional and retrospective studies from *T. solium* endemic countries reveals that: for taeniasis, the most reported prevalence rate is about 1.3-1.7%;[10,15-23] the most frequently reported seroprevalence rate for anti-*T solium* serum antibodies in humans as indicator of CC has been estimated at about 10-13.5%;[5,17,23-27] and the most frequent prevalence rate of antibodies for porcine CC has been estimated about 19-24%.[5,19,28-31] The taeniasis prevalence rates might seem low when compared to other intestinal parasitosis such as the common roundworms *Trichuris trichiura* and *Ascaris lumbricoides*, whose prevalence rates can be up to 85% and 67%, respectively.[20] Nevertheless, due to the extended longevity and high fecundity of the adult tapeworm, and highly resistant eggs, a few tapeworm carriers are enough to maintain the transmission cycle. In fact, according to Cruz, Davis, Dixon, Pawlowski, and Proano (1989), a geographical area is considered hyperendemic when there is a taeniasis prevalence $\geq$ 1% in humans, and a porcine CC prevalence $\geq$ 5%.

In non-endemic countries, *T. solium* occurrence is associated with the presence of immigrants from endemic areas. For instance in the United States (U.S.), more than 1,000 cases of NC are reported annually, primarily in immigrants of Hispanic origin.[32-34] Locally acquired cases are also reported in the U.S. and are linked to tapeworm carriers from Latin America as well.[35] In Canada, the real frequency of *T. solium* infections is unknown. In the last two decades, there are only two publications indexed in MedLine.[36,37] Leblenc et al. (1986)[36] reported eight cases of NC occurring in immigrants to Canada, diagnosed in the 1980s at two major neurological centers affiliated with McGill University in Montreal, all cases occurring in immigrants. Sheth, Lee, Kucharczyk, and Keystone (1999)[37] reported the reactivation of a previously diagnosed and treated case of NC in a female resident of Toronto who was originally from Ecuador.

T. solium infections have an overwhelming socio-economic impact due to chronic morbidity and mortality, the decreased productivity of infected persons, the high cost of medical diagnosis and treatment, and economic losses to the pig industry.[1] For instance, estimated treatment costs for NC in Mexico alone mount up to US$ 89 million, and in Latin America, the losses reach US$ 164 million annually.[2,38] Even in the United States, a conservative estimate of hospital admission costs and wage loss is around $8.8 million annually.[38] The insufficient socio-economic resources in endemic countries strongly influence the transmission of *T. solium* infections and are responsible for their concentration in certain areas, thereby intensifying the parasite's prevalence, which maintains the vicious circle of poverty and disease.

Recent community-based studies have identified risk factors that perpetuate the cycle of human CC and taeniasis, including gender, age, rudimentary pig-farming husbandry, insufficient education, frequent consumption of pork, close proximity to tapeworm carriers, a history of passing proglottids, poor personal and household hygiene, poor sanitary facilities, lack of relevant knowledge about the parasite, living in endemic area, and number of household population.[15,19,20,39-46]

In Central and South America, *T. solium* has been reported in 18 countries. In these countries, an estimated 75 million persons live in endemic areas, and around 400,000 may have symptomatic disease.[47] In the past decade, several epidemiological studies have estimated *T. solium* infection rates in humans and pigs by community-based surveys in Latin America, most notably in Mexico, Guatemala, Honduras, Ecuador and Peru.[5,17,20,30,39,42,45,48-52] Through those studies, NC has been identified as an important public health problem of long-term consequences.[12,20,30,50,51,53] In Latin America, clinical studies in epileptic patients have demonstrated that NC was the primary etiology in 30-50% of cases.[5,7] Epilepsy caused by NC consequently represents an enormous expenditure for the developing countries in terms of human suffering, lost production, and the cost of anti-convulsants and the utilization of medical resources. This economic burden may in turn be a barrier to providing adequate diagnosis and treatment for patients.[11,13]

Several studies have confirmed that Honduras is an endemic country for *T. solium* infections.[12,20,30,50,51,53] Moreover, in comparison to other countries in Latin America, the infection rates in Honduras seem to be higher.[54] The average prevalence of taeniasis has been estimated about 2%; the seroprevalence rates of human antibodies (15% - 34%) and the seroprevalence of porcine antibodies (27.1%). Both field and clinical studies in Honduras indicate that NC is the major cause of epilepsy.[12] In addition, Honduras has the lowest reported rates of access to health services (46%), poor sanitation and environment, and undeveloped pig-farming practices.[54]

Due to the high prevalence of *T. solium* infection and its great impact on human health and economy, establishing effective control strategies is currently urgent in

Honduras. However, considering the limited financial resources of the country, to better plan control strategies thereby obtaining the most cost-effective return is crucial and necessary. To achieve this goal, several tasks should be performed ahead of implementing any control strategy, which include: assessing the current prevalence of taeniasis and seroprevalence of antibodies, and determining risk factors directed to *T. solium* transmission.

The purpose of this thesis was to estimate the local prevalence and investigate risk factors associated with *T. solium* infection, using data previously collected from a cross-sectional study undertaken in the Honduran rural village of Jalaca in 2002. Statistical analyses were conducted to identify risk factors involved in the parasite's transmission and to assess the level of *T. solium*-related knowledge of the studied population.

This study adds to existing knowledge about the epidemiology of *T. solium* in rural areas of Latin America. Moreover, since Jalaca is representative of rural standards of living and culture in Honduran rural communities, the results from this study provides further evidence of the need for the establishment of *T. solium* prevention and control in Honduras.

CHAPTER TWO: REVIEW OF LITERATURE

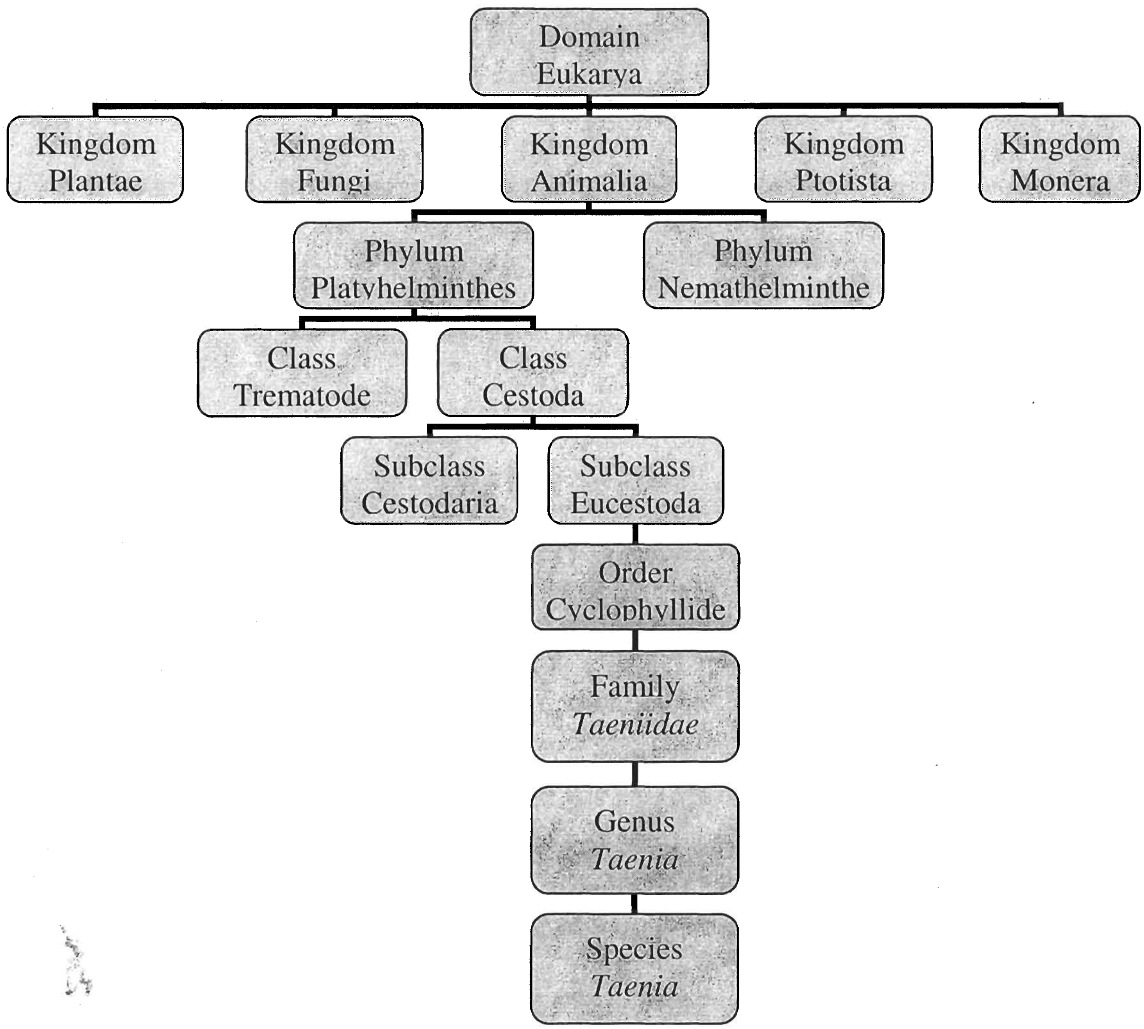
HISTORY

According to popular knowledge, the origin of the relation between humans and *Taenia* arose no more than 10,000 years ago, coinciding with the domestication of major food animals, including cattle, swine and the advent of agriculture.[55] Dating back to about 1550 BC, tapeworms were probably mentioned for the first time in a written documentary, named the *Papyrus Ebers*, and were described by ancient Greeks. Porcine CC was also detected by ancient Greeks, and mentioned by Aristophanes of Athens (448-386 BC) in his play "The Kights". In addition, human CC may be described the first time by Rumbler in 1558, and its importance was not recognized until the 16th century when European pathologists associated the condition with human disease and described NC in the brain of an epileptic patient.[56,57] Since the unravelling of the tapeworm structure, especially the discovery of scolex by the Edward Tyson in 1683, *T. solium* was separated from *Taenia* sp. As quoted by Grove (1990), Goeze recognized that the cysts found in pork meat were helminthic in nature, and clearly described their morphology in 1784. The mode of transmission and the relationship between adult and larval stages of *T. solium* were elucidated by Küchenmeister around 1850, through a series of experiments performed on dogs and imprisoned human convicts.[57] In present times, ongoing research on the biology, immunology, diagnosis and epidemiology of the parasite has improved the understanding of the nature of *T. solium* taeniasis and CC and their actual prevalence while large-scale migration of populations has continued to expand its distribution.[1] Efficient prevention, control and eradication strategies for *T. solium* transmission are deemed as urgent and premier tasks not only at the present but also in the near future.

TAXONOMY

The genus *Taenia* has about 20 species, but only a few species present potential health hazards to both humans and animals, such as *Taenia solium* and *Taenia saginata*.[1] However, only *T. solium* can cause both taeniasis and CC in humans.[55] As introduced by Muller (2001) and Pawlowski (2002), the taxonomic position of *T. solium* is shown in Figure 2.1.

Figure 2.1. Taxonomic position of *T. solium*

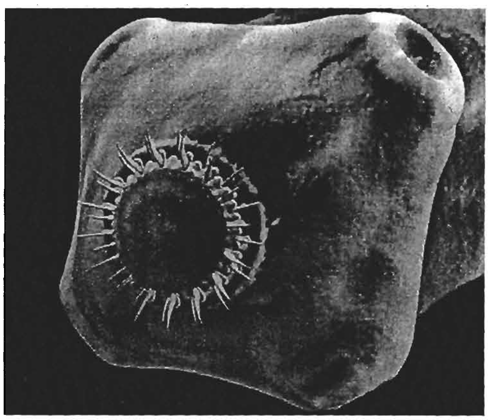


MORPHOLOGY

The adult intestinal *T. solium* can measure three to five meters in length. The body of the tapeworm is composed by: 1) scolex (see Figure 2.2): a holdfast organ armed with four muscular suckers and a rostellum displaying two rows of characteristic hooks (approximately 22 to 32 hooks each row) for attaching to the gastrointestinal mucosa; 2) neck; and 3) strobila, containing about 800 to 1,000 segments called proglottids.[58] The strobila arranged in sections is immature, mature and gravid proglottids, which differ in size, shape and stage of development with respect to their internal reproductive organs and egg content. Since cestodes are hermaphroditic, each mature or gravid proglottid has both male and female organs.[3] Immature proglottids, which are small and short, originate from the neck and evolve posteriorly to mature proglottids. Mature proglottids are almost rectangular and develop into gravid proglottids eventually. Every gravid proglottid is elongated, measuring approximately 12 mm long and 6 mm wide, and has a hypertrophic uterus with 7 to 13 lateral branches on each side of central uterine stem.[58] The gravid proglottids detach from the strobila either individually or in chains of 2 to 6 proglottids and are released into the intestinal lumen. The detachment happens several times a week and each gravid proglottid may contain 40,000 to 50,000 infective eggs.[3]

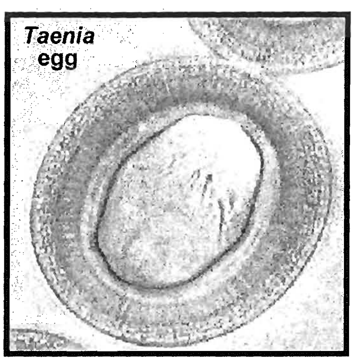
T. solium eggs shown in Figure 2.3 are morphologically indistinguishable from those of other *Taenia* species. Eggs are spherical and each has a thick striated cover, under which an embryophore exists. The embryophore is globular in shape, measuring 31 to 43 μm, and contains an oncosphere armed with six typical embryonic hooklets when mature. The embryophore protects the oncosphere against various unfavorable environments but is easily broken in the intestine of the intermediate host.[58] The oncosphere is the true larva of the parasite and is called hexacanth embryo.

Figure 2.2. Scolex of adult *Taenia solium*



From "http://research.amnh.org/exhibitions/epidemic/taenia.jpg "by S. Jim, 1998, Epidemic Microbe Models. Copyright 1998 by American Museum of Natural History.

Figure 2.3. Taenia sp. egg (direct microscopy 40×)



From "http://www.cdfound.to.it/html/ts5.htm" by Caramello, P., 2003. Atlas of Medical Parasitology, Copyright 2003 by the Carlo Denegri Foundation. Adapted with permission of the author.

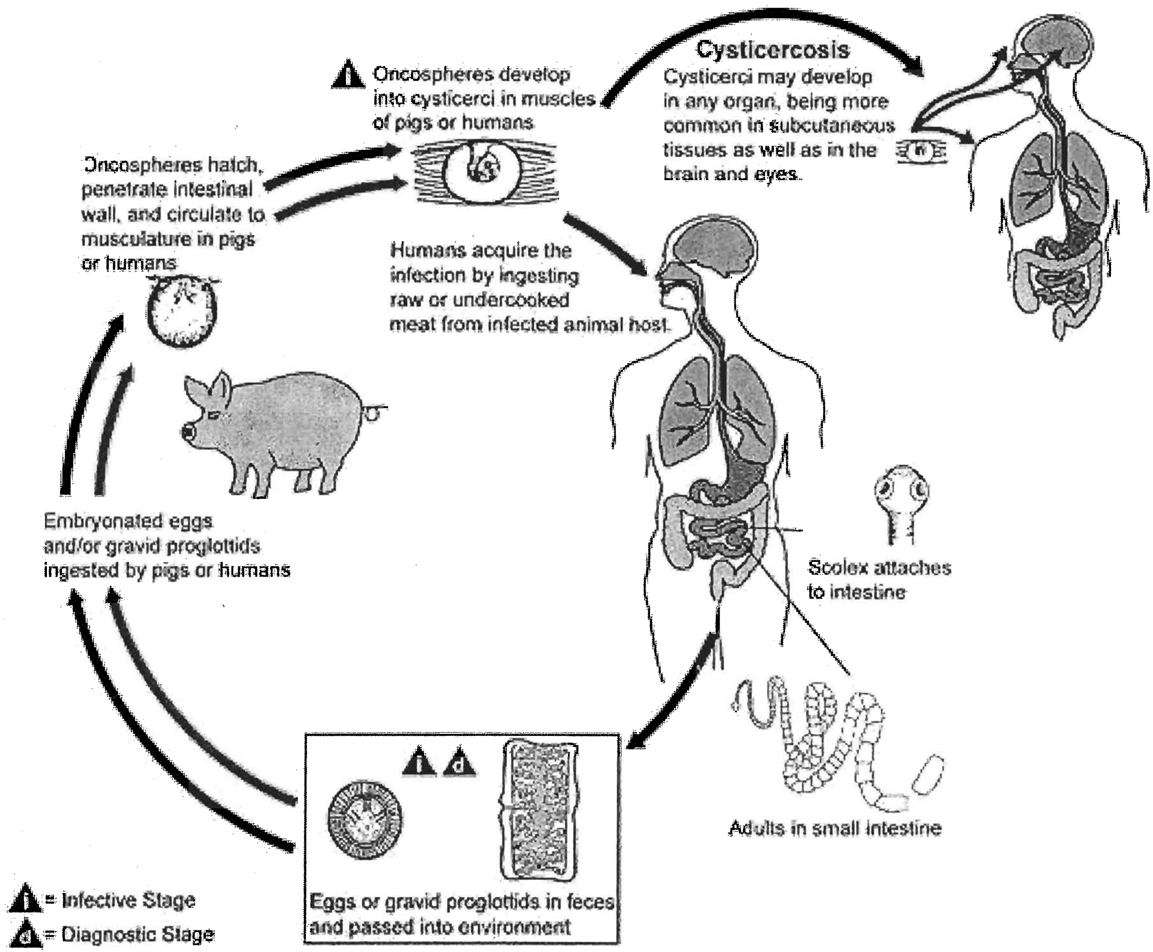
Once ingested by intermediate hosts, eggs will develop into metacestodes that are the larval stage of *T. solium*, also known as cysticerci. The cysticercus is an ovoid bladder filled with an opalescent fluid that nurtures an invaginated scolex. Cysticercus is approximately 6 to 18 mm in width and 4 to 6 mm in length.[58] In both pigs and humans, cysticerci can localize in different tissues and organs, where they become surrounded by host tissue. At this stage, cysticerci are often referred to as cysts or cystic stages.[3]

LIFE CYCLE

The natural life cycle of *T. solium* (Figure 2.4) requires two hosts: humans and swine. Humans are the only known definitive hosts; swine are the natural intermediate hosts. In addition, humans often act as accidental intermediate hosts. When humans ingest undercooked or raw pork containing viable cysticerci, larvae evaginate from the cysts and attach to the small intestine wall by their scolices.[3] After about two to three months, larvae develop into adult tapeworms and reside in the small intestine for years. Normally, infection consists of only one tapeworm, although multiple infections can occur.[58] The gravid proglottids with infective eggs separate from the adult tapeworm and reach the large intestine, and then gravid proglottids or free eggs are passed into feces of infected humans.[3]

Pigs are infected by ingesting eggs or gravid proglottids shed to the environment through feces of human tapeworm carriers. Once eggs are ingested, oncospheres hatch from eggs in the swine's small intestine, and penetrate the intestinal wall. Then they move through the blood and lymphatic circulations and lodge in body organs and tissues, especially skeletal muscles, as well as the brain, liver, and other organs, where they develop into cysticerci and form cysts which become surrounded with peripheral tissue of hosts.[3] Cysts may survive for undetermined periods but slowly start to die and finally become calcified cysts. Once pork meat with viable cysticerci is eaten by humans, the life cycle is completed.

Figure 2.4. Complete life cycle of *Taenia solium*



From"http://www.dpd.cdc.gov/dpdx/HTML/Cysticercosis.asp?body=Frames/A-F/Cysticercosis/body_Cysticercosis_page1.htm" by Anonyms, 2002, CDC's Division of Parasitic Diseases. Copyright 2002 by the Centers of Disease Control and Prevention.

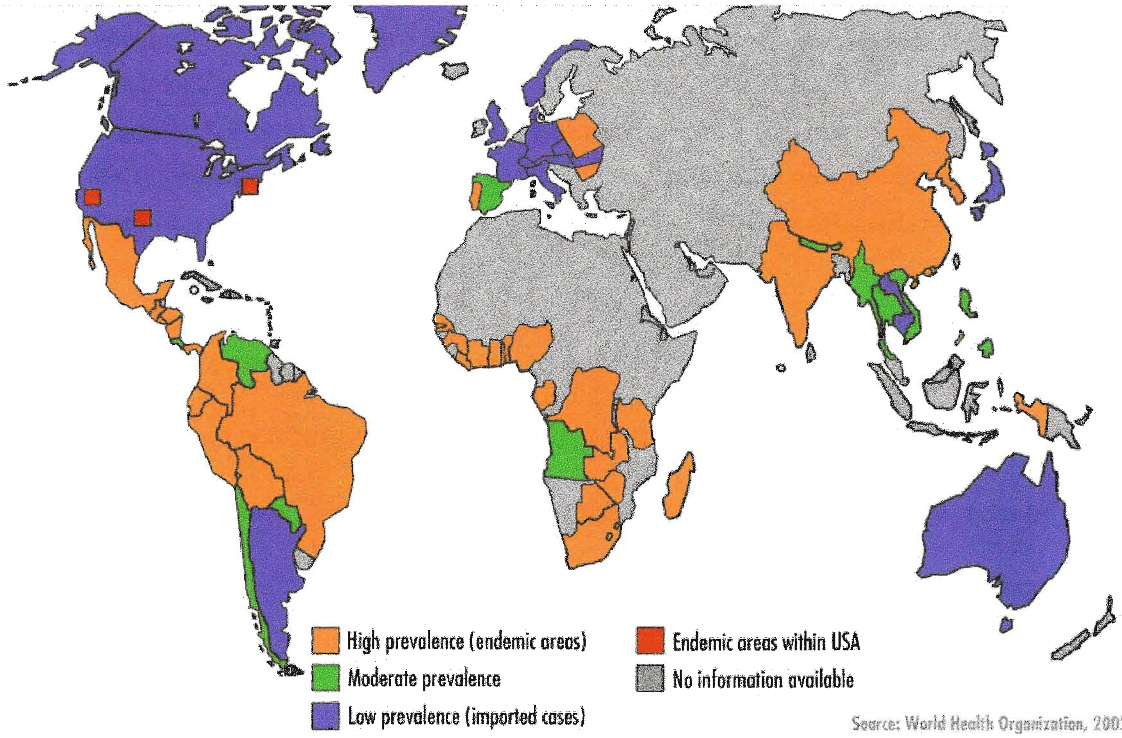
Accidentally, humans become intermediate hosts either by ingestion of food or water contaminated with feces of *T. solium* carriers, or by autoinfection. In the latter case, tapeworm carriers with poor hygiene habits, may auto-infect themselves by fecal-oral contamination. Similar to what occurs in pigs, cysticerci can inhabit in many body tissues and organs, and cause CC. The main locations in human are the CNS (including brain parenchyma, meninges, subarachnoid space, ventricles, and spinal cord), subcutaneous tissue, eyes and muscles. The invasion of cysticerci in the CNS is called neurocysticercosis, which can cause serious sequelae.[4]

EPIDEMIOLOGY

Global Distribution

Taenia solium infection is widely endemic in rural areas of developing countries, especially in the Andean area of South America, Brazil, Central America and Mexico; China, the Indian subcontinent and South-East Asia; and most areas of sub-Saharan Africa as shown in Table 2.5.[13] According to a conservative estimate, there are some 50 million infected people all over the world, and roughly 50,000 humans die of *T. solium* infection.[2] Global distribution of *T. solium* infections will be introduced in two parts, namely prevalence of *Taenia solium* in the Americas and prevalence of *Taenia solium* outside the Americas.

Figure 2.5. Global distribution of *Taenia solium*



From "http://www.who.int/gb/EB_WHA/PDF/WHA56/ea5610.pdf"by WHO, 2002, Control of Neurocysticercosis: Report by the Secretariat. Copyright 2002 by World Health Organization.

Prevalence of Taenia solium in the Americas

The infection is reported in 18 countries of Central and South America, mainly in Bolivia, Brazil, Ecuador, Guatemala, Honduras, Mexico, Peru.[1] Of the American countries, only Canada, the United States, Argentina and Uruguay appear to be free of transmission involving the pig-human cycle.[1] However, these countries are observing both travel-acquired and locally acquired infections due to immigration of people from endemic countries and contact with immigrants from those countries.[1,2,32]

Prevalence of Taeniasis

In the Americas, a variety of community-based studies has been performed in different countries and obtained varied prevalence rates of taeniasis by using either parasitological tests (fecal direct or concentration techniques) or immunological assays (coproantigen-detection technique). Prevalence rates by countries and communities are shown in Table 2.1. It is important to note that the highest prevalence rate occurs in a rural village of Peru with 6.7% by coproantigen technique, and the lowest one was reported in an urban community of Mexico with 0.1% by parasitological methods.[17,59,60] Mexico has more studies and reports than other Latin American countries. Due to the extended longevity (up to 25 years) and high fecundity of adult tapeworms as well as the strong resistance of eggs, hyperendemicity has been defined as a taeniasis prevalence of at least 1%.[16] Based on this definition, the above countries are all *T. solium* hyperendemic countries and contribute to the global distribution.

In non-endemic countries, a few taeniasis cases might occur among immigrants, especially Hispanic immigrants.[34,61] In Canada, there are no published reports on taeniasis in the last two decades.

Table 2.1. Prevalence estimates of human *Taenia solium* taeniasis in the Americas

Country	*Community*	*Prevalence of taeniasis*	*References (Ref. #)*
Bolivia	Chaco region	1.3% (5/382)^{p}	Carrique-Mas et al., 2001 (15)
Brazil	Lagamar	1.3% (24/1850)^{c}	Silva-Vergara et al., 1998 (21)
	Mulungu & do Morro	4.5% (26/577)^{c}	Gomes et al., 2002 (62)
Ecuador	Loja & El Oro	1.6% (148/9529)^{p}	Cruz et al., 1989 (16)
Guatemala	Four communities	2.7% (92/3399)^{p}	Allan et al., 1996 (39)
	Santa Gertrudis & El Tule	3.5% (56/1582)^{c}	Allan et al., 1997 (63)
	Quesada	1.0%$^{p, c}$	Garcia-Noval et al., 1996 (24)
	El Jocote	2.8%$^{p, c}$	Garcia-Noval et al., 1996 (24)
Honduras	Agua Caliente	1.5% (1/64)^{p}	Sanchez et al., 1997 (20)
	Salama	2.5% (12/480)^{p}	Sanchez et al., 1999 (30)
	Urban community in Tegucigala	0.6% (2/328)^{p}-total	Sanchez et al., 1998 (51)
Mexico	Tianquizolco	1.2% (5/403)^{c}	Martinez-Maya et al., 2003 (64)
	Urban community in Mexico City	0.1% (1/993)^{p} 0.5% (5/993)^{c}	Garcia-Garcia et al., 1999 (59)
	Tedzidz	1.5% (7/475)^{p} 2.1% (10/475)^{c}	Rodriguez-Canul et al., 1999 (19)
	Chalcatzingo	0.1% (2/1404)^{p} 0.8% (11/1404)^{c}	Sarti et al., 1997 (60)
	Xoxocotla	0.3% (4/1531)^{p}	Sarti et al., 1992 (44)
	Angahuan	0.2% (2/828)^{p}	Sarti et al., 1994 (45)
Peru	Saylla	3.0% (3/101)^{p}	Garcia et al., 1998 (42)
	9 villages, Quilcas	0-1.9%^{p}, 0.8%-average 0-6.7%^{c}, 2.8%-average	Garcia et al., 2003a (17)

Note. ^{c}: by coproantigen detection; ^{p}: by parasitological methods

Seroprevalence of Human Anti-Taenia solium Antibodies and Associated Epilepsy

Seroprevalence of human anti-Taenia solium antibodies

During the past decades, extensive epidemiological research on cysticercosis has been carried out in some Latin American countries. In most publications, the presence of

T. solium–specific serum antibodies has been widely used as a synonym of cysticercosis, the systemic invasion of tissues by larval stages of the parasite. Using seropositivity as an indicator of CC or NC has some limitations. The presence of serum antibodies may indicate a number of instances: exposure to *T. solium* eggs with unestablished cysticercal infection, past and resolved infection, past and inactive infection (i.e., calcified cysticerci) or current active infection.[65] As well, some studies have reported that intestinal taeniasis may elicit serum antibodies.[66,67] Nonetheless, it is agreed by the scientific community that seroprevalence documents level of exposure to eggs and is a good indicator of active transmission in a particular population group.

A wide array of assays with variable sensitivity, specificity and predictive values has been used in the past two decades to estimate seroprevalence.[68] This variability has made comparisons within- and between-countries difficult and inaccurate. However, current improved immunologic assays such as the enzyme-linked immunoelectrotransfer blot (EITB) and some antigen-specific enzyme-linked immunosorbent assays (ELISA) yield more accurate prevalence data that allow assessing and comparing the degree of endemicity in different countries.

Seroprevalence of antibodies has wide variation in the American countries. The highest prevalence rate can up to 34.0% in a Honduran rural community; in contrast, the lowest prevalence data has been reported in Brazil with 1.6% (shown in Table 2.2).[20,62]

In the US, two epidemiological studies report seroprevalence rates of 10% and 1.3% among migrant workers in North Carolina and local residents in an Orthodox Jewish community in New York City, respectively.[71,72] In contrast, there is no published seroprevalence data for Canada.

Table 2.2. Seroprevalence estimates of human anti-*T. solium* antibodies in the Americas

Country	*Community*	*Seroprevalence of antibodies*	*References (Ref. #s)*
Bolivia	Chaco region	22% (99/447)	Carrique-Mas et al., 2001 (15)
	3 rural regions	2-9%	Jafri et al., 1998 (69)
Brazil	Rural area	2.1 % (40/1863)	Bragazza et al., 2002 (70)
	Mulungu & do Morro	1.6% (11/694)[a]	Gomes et al., 2002 (62)
Ecuador	San Pablo	14% (6/42)	Cruz et al., 1999 (5)
	Del Lago	22.6% (28/124)	Cruz et al., 1999 (5)
Guatemala	Quesada	10%	Garcia-Noval et al., 1996 (24)
	El Jocote	27%	Garcia-Noval et al., 1996 Garcia-Noval et al., 2001 (24,48)
Honduras	Agua Caliente	34% (23/68)[e]	Sanchez et al., 1997 (20)
	Salama	17% (80/480)[a]	Sanchez et al., 1999 (30)
	Urban community in Tegucigalpa	22% (9/41)[a]-rural 15% (54/363)[a]-urban 15.6%(63/404)-total	Sanchez et al., 1998 (51)
Mexico	Tianquizolco	3.3% (3/92)[a]	Martinez-Maya et al., 2003 (64)
	Urban community	12.2% (122/999)[a]	Garcia-Garcia et al., 1999 (59)
	Tedzidz	3.7% (5/134)[a]	Rodriguez-Canul et al., 1999 (19)
	Xoxocotla	10.8% (168/1552)[a]	Sarti et al., 1992 (44)
	Angahuan	4.9% (49/1005)[e]	Sarti et al., 1994 (45)
Peru	Saylla	23.8% (24/101)[a]	Garcia et al., 1998 (42)
	9 villages, Quilcas	7.0-26.9%[a] 13.7%-average	Garcia et al., 2003a (17)
	12 communities (rural+urban)	6-24% 12.3%-average	Bern et al., 1999 (47)
	Haparquilla	13% (14/108)	Garcia et al., 1999 (49)
	Vichaycocha	21% (66/316)	Moro et al., 2003 (43)
The United States	One Jewish community	1.3% (23/1789)	Moore et al., 1995 (71)
	eastern North Carolina	10% (14/138)	Cielielski et al., 1993 (72)

Note. [a]: by enzyme-linked immunoelectrotransfer blot technique; [e]: by enzyme-linked immunosorbent assays.

Human seropositivity for Taenia solium and associated epilepsy

Neurocysticercosis remains a major public health problem, not just in developing countries but also in developed countries. Epilepsy, on the other hand, is another serious neurological disorder that although largely unrecognised, exerts an increasing economic cost on health and social services within developing countries. When compared to developed countries, the rates of epilepsy in developing countries are twice as high,[73] and according to the WHO, NC is one of the main causes of epilepsy in *T. solium*-endemic countries.[13]

To determine the relationship between NC and epilepsy, several studies were performed in the last two decades. Hospital-based studies suggest that NC is the main cause of late-onset epilepsy in most developing countries, such as Honduras, Peru, Brazil, and Mexico, accounting for 19-50% of cases.[6,7] In Ecuador, Honduras, and Mexico, 27%, 19%, and 50% of epileptic patients had NC, respectively.[7,12,74] In Brazil, Ecuador and Peru, 25.2%, 55% and 12-34% of epileptic patients had a positive result of EITB, respectively.[6,74-76] Since clinical studies do not reflect the frequency of NC in common populations,[75] field-based studies have been undertaken in Peru, Honduras, Mexico, and Ecuador. These studies have also confirmed that NC plays an important role in the etiology of epilepsy. In Mexico and Peru, anti-*T. solium* antibodies have been found in 28.6% and 9.1-22.5% of epileptic individuals, respectively.[17,45,47] Moreover, hospital-based studies also were carried out in industrialized countries, such as the US, in which NC accounted for 2-16% of epilepsy cases occurred mainly in Hispanic immigrants.[61,77]

Seroprevalence of anti-T. solium antibodies and prevalence of cysticercosis in swine

Table 2.3. Seroprevalence of antibodies and prevalence of porcine CC in the Americas

Country	*Community*	*Seroprevalence of antibodies*	*Prevalence by tongue palpation*	*References*
Bolivia	Chaco region	37% (102/273)	ND	Carrique-Mas et al., 2001 (15)
Ecuador	San Pablo del Lago	ND	7.5%	Cruz et al., 1999 (5)
Guatemala	Santa Gertrudis; El Tule	55% (148/269)[a]	ND	Allan et al., 1997 (63)
	Quesada	ND	4.0%	Garcia-Noval et al., 1996 (24)
	El Jocote	ND	14.0%	Garcia-Noval et al., 1996 (24)
Honduras	Salama	27.1%[a] (52/192)	ND	Sakai et al., 1998 (50)
Mexico	Tedzidz	35% (26/75)[a]	23% (17/75)	Rodriguez-Canul et al., 1999 (19)
	Chalcatzingo	5.2% (10/194)[a]	2.6% (5/194)	Sarti et al., 1997 (60)
	Xoxocotla	ND	4.0% (23/571)	Sarti et al., 1992 (44)
Peru	Saylla	35.8% (19/55)[a]	ND	Garcia et al., 1998 (42)
	9 villages, Quilcas	42.3-75%[a]	ND	Garcia et al., 2003a (17)
	Haparquilla	43% (38/89)	ND	Garcia et al., 1999 (49)
	Vichaycocha	65% (32/49)	ND	Moro et al., 2003 (43)

Note. [a]: by enzyme-linked immunoelectrotransfer blot technique; ND: not done.

Seroprevalence rates of antibodies in pigs have been obtained from endemic countries. The published seroprevalence rates are generally high in American countries, and the highest and lowest seroprevalence data are 5.2% in Mexico and 75% in Peru, respectively.[17,60] There is no reported seroprevalence in non-endemic countries, because the modern pig husbandry and strict pork inspection prevent the occurrence of porcine CC. Moreover, infection rates of porcine cysticercosis have been detected by tongue palpation in some studies. Two rural communities in Mexico report the highest and lowest prevalence rates of 23.0% and 2.6%, respectively.[19,60]

Prevalence of Taenia solium Outside of the Americas

Taenia solium infection is also endemic in parts of Asian countries and most of African countries. In Asia, transmission has been reported in Central and Eastern Asia, the Indian subcontinent and South-East Asia Region, mainly including China, India, Nepal, Indonesia, Vietnam and Papua New Guinea.[11]

In Africa, the parasite is transmitted throughout most of the continent with the exception of the strictly Muslim areas of North and sub-Saharan Africa.[1] Although *T. solium* exists in both Asia and Africa, epidemiological data from community-based studies are sparse and available only for a few countries. This section will be reviewed based on the limited publications available.[78]

Prevalence of Taeniasis

In Asia, there are only a few studies on the prevalence of taeniasis. As well, considering the economic factor, these studies have been reported using stool examinations only and not coproantigen examinations. Therefore, it might be expected that these prevalence rates could be actually higher. The prevalence rates shown in Table 2.4 range from 0.1% to 50.0% with wide variations.[18,22,23,78-86] It can be noted that taeniasis is highly endemic in some areas in China and Nepal.

In Africa, prevalence data on human taeniasis is extremely limited. As shown in Table 2.4, prevalence rates are reported by seven countries and range from 0.09% to 16%. These prevalence data shows that Kenya, Nigeria and part of South Africa are hyperendemic regions for *T. solium* transmission.[25,87-91]

Table 2.4. Prevalence estimates of human *Taenia solium* taeniasis in Asian and African countries

Country	*Community*	*Prevalence of taeniasis*	*References (Reference #s)*
		Asian Countries	
China	Nationwide	0.112%	Yu et al., 1994 (85)
	5 counties, in Shandong	0.1% (36/35512)	Liu et al., 2000 (80)
	Pumi	19.5%	Wang et al., 1997 (23)
	NeiMeng	0.81% (33/4092)	Zhang et al., 2000 (86)
India	Rural regions	0.5-2%	Mahajan et al., 1982 (81)
	Uttar Pradesh	2% (12/600)	Pathak et al., 1989 (18)
	Rural area	3.9%	Mitra et al., 1998 (82)
Indonesia	Bali	0.4-23%	Suweta, 1991 (22)
	Bali	0.72% (3/415)	Sutisna et al., 1999 (83)
Korea	*	0.02% (nationwide)	Eom et al., 2001 (79)
Nepal	*	10-50%	Rajshekhar et al., 2003 (78)
Vietnam	*	0.2-7.2%	Willingham, III et al., 2003 (84)
		African Countries	
Burundi	Bururi	<1.0%	Newell et al., 1997 (88)
Cameroon	2 communities	0.10% (3/3109)	Vondou et al., 2002 (91)
Kenya	Rural areas	2-10%	Mafojane et al., 2003 (25)
Mozambique	Maputo(urban)	0.4% (1/269)	Noormahomed et al., 2003 (89)
Nigeria	Nsukka area	8.6% (131/1525)	Onah et al., 1995 (90)
South Africa	Rural areas	from <1% to 16%	Mafojane et al., 2003 (25)
Togo	Northern	0.09-0.26%	Dumas et al., 1989 (87)

Note. * review study

Seroprevalence of Human Anti-Taenia solium Antibodies and Associated Epilepsy

Seroprevalence of human anti-Taenia solium antibodies

There has been increasing international awareness of the epidemiologic situation of human cysticercosis or neurocysticercosis in both African and Asian countries as a growing number of those studies are being carried out and published. However, at the present moment, few studies are accessible. Consequently, the actual prevalence of Cysticercosis/Neurocysticercosis is not clear.

In Asia, current seroprevalence rates of anti-*Taenia solium* antibodies are variable and listed by countries in Table 2.5, with the highest rate of 50.6% in Irian Jaya, Indonesia and the lowest rate of 0.03% in Liaoning province, China.[92,93] Unfortunately, there is no available community-based prevalence data on cysticercosis from other endemic countries in Asia, such as India, Nepal, etc.

In Africa, few community-based seroprevalence studies have been undertaken, and again, the reported seroprevalence rates (Table 2.5) are variable, ranging from 0.4% in Cameroon to 24.0% in South Africa.[9,25,26,87-89,94,95]

Human seropositivity for Taenia solium and associated epilepsy

There are few published articles reporting the relationship between NC and epilepsy in both Asian and African countries. A study in southern India, reported in 2000, found an association between NC and localization-related symptomatic epilepsy in 51% of patients.[13] Moreover, two studies in China reported that 61.4-75% of NC patients accompany with epilepsy.[96,97] Studies in Burundi and South Africa also have shown an important link between cysticercosis infection and the occurrence of epilepsy.[13]

Table 2.5. Seroprevalence estimates of human anti-*Taenia solium* antibodies in Asian and African countries

Country	*Community*	*Seroprevalence of antibodies*	*References*
		Asian Countries	
China	5 counties,Shandong	0.1%(38/35512)[e]	Liu et al., 2000 (80)
	Yanzhou	3.2% (92/2898)[e]	Cao et al., 1996 (98)
	Lanping	11.3% (44/390)[e]	Wang et al., 1997 (23)
	Liaoning	0.03%(27/78274)[e]	Li et al., 2002 (92)
Indonesia	Bali	1.65% (6/363)[a]	Sutisna et al., 1999 (83)
	Bali	13% (94/746)[a]	Theis et al., 1994 (27)
	Irian Jaya	50.6% (81/160)	Subahar et al., 2001 (93)
	*	2.0-48.0%	Simanjuntak et al., 1997 (99)
Vietnam			
	northern	5.7% (12/210)[e]	Erhart et al., 2002 (100)
	*	5-7%	Willingham, III et al., 2003 (84)
		African Countries	
Benin	Nationwide	1.3% (36/2625)[a]	Houinato et al., 1998 (94)
	6 departments	0-3.3%[a]	
Burundi	Bururi	2.8% (2/72)[a]	Newell et al., 1997 (88)
		4.2% (3/72)[e]	
		24%	Nsengiyumva et al., 2003) (9)
Cameroon	3 communities, Menoua	0.4-3%	Nguekam et al., 2003 (26)
Mozambique	Maputo(urban)	20.8% (56/269)[e]	Noormahomed et al., 2003 (89)
South Africa	2 rural areas, Transkei	5.5%	Shasha et al., 1991 (95)
	*	0.7-24%	Mafojane et al., 2003 (25)
Togo	Northern	2.4%(125/5264)[e]	Dumas et al., 1989 (87)

Note. [a]: by enzyme-linked immunoelectrotransfer blot technique; [e]: by enzyme-linked immunosorbent assays; *: from review study.

Seroprevalence of Porcine Anti-Taenia solium Antibodies and Prevalence of Porcine Cysticercosis

In Asian countries, though few seroprevalence data has been reported, the published seroprevalence rates are 4.41% in China;[80] 0.02-2.63% in Indonesia;[22] 9.91% in Vietnam.[84] As well, infection rates of porcine cysticercosis have been reported more than seroprevalence rates, in which the highest rate (32.0%) and lowest rate (0.02%) occurred in Nepal and Vietnam, respectively.[78,84]

In Africa, porcine cysticercosis has recently been studied in many countries. The available seroprevalence rates of anti-*Taenia solium* antibodies shown in Table 2.6 are reported mainly in three countries, that is, 11.0-39.8% in Cameroon, 6.5-33.3% in Mozambique, and 9.3-56.6% in Zambia.[25,29,31,101,102] Moreover, more studies have reported the infection rates of porcine cysticercosis, ranging from 2% in Burundi to 50.0% in South Africa.[25,26,28,29,31,87,88,90,101-103]

Summarized from the above data, it is evident that *Taenia solium* transmission is active and high in almost all Latin American countries and recent reports demonstrate that many Asian and African countries are also *Taenia solium* endemic countries. Although *T. solium* originated in ancient Europe, today, as a result of improvements in swine husbandry, sanitation and hygiene, the infection has largely disappeared. However, locally acquired infections are still occasionally reported from some European countries, including Spain, northern Portugal, southern Italy and Poland, indicating foci of transmission in some regions.[104]

Table 2.6. Seroprevalence of porcine anti-*Taenia solium* antibodies and prevalence of porcine cysticercosis in Asian and African countries

Country	*Community*	*Seroprevalence of antibodies*	*Prevalence*	*References(Ref#s)*
		Asian Countries		
China	Central Shandong	4.41	0.12-0.48%	Liu et al., 2000 (80)
	*	ND	0.84-15.0%	Cited in (Rajshekhar et al., 2003;) (78)
India	*	ND	7-12%	Cited in (Pathak et al., 1989) (18)
Indonesia	Bali	0.02-2.63%	0.15%	Suweta, 1991 (22)
			24.0%	Subahar et al., 2001 (93)
Nepal	*	NA	14-32%	Cited in (Rajshekhar et al., 2003) (78)
Philippines	*	ND	0.16-1.67%	Cited in (Rajshekhar et al., 2003) (78)
Vietnam	Northern	ND	4.3% (9/210)	Erhart et al., 2002 (100)
	*	9.91% (32/323)[e]	0.02-0.9%	Cited in (Willingham, III et al., 2003)
		African Countries		
Burundi	Bururi	ND	2% & 39%	Newell et al., 1997 (88)
Cameroon	3 communities	ND	11%	Nguekam et al., 2003 (26)
		21.8%	ND	Pouedet et al., 2002 (102)
	*	11.0-39.8%	2.3-24.6%	Cited in (Zoli et al., 2003) (31)
Ghana	East Region	ND	11.7%[s]	Permin et al., 1999 (28)
Kenya	*	NA	10-14%	Cited in (Mafojane et al., 2003) (25)
Mozambique	*	6.5-33.3%[e]	NA	Cited in (Phiri et al., 2003) (101)
Nigeria	Nsukka area	ND	20.5%(483/2358)	Onah et al., 1995 (90)
South Africa	*	ND	≈50.0%	Cited in (Mafojane et al., 2003) (25)
Tanzania	Northern	ND	13.30%-average 4.5-37.7%	Bao et al., 1995 (103)
Togo	Northern	ND	2.4% (104/5264)	Dumas et al., 1989 (87)
Uganda	*	ND	9.4-45%	Cited in (Mafojane et al., 2003 Phiri et al., 2003) (25,101)
Zambia	NA	9.3-20.8%[e]	5.2% and 8.2%[t] 10.9%(143/1316)[l] 20.6%(271/1316)[s]	Phiri et al., 2002 (29)
	*	9.3-56.6%	5.2-28.4%	Cited in (Mafojane et al., 2003 Phiri et al., 2003) (25,101)
Zimbabwe	*	ND	2.7-28.6%	Cited in (Mafojane et al., 2003 Phiri et al., 2003 (25,101)

Note. [e]: by enzyme-linked immunosorbent assays; [t]: by tongue palpation; [l]: by lingual examination; [s]: by meat inspection; *: from review study; NA: not available; ND: not done.

Risk Factors

The implementation of intervention strategies to prevent and control *T. solium* transmission requires a better understanding of the risk factors associated with the occurrence of infection. A variety of epidemiological studies have revealed risk factors that increase the probability of infection with the intestinal tapeworm (i.e., taeniasis) or the tissue larval stages (i.e., cysticercosis).

Risk Factors Associated with Taeniasis

Out of 29 journal articles reporting risk factors for *T. solium* infection, only three reported a similar number of risk factors associated with taeniasis, i.e. gender, age, and consumption of undercooked pork meat.[39,105,106]

The first identified risk factor is gender, that is, taeniasis is observed frequently in females than in males in *T. solium*-endemic regions (Relative Risks (RR) =1.21; Confidence Interval (CI) = 1.04-1.42; $p <.04$).[39] One probable explanation for this gender difference is that in most countries, women are in charge of preparing meals for their families. Food preparation may involve tasting undercooked meat which if infected, may result in human teaniasis.[24,39,42,71]

The second risk factor is age, since diagnosis of tapeworm carriers tends to peak in subjects aged 30-39 years ($\chi^2 = 8.91$; $p <.003$).[39] This might be related to occupations (breeders, butchers, cooks, housewives, etc.); eating habits (people aged 30-39 years generally eat more pork meat than children and the elderly, so obviously they have higher risk of infection); built-up immunity that leads to asymptomatic infections of taeniasis and lack of unconsciousness of the need for treatment.[42,53]

The third risk factor is the frequency of pork consumption more than once a week (Odds ratio (OR) = 2.65, CI = 1.37-5.12; $p < .05$),[44,90,106] The more frequent to consume pork meat, the more opportunities to get infected.

Risk Factors Associated with Human Cysticercosis

Since human cysticercosis is acquired by contact with the contaminated feces from a tapeworm carrier, risk factors associated with human cysticercosis are varied and complex, and have to do with exposure to a contaminated environment and/or infected persons in the household or community. Therefore many factors, such as economic resources, sanitary infrastructure, human behaviours, and education will all play important roles in *T. solium* transmission.

Most articles reported risk factors of cysticercosis, especially NC. The most frequently reported risk factors for this category include age more than 20 years;[15,17,30,41,42,98,107] personal history of epilepsy/seizures/convulsions;[17,41,44-46,105] having raised pigs in household and poor pig-raising practices;[17,40,41,43,51,98,105,108] being unable to recognize cysticerci-containing pork meat;[15,19,40,51,98] having a history of passing tapeworm proglottides/taeniasis;[20,40,41,44,105] absence of sanitary facilities and outdoor defecation;[15,51,98,105,108] poor formal education;[15,43,51,105,107] close proximity to a tapeworm carrier in household;[17,19,20,77,106] poor household conditions;[20,44,51,84,105] and poor personal hygiene.[40,44] Other risk factors are frequent consumption of pork;[44,84,108] gender (females > males);[42,109] and close proximity to a person who had previous taeniasis,[20] etc.

Table 2.7 shows risk factors associated with seropositivity for anti-*T. solium* antibodies as reported in several studies. Data of risk factors would provide help for further studies in endemic countries/areas and suggest strategies for control and prevention of *T. solium* transmission.

Table 2.7. (continued)

Risk factor	*OR*	*95%CI*	*P*	*Description of the observation*	*Reference*
Gender	1.21	1.04-1.42	<0.04	Female>male	(Allan et al., 1996) [39]
Frequent consumption of pork meat	1.6	1.18-2.37	0.004		(Sarti et al., 1992) [44]
Absence of sanitary facilities and/or outdoor defecation	2.92	1.35-6.05	<0.05		(Sanchez et al., 1998) [51]
	1.87	1.14-3.00	<0.05		(Carrique-Mas et al., 2001) [15]
	1.94	0.70-5.40	<0.001		(Aranda-Alvarez et al., 1995) [105]
	1.35	1.01-1.81	<0.05		(Cao et al., 1996) [98]
	1.76	NA	<0.001		(Morales et al., 2003) [108]
	1.9	1.09-3.33	<0.05		(Rodriguez-Canul et al., 1999) [19]
Being unable to recognize cysticerci-containing meat	18.4	2.90-INF	<0.01		(Cao et al., 1997) [40]
	2.39	1.26-4.49	<0.05		(Sanchez et al., 1998) [51]
	4.09	1.53-10.97	<0.05		(Cao et al., 1996) [98]
Poor personal hygiene	3.5	1.87-6.40	0.0002		(Sarti et al., 1992) [44]
	36.2	4.90-266.40	<0.01		(Cao et al., 1997) [40]
Close proximity to a person who had previous taeniasis	1.39	0.89-2.15	<0.05		(Sanchez et al., 1997) [20]

Note. NA: not available.

Table 2.7. (continued)

Risk factor	*OR*	*95%CI*	*P*	*Discription of the observations*	*Reference*
	1.68	0.96-2.92	<0.05		(Moro et al., 2003) [43]
	5.39	1.42-19.50	<0.05		(Sanchez et al., 1998) [51]
	2.6	1.20-5.70	<0.05		(Cao et al., 1997) [40]
Having raised pigs in household and poor pig-raising practices	2.62	1.84-3.73	<0.05		(Garcia et al., 1995) [41]
	1.27	1.01-1.61	0.043		(Garcia et al., 2003a) [17]
	1.51	0.73-3.14	<0.001		(Aranda-Alvarez et al., 1995) [105]
	2.16	NA	<0.0001		(Morales et al., 2003) [108]
	2.2	1.12-4.26	<0.05		(Sanchez et al., 1997) [20]
	2.26	1.20-4.40	0.016		(Sarti et al., 1992) [44]
Having a history of passing tapeworm proglottides/ taeniasis	2.35	1.17-4.70	<0.016		(Aranda-Alvarez et al., 1995) [105]
	1.85	1.16-2.95	<0.05		(Garcia et al., 1995) [41]
	14	2.90-67.40	<0.01		(Cao et al., 1997) [40]
	NA	2.30-12.1	<0.05		(Sarti et al., 1994) [45]
	3.84	1.12-13.25	0.03		(Sarti et al., 1992) [44]
Personal history of epilepsy/seizures/convulsions	1.78	0.94-3.36	<0.001		(Aranda-Alvarez et al., 1995) [105]
	1.86	1.01-3.39	0.029		(Garcia et al., 2003a) [17]
	2.21	1.50-3.25	<0.05		(Garcia et al., 1995) [41]

(table continues)

Table 2.7. Review of worldwide literature on risk factors associated with seropositivity for anti-*T. solium* antibodies in humans

Risk factor	*OR*	*95%CI*	*P*	*Description of the observations*	*Reference*
Age	NA	NA	<0.001	Being older than 30	(Garcia et al., 1998) [42]
	2.43	1.57-3.77	<0.05	Being older than 20 years	(Garcia et al., 1995) [41]
	NA	NA	<0.05	Peak at 11-20 & 31-40 years	(Goodman et al., 1999) [107]
	4.25	1.61-11.29	<0.05	Peak at 51-60 years of age	(Carrique-Mas et al., 2001) [15]
	NA	NA	<0.05	Peak at 51-60 years of age	(Garcia et al., 2003a) [17]
Poor household conditions					
General	2.64	1.28-5.44	0.009		(Sarti et al., 1992) [44]
Earthen floor	2.48	1.28-4.73	<0.05		(Sanchez et al., 1998) [51]
	4.15	2.70-6.43	<0.05		(Sanchez et al., 1997) [20]
Lack of potable water	3.66	1.25-9.94	<0.05		(Sanchez et al., 1998) [51]
	2.19	NA	<0.001		(Widdowson et al., 2000) [110]
Overcrowded	2.39	NA	<0.001		(Widdowson et al., 2000) [110]
	2.96	1.82-4.80	<0.05		(Sanchez et al., 1997) [20]
Precarious roof on home	1.92	0.86-4.30	<0.001		(Aranda-Alvarez et al., 1995) [105]
Lack of toilet in the house	1.59	1.05-2.40	<0.05		(Garcia et al., 1995) [41]
	2.65	1.05-6.55	<0.05		(Garcia et al., 1993) [6]
Close proximity to a carrier of *T. solium* in household	4.33	2.34-7.98	<0.001		(Garcia et al., 2003a) [17]
	0.89	0.48-1.61	<0.05		(Sanchez et al., 1997) [20]

(table continues)

PATHOLOGY, IMMUNOLOGY, CLINICAL PRESENTATION, DIAGNOSIS AND TREATMENT OF TAENIASIS AND CYSTICERCOSIS

Taeniasis

Pathology and Immunology of Taeniasis

Human taeniasis occurs in the small intestine. The presence of the adult parasite may cause a slight degree of mucosal inflammation at the site of attachment, developing with scarce macrophages, a slight increase of plasma cells, lymphocytes and fibroblasts, a moderate increase of eosinophils and neutrophils, and high numbers of goblet and mast cells.[111] The actual effects on human health may vary considerably.

Taeniasis does not cause protective immunity; however, reinfections may induce partial protective immunity.[112,113] Recently, it was demonstrated that adult *T. solium* could induce a specific humoral immune response and anti-parasite IgG and IgA antibodies can be detected in the serum of tapeworm carriers.[114] The role of these antibodies remains unclear.

Clinical Presentation of Taeniasis

Usually infections are asymptomatic, and infected persons only become aware of the infection when passing proglottids in feces. However, in some cases a variety of non-specific symptoms such as constipation, epigastric pain, dyspepsia, loss of weight and diarrhoea, are present.[58]

Diagnosis of Taeniasis

According to *T. solium*'s life cycle, detection of eggs and proglottids in human feces are the hinge of diagnosing taeniasis.[68] There are three diagnostic approaches: parasitologic diagnosis, immunologic diagnosis and molecular techniques.

Parasitologic Diagnosis

Parasitologic diagnosis involves the use of direct microscopic examination to eggs, gravid proglottids or the presentation of both in feces. Microscopic identification is simple and relatively inexpensive; nevertheless, it is insensitive, as it is impossible to be detected before larvae develop to adult tapeworms during the prepatent period (i.e. two to three months after infection). Moreover, eggs and proglottids are periodically absent, irregularly distributed or in few numbers in feces.[115] In addition, since the differentiation of eggs between *T. solium* and *T. saginata* is not possible, microscopic demonstration of tapeworm eggs in stool samples is non-specific.[68]

Repeated stool examinations collected with an interval of 2 or 3 days, and the use of egg concentration techniques, such as Kato-Katz and formol-ether concentration techniques, could increase the sensitivity of the direct parasitologic examination and the possibility of detecting infections.[58,115] Questioning individuals regarding the passing of proglottids is a supplementary indication of infection.[116]

Immunologic and Molecular Diagnoses

A variety of immunological and molecular techniques have been employed for several years to improve the diagnosis of human taeniasis.[59,114,117,118] Recently, a coproantigen (CoAg) detection test has been developed and implemented for the diagnosis. This test uses enzyme-linked immunosorbent technique (ELISA) and shows high sensitivity as well as specificity at genus level.[112,115] The CoAg test appears to be more sensitive than microscopic examinations. Both reports of Allan (1996) and Schantz (1995) have indicated that the CoAg test detected 2.6 times as many confirmed cases of human taeniasis as microscopic tests. However, similar to the microscopic examination, it also lacks of species-specificity, and a positive result indicates that either *T. saginata* or *T. solium* can be detected by the CoAg test. Further improvement to achieve the differential diagnosis between these two parasites would broaden the applicability of CoAg tests.

The objective to develop a *Taenia*-specific technique appears to have been achieved using molecular techniques. The recent polymerase chain reaction (PCR) technique has been developed using species-specific oligonucleotides as probes on differential detection of *T. solium* and *T. saginata* proglottids' deoxyribonucleic acids (DNA)[119-121] or egg DNAs.[118] Experimental evaluations show that the PCR technique is a rapid, reliable, sensitive and specific method for diagnosis of human taeniasis.[120,122] A major limitation is the lack of widespread availability. In addition, it still needs to be evaluated in comparison with conventional parasitological methods in both clinical and epidemiological studies.[122]

Treatment of Taeniasis

Chemotherapy of taeniasis is simple, effective and affordable. Two anthelminthics, namely niclosamide and praziquantel, are currently recommended and widely available. Both are given in a single oral dose, and the efficacy of each is beyond 90%.[123]

Niclosamide is effective against not only *T. solium* but also other intestinal cestodes. It can exert anthelminthic influence through inhibition of oxidative phosphorylation or through stimulating adenosine triphosphatase.[123] The recommended dose is 2 gram for adults and 1 to 1.5 gram for children. Occasionally, nausea and abdominal pain may occur following oral treatment with niclosamide.

Praziquantel can be used effectively against not only larval and adult *T. solium*, but also trematodes and other cestodes. Praziquantel causes muscle contraction, paralysis and death through promoting calcium permeability of the tapeworm. The recommended dose for treatment of taeniasis is 5 - 10 mg/kg of bodyweight, and a much lower dose than that is used for treatment of NC. Praziquantel seldom causes side effects, and is cheaper than niclosamide.[123]

Cysticercosis

The presence of *T. solium* cysticerci in tissues and organs of the host is called cysticercosis. Both humans and swine can get CC by ingestion of infective eggs, namely human and porcine CC.

The occurrence of porcine CC is crucial to humans, because pigs are the natural intermediate hosts of *T. solium* and humans infect taeniasis by eating raw or undercooked pork meat which contains viable *T. solium* cysts. Therefore, porcine CC is a serious threat to food security in endemic countries. In addition, porcine CC affects the quality of pork meat and the result is a dramatic economic loss in areas where *T. solium* is endemic and pig farming is an important supporting industry. For instance, Latin America may lose about US$ 164 million annually due to *T. solium* transmission. And in Mexico, porcine CC is responsible for loss of more than half the national investment in pork production.[2] Control of porcine CC is fundamental to reduce both taeniasis and CC in humans. Strategies for this control will be discussed in the last part of this chapter.

There are several forms of human cysticercosis, such as subcutaneous CC, ocular CC, muscular CC, and NC. Due to the fact that NC is the most reported and serious presentation of CC, NC will be the focus of the discussion in this thesis.

Human Neurocysticercosis

Pathology and Immunology of Neurocysticercosis

The resultant pathology associated with human NC depends on the combination of several variables, which can affect the course and severity of NC. These variables can be parasite-related or host-dependent. Parasite-related variables include: 1) location; 2) number; 3) size; 4) evolutional stages of cysticerci. The host-dependent variable is regarding the host immune response against the parasite.[124,125]

Because the CNS is a particularly "sensitive" area of the human body, few cysticerci or perhaps only one cysticercus might result in irreparable damage. For example, a cysticercus in the meninges and brain parenchyma could lead to acute and recurrent unprovoked seizures, respectively; a cysticercus in the spinal cord could cause intense inflammation and lead to paralysis, a cysticercus in the ventricular system could lead to hydrocephalus.[126]

The number of cysts in the human CNS can vary. In ventricular infections, a single cysticercus is usually present, but in the brain parenchyma or meninges, massive infection can occur.[126] In active parenchymal NC, cysticercal encephalitis results from infection with large numbers of cysticerci, inducing an intense host immune response and diffuse brain edema. This presentation is more common in children and young women.[33]

The size of cysts is varied in different locations of the CNS. The average size of cysts in parenchymal NC is approximately 10 mm, ranging from 4 to 20 mm in diameter.[33] Large or giant cysts are identified in ventricular NC.[127] For example, the racemose form of cysticerci with a grapelike appearance may enlarge to reach 100 mm in diameter, and are usually devoid of scolex. This type of cyst occurs more frequently in the subarachnoid cisterns, because their growth is not limited by the effect of pressure within the brain parenchyma.[33,126,127] When cysticerci begin to die, they will expand up to several cm in diameter due to osmotic dysregulation.[125]

The biological stage of the cysticerci and the degree of the immune response elicited in hosts play important roles in pathology.[126] The evolution of larvae involves a series of stages, namely vesicular, colloidal, granular-nodular and calcified stages. In the vesicular stage, viable cysticerci have minimal associated inflammation.[124] Although viable cysticerci in parenchyma or ventricular are space-occupying lesions, they have little surrounding inflammation. When present, inflammation consists of discrete areas of lymphocytes and few eosinophils.[33] As cysticerci lose their abilities to control the host response, cysts evolve to the colloidal stage. This stage is characterized by degenerative changes in the aging cysticerci, such as hyaline degeneration and early mineralization, consequent upon host immunological response.[124] The cyst wall is infiltrated and then host inflammatory cells composed mainly of mononuclear cells (plasma cells, lymphocytes, macrophages, and eosinophils) will surround and enter the cyst fluid. The inflammatory processes provoke more problems than the cysts themselves, such as inducing the provoked seizure in some previously asymptomatic patients.[128] As the host response progresses, cysticerci degenerate into the granular-nodular stage, characterized by fibrosis and the collapse of the cyst cavity.[125] The general breakdown of the cyst wall results in the release of parasitic antigens which cause an intense inflammatory and a local production of antibodies which can be detected by immunological assays. The final stage is the calcified stage, in which progressive fibrosis replaces the parasite, ending with total calcification and death of the parasite.[125,126]

Seizures, the most common presentation of NC, may occur with any evolutionary stage of the parasite. Acute seizures are frequent with dying (transitional) form of cysts located in cortical or subcortical layer due to the inflammatory reaction. Recurrent seizure (i.e., epilepsy) probably occurs in the inactive or calcified form of cysts. Epilepsy is attributed to residual peri-lesional gliosis that results in chronic epileptogenic foci. The persistent mild inflammation around the calcified stage of NC may be the reason for the increased risk of recurrent seizures. The pathology of seizures referred to above is theoretical and further confirmatory studies are required.[73]

Experimental models have identified the mechanisms used by the cysticercus to modulate the immune and inflammatory responses of hosts. Larvae can secrete a serine proteinase inhibitor, which inhibits complement activation, lymphocyte activation, and cytokine production.[129]

Clinical Presentations of Neurocysticercosis

The clinical presentation of NC is varied and ranges from asymptomatic, to various neurological symptoms, to death, depending upon the biological stages of the cysticerci, topographic location of cysts, number of cysts and the host's immune response.[4]

Neurocysticercosis causes several syndromes, each with different symptoms and signs. When cysticerci lodge in brain parenchyma, the main clinical manifestation is epilepsy and headache; when cysticerci locate in meninges or ventricles, the clinical manifestations are those occurring secondary to inflammation, hydrocephalus and vasculitis.[130]

The symptoms and signs of NC are non-specific, mainly including seizures, headache, nausea/vomiting, raised intracranial pressure, focal neurological deficit, a variety of psychiatric manifestations and dementia.[131]

Epilepsy, the most frequent manifestation of NC, occurs in up to 70% of NC patients.[126] Seizures are frequent when parenchymal cysts and granulomas are present, but rarely with meningeal and ventricular cysts. Seizures may be single, clustered or recurrent (epilepsy). They are either focal with or without secondary generalization or may be generalized at the onset.[131]

Headache is another common symptom, which occurs in parenchymal and ventricular NC. Headache may be hemicranial or bilateral, and also be transient, continuous or uncommon type.[131] In some cases, patients may present signs of raised intracranial pressure, of which not only headache, but also vomiting, altered psychosis, visual changes or dizziness can be present.[126]

Besides these common signs and symptoms, NC also has other less frequent features, including neurocognitive defects (e.g. learning disabilities) and mental disturbances (e.g. depression and mania).[33] NC also causes different complications involve intraventricular shunt complications; intracranial herniation; stroke; and other complications resulting from long-term use of anticonvulsant.[130]

Diagnosis of Neurocysticercosis

NC is the most common parasite infection of the CNS, yet a diagnosis with a 100% certainty cannot always be achieved. A combination of diagnostic criteria must be used to obtain a NC diagnosis with different degrees of certainty. A chart of diagnostic criteria (Table 2.8) for the diagnosis of NC was proposed and revised by Del Brutto et al.[132,133] Interpretation of these criteria permits two degrees of diagnostic certainty, which are definitive and probable diagnoses.

Table 2.8. Diagnostic criteria for neurocysticercosis[133]

Categories of criteria	*Criteria*
Absolute	1) Histologic demonstration of the parasite from biopsy of a brain or spinal cord lesion
	2) Cystic lesions showing the scolex on CT or MRI*
	3) Direct visualization of sub-retinal parasites by funduscopic examination
Major	1) Lesions highly suggestive of NC on neuroimaging studies[1]
	2) Positive serum EITB*,[2] for the detection of anticysticercal antibodies
	3) Resolution of intracranial cystic lesions after therapy with albendazole or praziquantel
	4) Spontaneous resolution of small single enhancing lesions[3]
Minor	1) Lesions compatible with NC on neuroimaging studies[4]
	2) Clinical manifestations suggestive of NC[5]
	3) Positive CSF ELISA for detection of anticysticercal antibodies or cysticercal antigens
	4) CC outside the CNS[6]
Epidemiologic	1) Evidence of a household contact with *Taenia solium* infection
	2) Individuals coming from or living in an area where CC is endemic
	3) History of frequent travel to disease-endemic areas

Note. * CT = computed tomography; MRI = magnetic resonance imaging;
EITB = enzyme-linked immunoelectrotransfer blot

[1] CT or MRI showing cystic lesions without scolex, enhancing lesions, or typical parenchymal brain calcifications.

[2] Enzyme-linked immunoelectrotransfer blot assay using purified extracts of *Taenia solium* antigens, as developed by the Centers for Disease Control and Prevention (Atlanta, GA).

[3] Solitary ring-enhancing lesions measuring less than 20 mm in diameter in patients presenting with seizures, a normal neurologic examination, and no evidence of an active systemic disease.

[4] CT or MRI showing hydrocephalus or abnormal enhancement of the leptomeninges, and myelograms showing multiple filling defects in the column of contrast medium.

[5] Seizures, focal neurologic signs, intracranial hypertension, and dementia.

[6] Histologically confirmed subcutaneous or muscular CC, plain X-ray films showing "cigar-shaped" soft-tissue calcifications, or direct visualization of cysticerci in the anterior chamber of the eye

Definitive diagnosis: 1. Presence of one absolute criterion; and 2. Presence of two major plus one minor and one epidemiologic criterion

Probable diagnosis: 1. Presence of one major plus two minor criteria; 2. Presence of one major plus one minor and one epidemiologic criterion; and 3. Presence of three minor plus one epidemiologic criterion.

From "Proposed Diagnostic Criteria for Neurocysticercosis", by O. H. Del Brutto, 2001, *Neurology, 57,* p. 179, Copyright 2001 by AAN Enterprises, Inc.

Recently, based on the criteria suggested by Del Brutto et al. (1996), some modifications have been suggested by Sanchez, Ljungstrom, and Medina (1999) to facilitate diagnosis easily. First, they combined the diagnostic criteria and degrees of certainty together, facilitating the use and interpretation of diagnostic protocol. Second, they omitted the diagnosis of subcutaneous and ocular CC, because they rarely pose difficulties as NC diagnosis. Third, they proposed the finding of specific antibodies and/or antigens in CSF as absolute criterion for NC diagnosis. Finally, they did not merge the different categories of criteria to assess a degree of certainty, as this would have lead to an over-diagnosis in many cases.[12]

Clinical Diagnosis

Since signs and symptoms of NC are varied and non-specific, diagnosis of NC solely depending on clinical grounds is difficult and inaccurate, but clinical diagnosis is a good supplementary method for diagnosis of NC.[33]

Histological Diagnosis

Detection of characteristic scolex or the parasitic membranes in the CNS through biopsy or autopsy is the golden standard for definitive diagnosis of NC, but is rarely used in practice.[127] In addition, biopsy of calcified cysticerci cannot confirm the diagnosis of NC, due to the absence of characteristic scolex or the membranes. Besides, being an invasive and dangerous diagnostic method, biopsy is not applicable in most diagnostic practices.

Neuroimaging Diagnoses

Neuroimaging diagnoses include X-rays, computed tomography (CT) and magnetic resonance imaging (MRI).[126] X-rays can only detect calcified cysticerci.[134] Due to its low sensitivity and specificity, X-rays have been replaced by CT and MRI gradually. From the many neuroimaging findings of NC, only the presence of cystic lesions demonstrating the scolex should be considered pathognomonic.[135] MRI is superior for showing intraventricular or subarachnoid cysts, but CT is better for showing calcification of inactive lesions.[127] CT and MRI allow easy, non-invasive ways to visualize lesions, establish diagnosis in most cases, even determine and evaluate the methods of treatment. However, they are very expensive and not widely available in most endemic countries.[68]

Immunologic Diagnoses

Immunologic tests have long been sought as one possible solution to diagnostic problems, because they are less expensive, available, and easier to implement than imaging examinations.[68] Two main approaches used today are antibody-detection techniques, which indicate present or past infection, and antigen-detection, which indicates current infection. Either antibody- or antigen-detection can be performed in serum or CSF samples.[136]

Antibody-detection techniques

Antibody-detection techniques are useful in both clinical and epidemiological studies. In clinical studies, the presence of antibodies supports clinical suspicion. In epidemiological studies, they are used for evaluating the seroprevalence of antibodies in certain areas or groups, and identifying risk factors associated with *T. solium* transmission.[137] Different antibody-detection techniques have been described and evaluated, such as the complement fixation test, hemagglutination, radioimmunoassay, ELISAs and latex agglutination;[138-141] however, these assays have either relatively poor specificity or moderate sensitivity or, in some cases, both.[142]

The wide variation in sensitivity and specificity that ELISA-based techniques represent a major problem.[143-147] Furthermore most reported ELISAs do not correlate with clinical and imaging diagnoses and make it difficult to establish comparisons among and within endemic countries. This variability has prompted some researchers to discourage the implementation of ELISAs for NC diagnosis.[148,149] Recently, improved purification techniques make it possible to prepare more specific and sensitive antigens (e.g., from cyst fluid) that greatly increase the specificity and sensitivity of ELISA techniques.[138,150]

An immunoblot, called EITB, developed by Tsang, Brand, and Boyer in 1989 at the CDC in the United States, is currently the most specific assay for diagnosis of NC, and the only immunodiagnostic method recommended by the World Health Organization (WHO) and the Pan American Health Organization (PAHO) for confirming clinical and radiological presumptive diagnoses of CC, including NC. According to the original study, the reported sensitivity and specificity were 98% and 100%, respectively.[151] In subsequent clinical and epidemiological studies, EITB has been proven nearly 100% specific. However, the sensitivity has been shown to vary depending on the number and viability of the lesions. The sensitivity of EITB in patients with two or more lesions ranged from 72% to 100% in serum and 33% to 92.2% in CSF. In contrast, the sensitivity of EITB in NC patients with single lesion ranged from 60% to 80% in serum and approximately 35% in CSF.[146,149,152-155] These statistics indicate that antibodies were detected more frequently in serum than in CSF, which made it unnecessary to obtain CSF solely for detection of antibodies. However, if antibodies are present in CSF, NC can be confirmed.[12] The comparatively high cost of EITB is a disadvantage of this technique, which makes it less feasible as a field-applicable screening assay than ELISA techniques in clinical and epidemiological studies in developing countries. None the less, high specificity and positive predictive values make the EITB as an excellent tool for epidemiological investigation. Efforts are being made to improve current EITB technique itself, therefore enhancing its feasibility.[68,153,156]

Although there is no doubt that antibody-detection in sera is a valuable approach, it has three important limitations to consider when establishing a final diagnosis. The first one is that antibody-detection techniques may indicate exposure to infection and may be unnecessary to the presence of an established and viable infection, resulting in transient antibodies.[65] The second disadvantage is that antibodies may persist a long period after the parasite has been eliminated by immune mechanisms and/or drug therapy.[66,157] In contrast, antigen detection may provide a suitable alternative. The third drawback is that some studies have shown that intestinal taeniasis can elicit serum antibodies.[67,111,158] Thus, the presence of antibodies does not constitute direct evidence of a living parasite within the host.

Antigen-detection techniques

To overcome the limitations of antibody-based immunoassays, antigen-based detection techniques have been developed as a tool for diagnosis and monitoring disease progression and response to anticysticercal therapy.[159] Some antigen-detection ELISAs have been developed using polyclonal and monoclonal antibodies (MoAb) to detect the parasite antigens in serum samples as well as in CSF samples, but only the MoAb tests may ensure reproducibility and specificity.[100]

The sensitivities of antigen-detection ELISAs are varied. Garcia et al. (2000) reported a sensitivity of 85%, which is one of the highest records at present; however, instead of using imaging studies as a gold standard, in this study the ELISA was compared against EITB and neurological patients, which is not the ideal.

Antigen-detection techniques have not been widely implemented due to limitations, such as the relatively variant sensitivity, cross-activity with *T. saginata*, the disappearance and evasion of antigen because of the immune complex formation, and low yield of antigens detected due to technological problems.[159]

In summary, ELISAs have been widely used for detection of *T. solium* antigens. Further work should focus on improvement of ELISAs' diagnostic yield by the application of standardized, low-background specific MoAb cocktails and of amplifying systems such as the PCR technique.[115,159]

Treatment of Neurocysticercosis

Because of the diversity in clinical presentations, serious effects and neurological sequelae, the consideration for NC treatment should be individualized. Nash (2003) indicated that proper treatment of NC should obey three principles. The first is to recognize and treat life-threatening complications, such as epilepsy, hydrocephalus, stroke and mass effect of cysts and/or associated inflammation that are caused by cysts in tissues. The second is to prevent severe neurological sequelae, including recurrent epilepsy, strokes, mass effect from enlarging cysts, encephalomalacia secondary to repeated or prolonged intense inflammation, and hydrocephalus. The third principle is to minimize the duration of long-term medication and associated side effects.[160]

Surgical-based Treatment

Several treatments have been used for NC patients currently. These treatments can be divided into surgical-based treatment and non-surgical treatment. In general, patients are required to undergo surgery when they meet at least one of the following indications: the presence of hydrocephalus; when a cyst exhibits tumour-like effects; presence of intraventricular NC; when abrupt or rapid rise of intracranial pressure refractory to medical treatment is noted; and when diagnosis is in doubt.[160]

Clinical presentations primarily determine the need for, and choice of surgical approaches. There are two main choices of surgical procedures, elaborated ventriculoperitoneal shunt (VPS) and surgical excision. Placement of shunts is probably the most common surgical intervention in NC patients, and it proceeds directly by setting up a VPS to drain CSF proximal to the obstruction.[126] Hydrocephalus due to intraventricular cyst or inflammatory obstruction is treated with VPS. However, shunt cannot be applied to all cases, and it also has risk to get shunt dysfunction and infection.[126,161] The alternative procedure is excision, which is also indicated for removal of large parenchymal, cisternal, ventricular or spinal cysts producing local compression. For instance, patients who present hydrocephalus due to obstruction by a free cyst are best recommended to be operated by direct endoscopic excision of the cysts and thereby open up the CSF drainage pathway.[161] However, the need for surgical-based therapies has decreased dramatically over the past two decades. Currently, drug therapy for treatment of NC is used widely.[160]

Nonsurgical-based Treatment

Chemotherapy

Chemotherapy has been used widely to treat NC, which includes: 1) anthelmintic cysticidal treatment; 2) corticosteroids and other anti-inflammatory medication; and 3) anti-epilepsy medication.

1) Anthelmintic cysticidal treatment

Cysticidal agents are used to kill the cystic larvae when they are still viable. The drugs of choice are praziquantel and albendazole. They are both given orally in combination with anti-inflammatory drugs. Both drugs induce destruction of the cysticerci and result in a decrease in size or disappearance of cysts, especially in those patients with brain parenchyma cysts.[162] Even though, some authors still debate the clinical benefits of anti-parasitic therapy,[160,163] praziquantel and albendazole are being used worldwide.

Praziquantel was the first available drug with proven effectiveness to treat NC. The usual dosage is 50 to 75 mg/kg per day divided in three doses per 14 days. Praziquantel is well tolerated by patients; nevertheless it still has some frequent but minor side effects, including drowsiness, headache, mild abdominal pain, dizziness, nausea and skin rash.[164]

Albendazole a benzimidazole compound that was approved later than praziquantel has largely replaced praziquantel as it has a slightly higher association with a cure, higher efficacy in subarachnoid or ventricular cysts, lower cost and better availability.[160] The recommended dose is 15 mg/kg per day with a maximum of 400 mg/day divided into two doses for 7 to 30 days with repeated dosings as clinically warranted.[165] Albendazole is well tolerated but has a few side effects such as headache, nausea and vomiting.[164]

In a recent review of NC drug therapy done by Garcia et al. (2002), cure rates for both praziquantel and albendazole ranged from 60% to 85% at the usual dosage. The cure rate of albendazole was slightly higher than that of paziquantel.[165]

2) Corticosteroids and other anti-inflammatory drugs

Corticosteroids are often administered in NC on the premise that they reduce inflammation and oedema around dying cysts. Corticosteroids are recommended for treatment of cysticercotic encephalitis in children and disseminated NC, and treatment-induced inflammation occurring 2 to 5 days after initiation of cysticidal therapy, as well for treatment of acute neurological deficit resulting from oedema, vasculitis and large subarachnoid cysts. However, the standardized usage, duration, and timing of administration of corticosteroids are not clear.[166] Some clinicians empirically use 10 to 16 mg/day of dexamethasone in divided doses and taper the dose following therapy over 1 to 3 months. Patients with subarachnoid cysts or chronic meningitis may need continuous anti-inflammatory therapy and may have to switch to alternate anti-inflammatory drugs to reduce side effects, such as headaches, nosebleed, and low immunity resistance to infection.[160] Some researchers recommend the use of non-steroidal anti-inflammatory agents, and advised the routine pre-administration with these agents and persistence for four to six months after a course of cysticidal therapy.[166]

3) Anti-epilepsy medication

Since epilepsy is a common and serious clinical manifestation of NC, anti-epileptic treatment is crucial. Anti-epileptic medication is prescribed to decrease the severity and frequency of epilepsy. The usage among NC patients is similar to that among patients who have other epilepsy disorders. The administration of anti-epileptic medication should be determined based on the individual situation.[160]

Supportive care

Supportive care is widely used in NC to assist treatment and provide infected persons some relief. For instance, for NC patients presenting with stroke, rehabilitation and counselling to patients and their family members is necessary; for NC patients with neurological dysfunction, providing neuropsychological training to patients is a long-term and important therapy.[165]

Prognosis of Neurocysticercosis

Comparing to extraparenchymal forms of NC (i.e. meningeal, subarachnoid space, ventricular, and spinal cord NC), parenchymal forms carry a benign prognosis, because extraparenchymal disease is often associated with hydrocephalus that can be fatal if not properly managed.[33] NC patients presenting with seizures have an overall good prognosis regarding mortality, morbidity and control of seizures if the anthelmintic treatment with praziquantel or albendazole can be implemented. However, the prognosis is variable among different forms of seizures. Acute symptomatic seizures have a good prognosis because remission of epilepsy is frequent. Patients without hydrocephalus presenting with seizures have a better prognosis in comparison with those with hydrocephalus and large cysts.[125] The risk of epilepsy recurrence is high in patients with persistence of active brain lesions.[167] Patients with calcified cysts have worse prognosis than those with viable cysts, because medication is not effective to calcified lesions and surgery has risks to damage peripheral tissues of lesions in the CNS. Occasionally, several severe sequelae, including blindness, stroke and mental disabilities, may happen on NC patients who encounter massive infection of *T. solium* cysticerci.

PREVENTION, CONTROL AND ERADICATION STRATEGIES FOR TAENIASIS AND CYSTICERCOSIS

In 1993, the International Task Force for Disease Eradication (ITFDE) concluded that six diseases could probably be eradicated by using current technology, and taeniasis/cysticercosis is one of them.[168] The conclusion has been drawn due to the following reasons:

1. humans are the only definitive host and the only source of transmission to intermediate hosts;
2. pigs are the only significative intermediate hosts to humans and no wild reservoirs exist;
3. improved sanitary infrastructure decreases transmission;
4. sensitive and specific detection tools are available for both taeniasis and cysticercosis;
5. safe and effective anti-parasitic drugs for human taeniasis and NC are available; and
6. surveillance and control strategies have deserved more attention and have been enhanced gradually.

The eradication of *T. solium* from most of Europe, USA and Canada proves the conclusion of ITFDE commendably.[2] Factors credited for the eradication include general improvements in sanitation and hygiene, promotion of socioeconomic status, as well as industrialization of pig husbandry and exclusion of infected pig carcasses from the human food chain by strict pork inspection. However, a lack of economic support prevents eradication in many of the developing countries where the parasite remains endemic.[2,123]

Recent epidemiological studies have identified that community, behavioural and environmental interventions are effective, but must be adapted to the actual situation of endemic areas. Wider public access to mass media for the transmission of public health messages; health education aiming to modify human behaviour and mentality; developments in vaccine technology and the availability of effective drugs can be used as supplements to traditional approaches for *T. solium* control and elimination.[123]

The WHO and the PAHO have formulated two alternate programs for control of *T. solium* taeniasis/CC: comprehensive long-term intervention and short-term intervention based on mass treatment of taeniasis in existing foci.[2]

Comprehensive Programs of Long-term Intervention

A complete comprehensive program of long-term intervention would involve appropriate legislation, health education, modernization of swine husbandry, improvement of meat inspection, provision of adequate sanitary facilities, chemotherapy, adoption of measures to detect and treat human tapeworm carriers, and vaccination of pigs.[13] Such comprehensive programs have reduced transmission in many industrialized countries, such as some European countries and the United States.[14] The final goal of these programs is to completely control and thereby eliminate *T. solium* transmission in the world.

A successful long-term intervention is more likely achieved when the above approaches are combined and performed together. Such control programs are extremely desirable and contribute to the increase of life quality, and they should be advocated and implemented wherever possible. However, social, political, cultural and economic realities of rural areas offer little hope to implement all measures simultaneously and even baffle its successful execution.[2] For instance, modernization of swine husbandry and provision of adequate sanitary facilities are both expensive and time-consuming, and beyond socioeconomic capabilities of most rural communities. Furthermore, the changes on traditional attitudes, beliefs and behaviour patterns are a laborious task.

To achieve more rapid progress towards control and substantial reduction of the morbidity and mortality of *T. solium* infection, the WHO and the PAHO proposed short-term, targeted intervention programs in an attempt to identify foci and treat all diagnosed or suspected human cases of taeniasis.[2]

Short-term, Targeted Intervention Programs

The immediate goal of these program is to interrupt transmission from tapeworm carriers and eliminate taeniasis.[2] Targeted intervention programs aim at selecting those interventions that provide the most cost-effective return, and focus them to areas most in need.[169] Comparing to the long-term intervention programs, the short-term targeted intervention programs have a more restricted impact, but are probably more sustainable and can provide better short-term results.[169]

Developing an Action Plan of Intervention

In every endemic country, a national action plan should be formulated before implementing control strategies. As a first step, baseline data such as identification of endemic regions, prevalence of infection (taeniasis and CC), social and economic losses due to *T. solium* infection, etc. should be collected.[128] As well, standardized guidelines for diagnoses and treatment, reporting and surveillance should be prepared and implemented.

Depending on goals and resources, an action plan may combine different strategies that can be used in either short-term or long-term programs. These strategies are:

a. Health education;

b. Treatment of tapeworm carriers;

c. Diagnosis, treatment and surveillance of porcine CC

  c. 1. Treatment of infected pigs;

  c. 2. Establishing official meat inspection;

  c. 3. Vaccination of pigs;

d. Improvement of sanitation, hygiene and pig husbandry;

e, Maintenance activities, reporting and surveillance.

Health Education

Health education, as an important intervention strategy, is gaining more and more attention for infectious disease control. Before discussing health education specifically designed for *T. solium* control, a general theoretical background will be given to understand health education's theoretical basis.

As quoted by Breckon, Harvey and Lancaster (1989), the definition of health education is "the sum of experiences which favourably influence habits, attitudes and knowledge relating to individual, community health." Health education is an intervention tool that emphasize on changing and improving humans' knowledge, attitudes and practices, and is a supplement of other intervention strategies and the basis of short-term and long-term integrated programs. It is less expensive, more sustainable, and more transferable compared to other intervention strategies. Moreover, considering the reality of low-income countries, where financial resources are very limited, educational interventions in the context of a short-term intervention program represents a realistic approach to confront infectious diseases of major public health importance.

Community health education is defined as "a learning process through which people in a community inform or orient themselves for more intelligent health action".[170] It can be used not only in school, different career populations, patients, customers and health-related professionals but also in community.[171]

Community health education has been implemented in some studies on other infectious diseases and shown to be effective.[172-174] This success has encouraged the adoption of similar strategies for *T. solium* control. In Mexico, a study was undertaken in a rural community to evaluate the effect of health education in both short-term (six months) and long-term (forty-two months) programs.[60] The educational program was developed to promote recognition and knowledge of *T. solium* transmission and to improve behaviour and poor sanitary conditions that foster transmission. The efficacy of the educational intervention was assessed by measuring changes in knowledge and practices, and prevalence variations of human taeniasis and porcine cysticercosis before and after the intervention. The success of the study was demonstrated by the increase in knowledge and the significant decrease of porcine cysticercosis, which was 2.6% at the beginning of the study and reduced to 0% after the four-year intervention. Moreover, changes in practices were observed as fewer pigs were allowed to roam freely and therefore had reduced access to human feces. Despite the success, the study also demonstrated that the knowledge acquired did not appear to result in dramatic changes in risk behaviours, such as dietary preference and sanitation habits.[175] The reason is partially because economic and political incentives play crucial roles for the development of health education strategy in behavioural changes.[175]

Despite the fact that educational intervention is an effective, economical and widely adaptable control strategy, it cannot be used as a sole intervention to achieve persistent changes, and it must be followed up and used in the context of a program that addresses other areas.

Treatment of Tapeworm Carriers

Several studies have been carried out using mass treatment as a control intervention against taeniasis.[16,63,176-180] Except for one study that used albendazole[176] and one study using niclosamide,[63] praziquantel was be the drug of choice in these studies. Regardless of the drug used, follow-up studies showed reduction of taeniasis prevalence from 3.5% to 1% after ten months;[63] from 1.6% to 0% after one year;[16] from 1.32% to 0% after one year,[177] as well, a reduction of 53% after 6 months and of 56% after 42 months for human taeniasis treatment.[180]

Mass-treatment strategy for tapeworm carriers also presents with some problems. Although, all three drugs have been reported effective and have few side effects, praziquantel has been shown to cause neurological reactions occasionally, such as cerebral inflammation in individuals with undiagnosed concurrent NC, due to its anticysticercal properties. For instance, a clinical case has been reported that a previously undiagnosed individual developed severe headache within 24 hours following treatment of praziquantel with a dose of 10 mg/kg. After this event, numerous intracerebral cysticerci were detected in the patient's brain by CT scan.[181] Besides monitoring for potentially adverse reactions, mass-treatment campaign must be carefully designed to prevent environmental pollution. Providing latrines and toilet and/or health education and encouragement on their use should ideally be part of the strategy. However, building and using latrines and toilets also need government's economic support and individuals' active enforcement. In addition, chemotherapy of taeniasis has a short-term effectiveness, so it cannot be used as a sole strategy to eradicate *T. solium* transmission. Integration of chemotherapeutic intervention with other strategies will make intervention programs more sustainable and acceptable.

Diagnosis, Treatment and Surveillance of Porcine Cysticercosis

Porcine CC can be diagnosed either before or during slaughter. Before slaughter, the most widely used diagnostic method is tongue palpation, which aims to detect cysticerci like nodules in pigs' tongues. Newly developed immunologic test can identify either antibodies or antigens circulating in pigs' blood. During slaughter, meat inspection by necropsy is a general method and golden standard to detect the infected carcasses. After a diagnosis is made, three intervention strategies can be implemented: treatment of infected pigs, official meat inspection, and vaccination of pigs.

Chemotherapy of Infected Pigs

Several chemotherapeutic agents, mainly praziquantel, albendazole and oxfendazole have been studied and reported for the treatment of porcine cysticercosis.[182-186] A single-day treatment with praziquantel in three divided doses of 100 mg/kg, 50 mg/kg and 25 mg/kg was reported to be effective to kill cysts in pigs.[186] A 3-day albendazole treatment with the dose of 30 mg/kg/day was found to be effective for porcine cysticercosis.[184] A single dose of oxfendazole with 30 mg/kg has been demonstrated safely and effectively for destroying porcine CC without damaging pigs or the meat product, therefore oxfendazole has been considered superior to praziquantel and albendazole.[183]

Despite the relative success in treatment of infected pigs, this strategy also has some drawbacks. First of all, the cost of chemotherapeutic drugs is not affordable for most of the families that raise pigs, especially those in rural areas. Secondly, since the duration of cysts' disappearance after treatment is about twelve weeks, immediate pre-slaughter of treated pigs does not result in death and disappearance of cysticerci.[187] Thirdly, treatment of pigs without restraining their access to human feces will lead to re-infection. To maintain the effect of chemotherapy on infected pigs, decision of treatment time, accurate estimation of the duration of drugs' protective effect and build of pig-pens are crucial.[175,187]

Official Meat Inspection

Implementation of inspection measures, including building slaughterhouse, strict training to inspectors and rigorous surveillance system to slaughterhouses can contribute to the eradication of porcine CC. In industrialized countries, the eradication of porcine

CC due to sturdy meat inspection system has proved its effect. However, on account of economic and technological limitations, meat inspection cannot be performed in most rural areas. Moreover, even when slaughtering facilities are present, the success of meat inspection programs may be limited by a series of reasons, ranging from traditional customs, the fear of having infected pigs confiscated and therefore facing economic loss, or the need of meat as a source of proteins.

Vaccination of Pigs

An effective vaccine to prevent porcine CC would be a valuable new option to assist with control of *T. solium*. Several trials aimed at the development of a *T. solium* vaccine are being studied currently with a focus on recombinant oncosphere antigens.[188-190] A recent study found that an oncosphere antigen, TSOL18, could induce complete protection against pig infection.[156] This finding poses a promising prospect for development of a safe, effective, inexpensive and practical vaccine in the near future. So far, international collaboration is progressing towards the realization of a pig vaccine to reduce the global burden of *T. solium* transmission.

Improvements of Sanitation, Hygiene and Pig Husbandry

Improved sanitation, hygiene, including building of sanitary infrastructure, piped sewage disposal systems and other basic services are crucial to break up *T. solium* transmission. Industrialization of pig husbandry through the supply of pigpens, safe food, and security is also important to prevent transmission. However, to achieve the goal, considerable funds are required, also without public health and hygiene education, those facilities can be rejected or misused.[128] Hence, this strategy is difficult to be achieved in most developing countries at present.[191]

Maintenance Activities, Reporting and Surveillance

Once substantial progress in reducing transmission has been achieved, development of maintenance activities is necessary for any intervention strategy to sustain progress. One approach may be integration of control activities into primary health care systems. Maintenance activities include identification of new case of transmission followed by targeted application of measures to eliminate infection.[14]

A rigorous and thorough surveillance strategy will naturally lead to a more accurate understanding of the extent of the problem, to the identification of transmission foci, and a more active approach of public health decision makers towards prevention and control of the disease.[169] However, a surveillance system has not been established in some rural regions, and even after its establishment, it is impossible to become rigorous and thorough in a short period. The following table (Table 2.9) published in an article of Lightowlers (1999), shows a comparison of the different intervention strategies discussed above for control of *T. solium* transmission.

Table 2.9. Comparisons among different intervention strategies for control of *T. solium* transmissions

Control Strategy	*Advantages*	*Disadvantages*
Health education	• Lowest expenses • Wide range of adaptability • Provides benefits beyond control of *T. solium* • Easy to be implemented • Better effect through new media	• Short-term effect, repeat frequently to maintain long-term effect • Inefficient as a sole strategy • Transmission susceptible to immigration to and from community

(table continues)

Table 2.9. (table continued)

Control strategy	*Advantages*	*Disadvantages*
Chemotherapy of tapeworm carriers	• Wide availability • High efficacy and low side effect • Breaks transmission • Removes health risk • Relatively low expenses • Can take effect rapidly	• Short effect and requires repeated treatments • High expenses for long-term usage • Cannot absolutely break transmission due to immigration • Potentially cause risks in NC patients
Chemotherapy of porcine cysticercosis	• Wide availability • High efficacy • Provides economic benefits to pig farmers through the sale of clean carcasses	• Requires 4 weeks of preslaughter • No compliance in informal meat trade • Difficult to monitor compliance • Inefficient pork inspection
Improvement of sanitation, hygiene, pig husbandry and pork meat inspection	• Potential for eradication of *T. solium* • Benefits beyond taeniasis/CC • Long-term protection	• Requires national economic advancement • Time-consuming • High expenses • Unaffordable to countries with lower economic resources
Vaccination of swine	• Long-term protection • Not affected by informal meat trade • Possible to monitor compliance • Amenable to pig management	• On experimental period, no commercial products • Technological complexity

Note. From "Eradication of Taenia solium cysticercosis: a role for vaccination of pigs", by M. W. Lightowlers, 1999, International Journal for Parasitology, 29(6), p. 811, Copyright 1999 by Australian Society for Parasitology Inc.

In Honduras, several studies have confirmed taeniasis/cysticercosis as important public health problems.[12,20,30,50,51,116] Some of these studies carried out in rural areas of

Department of Olancho[30,192] have led to the implementation of basic intervention programs by the Ministry of Health. Due to these interventions, currently, several geographical areas of Olancho report a taeniasis prevalence of 0% (Mejia, F., personal communication, August 14, 2003). To promote a comprehensive long-term program in Honduras, similar efforts should be made in other parts of the country, such as Department of Francisco Morazan, one of the most important regions of Honduras.

The aim of the present proposal is to estimate the prevalence of human *Taenia solium* infections (i.e., taeniasis and cysticercosis), the knowledge about this parasite, and risk factors associated with transmission in a Honduran rural village, where no similar studies have been conducted. The results of the study might provide further evidence to the endemicity of this parasitic problem in Honduras, and validate current efforts for its prevention and control.

CHAPTER THREE: METHODOLOGY

Since *Taenia solium* infections have been confirmed as important public health problems, some succedent intervention programs have been proved to be effective in rural areas of Department of Olancho (Mejia, F., personal communication, August 14, 2003). To reduce the burden of *T. solium* transmission and to perform comprehensive long-term program nationally, control strategies should be processed in other areas. On account of limited financial resources in Honduras, it is advisable and feasible to choose those control strategies having the most cost-effective return. Furthermore, before determination of any control strategies, assessment of current situation of *T. solium* transmission and determination of local population's potential risk factors and relevant knowledge to the parasite are extremely crucial. Ulteriorly, this study offers more epidemiological information on *T. solium* transmission in rural areas of Latin America and helps to identify targets for intervention.

MATERIALS AND METHODS

Research Team

This study was a secondary analysis of questionnaire data and laboratory results from a previous study in a small Honduran village, which was conducted as a joint co-operation between Brock University and the National University of Honduras (UNAH). Under the supervision of Dr. Ana L. Sanchez (Principal Investigator), two graduate students are involved in the study: one MSc student at Brock University (Haiyan Pang) and one Master student of Public Health at UNAH (Maritza Canales). Maritza

Canales participated in the research design and organization and execution of field and laboratory works in Honduras, including supervision of undergraduate students of microbiology. Haiyan Pang participated in the creation of databases, statistical analyses of results and manuscript writing in Canada.

Objectives

General Objective

To estimate the prevalence of *Taenia solium*, risk factors of transmission and population's knowledge in a rural community in Honduras

Specific Objectives

1. To collect information about household conditions, sanitary conditions, pig farming practices, pork meat consumption, and history of taeniasis, NC and clinical symptoms associated with NC.
2. To determine the knowledge level of the selected population about *T. solium* transmission and its clinical significance.
3. To determine the prevalence of intestinal taeniasis.
4. To determine the seroprevalence of antibodies to *T. solium*.
5. To identify risk factors associated with the seropositivity of antibodies.

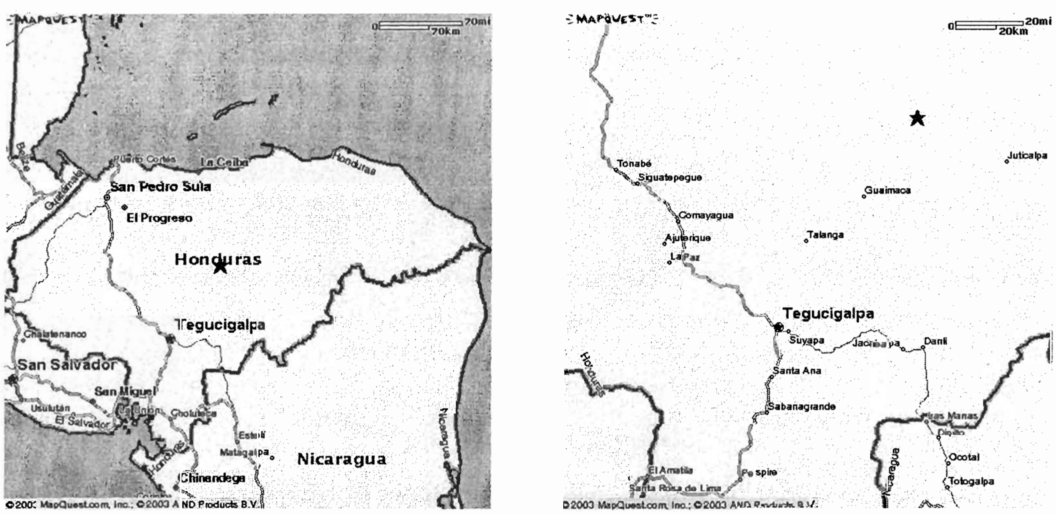
Research Design

Selection of the Study Community

Honduras is a *T. solium* endemic country, and pig farming is a generalized practice both at the industry and the household level. For this reason, any rural town would have been an appropriate study site. To ensure convenient travel from the National University of Honduras (UNAH) to the study site, the research areas were narrowed down to the Municipality of Talanga, Department of Francisco Morazan. Within Talanga, the town of Jalaca was chosen by recommendation of the mayor of Talanga, because pig-roaming in Jalaca is a serious problem.

Jalaca (Latitude 14°24'0N, Longitude 87°10'60W; Figure 3.1) is a rural area located in central Honduras, 50 km from Tegucigalpa, the country's capital city. The Greater Jalaca area has a population of 2,400 inhabitants. The study was done in Jalaca's Central Area where the population is of 1,400 inhabitants living in 248 households with suboptimal sanitary conditions. Villagers rely on subsistence agriculture and small-scale pig farming.

Figure 3.1. Geographical position of Jalaca, Honduras, Latin America



From "http://www.mapquest.com/maps/map.adp?addtohistory=&country=HN&city=&historyid=&submit.x=22&submit.y=10" by Anonyms, 2003. Copyright 2003 by MapQuest.com, Inc.

Study Population Selection

Selection and Exclusion Criteria

To be eligible to participate in the study, individuals had to be old enough to understand and answer the questions contained in questionnaires. Thus, the minimum age of participants was set at ten years. The only exclusion criterion was the refusal to participate.

Sample Size

To maximize research resources, a representative sub-sample of Jalaca Central area population (1,400 inhabitants) was randomly selected. To calculate sample size, Epi-info 2000 software (CDC, USA) was used.

According to Honduras' population pyramid,[193] 30% (420 individuals) of Jalaca's population of 1,400 is under 10 years of age. Therefore, the population from which the sub-sample was drawn is 980 (70% of 1,400). Out of a population of 980, and setting the expected seroprevalence of antibodies at 10%, the lowest acceptable seroprevalence at 5% and a confidence interval of 99%, a sample size of 192 individuals was calculated.

Selection of Households

Jalaca's population census only contains information on the number of households, location, and name of the head of the family. Therefore, to enrol the required 192 individual participants, the household was considered the sampling unit from which individuals were selected. Considering an average of five people per unit, the number of household required was set at 60. The random selection of households was done by a draw (i.e., 248 household numbers were written on individual pieces of paper, put into a box and drawn blindly). Once selected, household locations were obtained from the census and recorded into a list for further contact. Every selected household was visited by the research team and given a full explanation of the study. Each individual older than 10 years of age was invited to participate. At the same time, a letter of invitation and information about the study (Appendix A) was given to the head of the family. After thorough explanation regarding the benefits and minimum risks associated to participating in the study, consenting participants (or their guardians in cases of individuals younger than 16 years of age) were requested to sign informed consent forms (Appendix B).

Interview Process and Questionnaires

In order to design the questionnaires, it was necessary to obtain general information about the community and its inhabitants. Therefore, preliminary meetings were conducted with key 'informants' of the community (i.e., schoolteachers, nurse, health committee members, butchers, farmers and house-makers).

To obtain general demographic information and to determine their knowledge about *T. solium*, participants were subject to face-to-face interviews, using standardized questionnaires. Each question and its choices of the answers were explained as necessary, and answers were recorded by the interviewer in the questionnaire forms. Two questionnaires were used in this study, a general survey questionnaire (Q1), and a knowledge questionnaire (Q2) about the *T. solium* transmission and clinical importance. As well, consenting participants were requested to provide a blood and stool samples to determine anti-*T. solium* serum antibodies and *Taenia* sp. eggs, respectively.

The general survey questionnaire, Q1, was designed to obtain information about living conditions, pig-farming practices, hygiene habits, meat consumption habits and the presence of present and past infection of taeniasis/cysticercosis symptoms (Appendix C). The knowledge questionnaire, Q2, was designed as a ten-question multiple choice test for evaluating the knowledge of selected participants. Five questions measured knowledge on *T. solium* transmission and its life cycle, and the remaining five tested for knowledge about clinical presentation and importance of *T. solium* infections (Appendix D).

Collection of Biological Samples

Every participant was requested to provide a blood sample to detect anti-*T. solium* antibodies by EITB.[151] Blood samples consisted of 4 ml and were drawn by authorized phlebotomists. Collected blood samples were transported to the microbiology laboratory of UNAH the same day, centrifuged to obtain serum, and kept frozen at -20ºC until analysis by EITB technique (Appendix E).

Every participant was requested to provide a fecal sample to detect *Taenia* sp. eggs using Kato-Katz concentration technique.[194] For stool specimens, special containers were distributed and samples were collected the following day after the interview. After collection, fecal samples were also transported to the microbiology laboratory of UNAH and analyzed within 24 hours. The Kato-Katz concentration technique enables intensity of infection to be measured indirectly and expressed as the number of eggs per gram of faeces (Appendix F).

Research Ethics Approval

Research ethics approval for the whole community-based study to work with human subjects was obtained by the principal investigator, Dr. Ana Sanchez, from both the Brock University Research Ethics Board and the National University of Honduras, Directorate of Research (Direccion de Investigacion Cientifica) (Appendix G).

Both confidentiality and anonymity were secured during collection and analyses of information. Participants' personal information was obtained in order to provide them with their laboratory results. All confidential information was handled by the research team only. After creation of an electronic database, personal identification information was removed from the electronic database and replaced by identification codes. Hard copies of questionnaires will be kept indefinitely in a secure place in the principal investigators' office at Brock University.

Biosafety Measures

Since serum and fecal samples are potentially infective, biosafety level II practices were required. Standard precautions were observed in sample collection and transportation, as well as in the course of experiments. Biological samples and all material and equipment used in sample collection in the Jalaca community were transported in a safe manner to the laboratory of UNAH for process and analyses. After analyses, stool and serum samples and other experimental materials were autoclaved and properly discarded.

Data Analysis

Management of Data

Creation of Database

Data recorded in questionnaires was entered into an electronic database using the software program SPSS 11.0 and Epi-Info 2000. The information from two questionnaires and the laboratory results from biological samples were used as database variables and separated into nine groups (See Table 3.1). Most of the variables in the nine groups were discrete variables.

Data Checking and Cleaning

Before analyzing the data set, the secondary dataset was checked for missing or incorrect data. Frequency distributions and descriptive analyses were performed on all variables.

Before doing any statistical analyses, appropriate analysis is necessary to guarantee that data meet their assumptions. However, different statistical methods have different requirements on data checking and cleaning. The specific assumptions, such as normal distribution, equality of variances, multivariate normal distribution, etc., are dependent on the selected statistical method.

Table 3.1. Data grouping and sources

Group	*Data set*		
	Q1	*Q2*	*Laboratory analyses*
Personal information	√		
Household conditions	√		
Pig farming practices	√		
Hygiene	√		
Tapeworm carriers	√		
Presentation of NC	√		
Knowledge questions		√	
Antibody-detection test (EITB)			√
Kato-Katz concentration			√

Statistical Analysis

All data were analysed using SPSS 11.0 software program. Analyses were based on the research objectives posed at the beginning of the methodology section. The following research questions were answered using proper statistical analysis to evaluate the data collected for this study:

1. What are the current epidemiological characteristics in the rural community of Jalaca in Honduras, including household conditions, pig farming practices, sanitary conditions, and history of taeniasis, NC and clinical symptoms associated with NC?

A simple univariate analysis, that is, percentage, will be reported to describe the current epidemiological characteristics in the community of Jalaca. Intervals will be created for continuous variables (e.g. age) and the results will be reported using the categories to assist in the interpretation of the data. However, during multivariate analysis the continuous variables will remain intact.

2. What is the population's overall knowledge level about *T. solium* in the rural community of Jalaca in Honduras?

Answers to this question utilized data collected in the Q2. Every participant was assigned a score representing his or her knowledge about *T. solium*. The average of all scores reflected the population's overall knowledge. The calculating formula used was:

$$\text{Average of knowledge} = \frac{\text{Summation of all scores}}{\text{Total sample size}}$$

3. What is the prevalence of intestinal taeniasis in the rural community of Jalaca in Honduras?

The prevalence rate depended on the laboratory examination results by Kato-Katz concentration technique. It was reported as the percentage between the number of positive fecal samples and the total number of fecal samples. The calculation formula was as follows:

$$\text{Prevalence of taeniasis } \% = \frac{\text{Number of positive fecal samples}}{\text{Number of total fecal samples}} \times 100\%$$

4. What is the seroprevalence of antibodies to *T. solium* in the rural community of Jalaca?

The seroprevalence rate depended on the results of EITB assay. It was reported as the percentage between the number of positive serum samples and the total number of serum samples. The calculation formula was as follows:

$$\text{Seroprevalence } \% = \frac{\text{Number of positive serum samples}}{\text{Number of total serum samples}} \times 100\%$$

5. What are the risk factors associated with the seropositivity of antibodies in the rural community of Jalaca in Honduras?

Logistic regression was performed in order to predict the relationship between seropositivity of antibodies as indicative of transmission (as dependent variable, DV) and several possible or potential risk factors (as independent variables, IVs; or predictors). Before conducting logistic regression analysis, and to meet logistic regression models, four assumptions were checked: 1) specificity, to ensure the model contains all relevant predictors, and no irrelevant predictors; 2) independence of observation, so that outcomes are statistically independent (i.e., a single subject can be represented in the dataset only once); 3) no multicolinearity, to make sure that independent variables are not linear combinations of each other. Multicolinearity between predictive variables, if present, was solved by either choosing one or by combining the variables; and 4) adequate sample size, the empirical rule is that a minimum of 50 cases per predictor variable is sufficient.[195] An odds ratio and its 95% confidence interval were calculated. However, estimated from the fourth assumption, a relatively low sample size is presenting in this study, so there was a limited amount of variables that can be included in a single regression equation. Therefore, bivariate analyses (chi-squares) were conducted on all predictor variables to help select variables, and only a few variables will be entered into the equations at a time. The variables were systematically grouped by content area and entered one step at a time. The detailed procedures for variable selection are described in the following chapter (see Chapter 4.27). If one risk factor is a significant predictor of seropositivity, the odds ratio is not equal to 1.0.

CHAPTER FOUR: RESULTS

DEMOGRAPHIC AND EPIDEMIOLOGICAL VARIABLES

General Characteristics of Subjects

The study was carried out in the rural community of Jalaca in 2002 and 2003. Out of sixty households selected, four were unwilling to participate (response rate 93.3%). The refusal to participate was based on these four families not raising pigs; therefore did not feel that they were at any risk or could obtain any benefit from the study. From the 56 households that agreed to participate, 139 subjects completed two questionnaires (general survey questionnaire and knowledge questionnaire) and provided blood samples. Of the 139 participants, 123 (88.5%) provided stool samples. Table 4.1 shows the demographic characteristics of the 139 participants according to their responses to the general survey questionnaire.

The mean age was 33 years of age (*SD* = 17.3). The age of subjects ranged from 10 to 78 years of age. The majority (81.3%) of participants were younger than 50 years of age. More females (99/139, 71.2%) were involved in this study than males (40/139, 28.8%). Almost 75% (104/139) of these subjects were permanent residents of Jalaca. The remaining 35 had immigrated from other towns, 33 of them in the past year and 2 more recently.

One primary and one junior high school were available for the local residents in Jalaca. In the selected population, 15.8% (22/139) had formal education levels of high school or above. Participants with no schooling or primary school level only accounted for 17.3% (24/139) and 66.9% (93/139), respectively. Most residents (86.3%, 120/139) in this community reported consuming pork meat. Some specific questions for subjects who eat pork will be described subsequently.

Table 4.1. General characteristics of subjects (n=139)

Items	*Results*	
	n	%
Age (years)		
10-19	38	27.3
20-29	29	20.9
30-39	26	18.7
40-49	20	14.4
50-59	15	10.8
≥ 60	11	7.9
Gender		
Female	99	71.2
Male	40	28.8
Duration for living in Jalaca		
Always	104	74.8
More than one year	33	23.8
Less than one year	2	1.4
Formal education		
No schooling	24	17.3
Do not know how to read and write	16	11.5
Know how to read and write	8	5.8
Primary school (any level)	93	66.9
Incomplete	40	28.8
Complete	53	38.1
High school (any level)	21	15.1
Incomplete	17	12.2
Complete	4	2.9
Others	1	0.7
Pork consumption		
Yes	120	86.3
No	19	13.7

General Household Conditions

The characteristics of the selected 56 households are demonstrated in Table 4.2. Fifty percent of households had 1- 4 family members and the remaining 50% had 5 or more, for an overall mean of 5.4 persons per household. From the latter group, 8 households had 8 or more family members. In most cases, the number of bedrooms did not match the number of people in the households, with a mean of 2 bedrooms per household, which indicated that overcrowding was frequent. For instance, one family of 13 and another of 9 had one bedroom each.

The general survey questionnaire did not show any particular pattern for the type of floor used in the households. Almost 20% (11/56) of households had an earthen floor and 37.5% (21/56) used mixed materials.

Over 21% (12/56) of households reported not having any feces disposal facilities. Other reported having either toilets (28.6%, 16/56) or latrines (50%, 28/56). In two households, latrines were, however, not in working condition. Out of 44 households that had either a latrine or a toilet, only 7 (12.5%) reported using the latrine or toilet to discard sanitary paper. More than 80% (45/56) burned their sanitary paper, and 7.1% (4/56) dumped it outside the house.

More than half (51.8%) of the households reported having access to indoor tap water (municipal); 44.6% reported using outdoor well water, and the remaining 3.6% had neither. Regardless of the source, 8 households (14.3%) reported boiling the drinking water, 22 (39.3%) reported adding chlorine, and the remaining 26 (46.4%) reported drinking untreated water.

Table 4.2. Characteristics of household conditions (n=56)

Items	*Results*	
	n	%
Number of family members		
2-3	11	19.6
4	17	30.4
5-7	20	35.7
8 or more	8	14.3
Number of bedrooms		
1	18	32.1
2	22	39.3
3	12	21.4
4	4	7.1
Type of floor		
Earthen	11	19.6
Cement	14	25.0
Tiles	10	17.9
Mixed	21	37.5
Type of feces disposal system		
Toilet	16	28.6
Latrine	28	50.0
Working	26	46.4
Not working	2	3.6
None	12	21.4
Ways to discard sanitary paper		
Within latrine or toilet	7	12.5
Burns in the backyard	45	80.4
Dump outside the house	4	7.1
Access to water		
Indoor tap	29	51.8
Well	25	44.6
Neither	2	3.6
Treatment of drinking water		
Directly drink as it is	26	46.4
Chlorinated	22	39.3
Boiled	8	14.3
Whether or not raising pigs		
Yes	30	53.6
No	26	46.4

About 54% (30/56) of selected households were raising pigs at the time of the study, with a mean of 2.4 pigs per household. Table 4.3 describes further information about pig-raising practices. Among the 30 households in which the pigs were raised, 21 owned 1 or 2 pigs, and 9 owned 3 or more. Only one family of the latter group was raising 9 pigs. Although more than half of households had pigs, only 23.3% and 6.7% of owners kept their pigs in pens or tied up, respectively. The rest let their pigs roam free within the houses and backyards and the village. A history of having a cysticercotic pig was reported in 10% (3/30) of households.

Table 4.3. Characteristics of pig-raising households (n=30)

Items	*Results*	
	n	%
Number of pig(s)		
1	11	36.7
2	10	33.3
3	3	10.0
4	4	13.3
5 or more	2	6.7
Where pigs are kept		
Free within the house	5	16.7
Free within the town	8	26.7
Backyard with other animals	8	26.7
Pig-pen	7	23.3
Tied in the backyard	2	6.7
Ever have pig(s) with cysticercosis		
Yes	3	10.0
No	27	90.0

Recognition of Tapeworms, Current and Lifetime Taeniasis

To assess people's familiarity with adult tapeworms, a glass jar containing a formalin-fixed tapeworm was shown to participants. They were then asked if they could recognize this worm, to which 75.5% (105/139) responded that they had never seen it. At the time of the study, 4.3% (6/139) and 6.5% (9/139) of subjects reported that either they or their family members were passing tapeworm segments, respectively. Also 6.5% (9/139) subjects reported that one of their family members had passed tapeworm segments at some point before the time of the study; moreover, these 9 family members were from 7 households, in which 2 families had 2 tapeworm carriers each. Detailed information is shown in Table 4.4. The purpose of getting this information was to investigate its possible relationship with seropositivity and will be discussed later.

Table 4.4. Recognition of tapeworms, current and lifetime taeniasis in participants and family members (n=139)

Items	*Results*	
	n	%
Recognition of adult tapeworm		
Yes	34	24.5
No	105	75.5
Passing tapeworm segments currently		
Yes	6	4.3
No	133	95.7
Passing tapeworm segments by other family member(s)		
Yes	9	6.5
No	130	93.5
History of passing tapeworm segments by family member(s)		
Yes	9	6.5
No	130	93.5

History of Neurocysticercosis and Its Related Signs and Symptoms

Table 4.5 depicts findings regarding the history of NC and its compatible neurological signs and symptoms. Two participants (1.4%) reported having been diagnosed with NC, but did not provide further information about how long they had the disease. One participant (0.7%) reported a history of NC in a family member.

Regarding signs and symptoms compatible with NC, 61.9% of participants (86/139) reported having no symptoms. Nobody reported suffering of epilepsy or seizures alone or combined with other symptoms; 20.1% and 6.5% reported suffering from intense headaches and dizziness, respectively; and 11.6% reported combined two or three these symptoms and signs. Additionally, nobody reported having a symptom of vertigo alone.

Table 4.5. History of neurocysticercosis and related neurological signs and symptoms

Items	*Results*	
	n	*%*
History of NC		
Yes	2	1.4
No	137	98.6
History of NC in household		
Yes	1	0.7
No	138	99.3
History of suffering NC symptoms		
Epilepsy or seizures alone or combined	0	0.0
Intense headaches only	28	20.1
Dizziness only	9	6.5
Intense headaches + vertigo	13	9.4
Intense headaches + vertigo + dizziness	3	2.2
None	86	61.9
History of suffering NC symptoms in other family member(s)		
Headaches (intense)	36	25.9
Epilepsy	2	1.4
Both	2	1.4
No any symptoms	99	71.2

Handwashing Practices

More than 99% (138/139) of participants reported washing their hands before eating and cooking, and 97.1% (135/139) reported doing so after using the latrine or toilet (Table 4.6). Handwashing practices were analyzed against the sources of water available for the household and the results are shown in Table 4.7. No statistical significance was found using Chi-square statistics at three specific conditions of performing handwashing practices, namely before eating [$\chi2$ (2, N = 139) = 1.11, p = .573], after toilet or latrine [$\chi2$ (2, N = 139) = 1.16, p = .560], and before cooking [$\chi2$ (2, N = 111) = 1.10, p = .576]. However, as depicted in Table 4.7, more participants that had access to tap water within households reported not washing their hands.

Table 4.6. Handwashing practices of participants (n=139)

Items	*Results*	
	n	*%*
Handwashing before eating		
No	1	0.7
Yes	138	99.3
Handwashing after toilet or latrine		
No	4	2.9
Yes	135	97.1
Handwashing before cooking (n=111)		
No	1	0.9
Yes	110	~~99.1~~ 79.1%

Table 4.7. Relationship between handwashing practices and water source in the households

Handwashing practices	*Source of water*: *Indoor tap water* *n*	*%*	*Outdoor well water* *n*	*%*	*Neither* *n*	*%*
Before eating						
Washing hands (n=138)	68	49.3	65	47.1	5	3.6
Not washing hands (n=1)	0	0.0	1	100.0	0	0.0
After toilet or latrine						
Washing hands (n=135)	65	48.1	65	48.1	5	3.7
Not washing hands (n=4)	3	75.0	1	25.0	0	0.0
Before cooking						
Washing hands (n=110)	52	47.3	54	49.1	4	3.6
Not washing hands (n=1)	1	100.0	0	0.0	0	0.0

Pork-consumption Practices

Of the 120 subjects who reported eating pork meat, 31.7% (38/139) did so frequently (i.e., at least once a week). Ten percent (12/120) of subjects ate their self-raised pigs, but the majority (67.5 %, 81/120) reported buying pork meat from somebody in their community. Only 2.5% (3/120) of participants obtained pork meat from other sources. A great proportion (97.5%) of subjects was in favour of eating fresh pork meat. Furthermore, 89.2% preferred to consume well-cooked pork meat, and only 6.7% and 4.2% ate undercooked or uncooked pork (Table 4.8).

Table 4.8. Pork-consumption practices of participants (n=120)

Items	*Results*	
	n	%
Frequency of consuming pork meat		
Once a week or more	38	31.7
Every two weeks	24	20.0
Once a month	36	30.0
Once in a while	13	10.8
Other	9	7.5
Types of pork meat		
Fresh	117	97.5
Frozen	3	2.5
Source of pork meat		
From self-raised pigs	12	10.0
From neighbours' pigs	16	13.3
From somebody else in their community	81	67.5
From another village or town	8	6.7
Other	3	2.5
Degrees of pork preferred to be cooked		
Well cooked	107	89.2
Undercooked	5	4.2
Uncooked	8	6.7

PARTICIPANTS' KNOWLEDGE ASSOCIATED WITH *TAENIA SOLIUM*

Every participant completed a knowledge questionnaire containing ten questions that assessed knowledge on *T. solium* transmission and life cycle, clinical presentation of the infections, and the importance of *T. solium* infections. Every subject was scored for the number of correct answers and assigned a result. Since there is no published literature about knowledge scoring for *T. solium*, in the present study a score of 6 or more correct answers was considered a "pass" score (i.e., having a majority of correct responses); a score of 5 or less correct answers was considered a "fail" score. About 3% (4/139) participants had a pass score; whereas the vast majority (97.1%, 135/139) had a fail score. The mean number of correct responses was 2.6 per participant.

For further analyses, the 10 questions were organized by their contents into two subgroups. Subgroup 1 contained two categories, namely epidemiological and clinical questions. Questions 1- 5 were considered "epidemiology" questions because they measured knowledge on *T. solium* life cycle and its epidemiological importance. Questions 6 - 10 were considered "clinic" questions because they measured knowledge on clinical presentations and importance of *T. solium* infections. Subgroup 2 categorized questions by their contents regarding either taeniasis or NC questions. Questions 1, 5, 6, and 9 were regarded as taeniasis questions; whereas, Questions 2, 7, 8, and 10 were regarded as NC questions.

As seen in Table 4.9, for subgroup 1, the rates of correct responses on epidemiological questions ranged from 5% to 54%, whereas for the clinical questions, the range was 12.2% - 61.2%. Individual questions had different rates of correct responses, with Question 9 about treatment of taeniasis being the highest (61.2%) and Question 2 about acquisition of NC being the lowest (5%).

For subgroup 2, the correct responses regarding taeniasis questions varied widely from 15.1% to 61.2%; and the questions about NC had a much lower correct response rates from 5% to 20.1%. Knowledge on how pigs acquire CC (Question 3) was understood by 54% of the subjects. However, people did not really know what other animals can or cannot have the same cysticercosis (Question 4, 26.6%) as pigs do.

Table 4.9. Overall subjects' knowledge evaluated in the knowledge questionnaire* (n=139)

Question and correct answer	*Correct response*	*%*
Epidemiology questions (Question 1 – 5)		
1: How is the intestinal tapeworm acquired? b) eating undercooked pork meat with cysticercosis	43	30.9
2: How is brain cysticercosis acquired? a) eating raw vegetables contaminated with tapeworm eggs	7	5.0
3: How do pigs acquire cysticercosis? d) the pig ate human feces from someone with tapeworm	75	54.0
4: What other animals can have the same cysticercosis as pigs do? f) none of them	37	26.6
5: Epidemiological importance of a person with taeniasis c) because people with the tapeworm segments are the source for other people and pigs to acquire cysticercosis	31	22.3
Clinical questions (Question 6 – 10)		
6: What is the clinical importance of taeniasis? c) tapeworms cause diarrhea and steal your food in your intestine	21	15.1
7: What is the clinical importance of neurocysticercosis? b) seizures or epilepsy	19	13.7
8: Which choice does not cause seizures or epilepsy? a) intestinal worms	17	12.2
9: Which method is for treating a person infected with tapeworm? c) with special antiparasitic treatment	85	61.2
10: Is there cure for neurocysticercosis patients? b) Yes, there is treatment but it is only effective when the disease is starting	28	20.1

Note. * Refers to Appendix D. Local and understandable terms were used during interviews.

To determine if different individual characteristics were associated with correct responses, the results were analyzed by age, gender, and formal education level. These analyses are shown in Table 4.10 and 4.11 by gender, Table 4.12 and 4.13 by age, and Table 4.14 and 4.15 by formal education level.

Table 4.10 shows the correct responses to knowledge questionnaire broken down by question number and gender. Out of 139, 85 participants knew the correct response to No. 9 question (i.e., what is the treatment of taeniasis?) and 75 knew the correct response to No. 3 question (i.e., how pigs acquire CC?). Conversely, very few participants (7/139) knew the correct answer to No. 2 question (i.e., how humans acquire NC?) analyzed by gender, it was observed that females had a greater tendency to provide correct responses to most questions; however, no significant difference was not identified.

Table 4.10. Description of correct responses in different gender groups by questions (n=139)

Question Number	*Number of participants providing a correct response to the question*	*Gender*			
		Female (n=99)		*Male (n=40)*	
		Number of females providing a correct response to the question	*% (n/99)**	*Number of males providing a correct response to the question*	*% (n/40)**
1	43	32	32.3	11	27.5
2	7	5	5.1	2	5.0
3	75	54	54.5	21	52.5
4	37	31	31.3	6	15.0
5	31	20	20.2	11	27.5
6	21	16	16.2	5	12.5
7	10	8	8.1	2	5.0
8	17	12	12.1	5	12.5
9	85	62	62.6	23	57.5
10	28	23	23.2	5	12.5

Note. * Percentage of correct responses within that gender

Table 4.11 shows the mean of both genders on subgroup 1 and 2. Regardless of different genders, a comparison demonstrated the slightly greater mean on epidemiological questions (M = 1.26, SD = .90) than on clinical questions (M = 1.21, SD = 1.00) and far greater mean on taeniasis questions (M = 1.29, SD = .97) than on NC questions (M = .51, SD = .67). Meanwhile, a comparison between females and males showed that the mean for both subgroups of questions was greater for females than for males. Statistical analysis conducted by Independent-Samples T test, did not however, reveal any significant difference by gender in the number of correct responses in the following: total number of correct responses [$t(137) = 1.25, p > .05$]; the number of correct responses on epidemiological questions [$t(137) = 1.11, p > .05$], clinical questions [$t(137) = 1.20, p > .05$], as well as taeniasis questions [$t(137) = .35, p > .05$], and NC questions [$t(137) = .95, p > .05$].

Table 4.11. Comparison of mean number of correct responses by gender

Gender	*Correct responses*							
	Subgroup 1				*Subgroup 2*			
	Epidemiology (Q. 1 - 5)		*Clinic (Q. 6 - 10)*		*Taeniasis (Q. 1, 5, 6, 9)*		*Neurocysticercosis (Q. 2, 7, 8, 10)*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Overall (n=139)	1.26	.90	1.21	1.00	1.29	.97	.51	.67
Female (n=99)	1.31	.91	1.27	1.02	1.31	.96	.55	.67
Male (n=40)	1.13	.88	1.05	.93	1.25	1.01	.42	.68

In Table 4.12, it can be observed that in general participants in the 30-39 and 50-59 years of age groups provided more correct responses. It can also be found that for some age groups, some specific questions were particularly difficult, for instance: nobody in the age groups of 20-29 years and at least 60 years could correctly answer the No. 8 question on the causes of epilepsy and the No. 2 questions regarding the acquisition of human neurocysticercosis, respectively.

Table 4.13 shows the mean across all age groups on subgroup 1 and 2. As demonstrated in Table 4.13, regardless of different age groups, the overall mean for epidemiological questions was slightly greater than for clinical questions, and the mean for taeniasis questions was far greater than for NC questions. Meanwhile, a comparison among different age groups showed that with an exception of 30-39 and 40-49 age groups, the means for epidemiological questions were greater for clinical questions. In addition, among all age groups, the means was greater for taeniasis questions than for NC questions, which are depicted in Table 4.13. Statistical analyses conducted by One-Way ANOVA, identified significant differences in the total number of correct responses among age groups [F (5, 139) = 2.44, $p < .05$] and in the number of correct responses on taeniasis questions [F (5, 139) = 2.19, $p < .05$]. However, ANOVA did not find the significant differences in the number of correct responses on epidemiological questions [F (5, 139) = 2.05, $p > .05$], clinical questions [F (5, 139) = 1.10, $p > .05$], and NC questions [F (5, 139) = 1.23, $p > .05$].

Table 4.12. Description of correct responses in different age groups by questions

Question #	*Number of participants providing a correct response to the question*	*Age (years)*											
		10-19 (n=38)		*20-29 (n=29)*		*30-39 (n=26)*		*40-49 (n=20)*		*50-59 (n=15)*		*≥ 60 (n=11)*	
		n[@]	*%*[(1)] *(n/38)*	*n*[@]	*%*[(2)] *(n/29)*	*n*[@]	*%*[(3)] *(n/26)*	*n*[@]	*%*[(4)] *(n/20)*	*n*[@]	*%*[(5)] *(n/15)*	*n*[@]	*%*[(6)] *(n/11)*
1	43	8	21.1	7	24.1	12	46.2	7	35.0	8	53.3	1	9.1
2	7	1	2.6	1	3.4	2	7.7	2	10.0	1	6.7	0	0.0
3	75	13	34.2	16	55.2	19	73.1	12	60.0	10	66.7	5	45.5
4	37	13	34.2	11	37.9	7	26.9	2	10.0	2	13.3	2	18.2
5	31	6	15.8	6	20.7	5	19.2	5	25.0	7	46.7	2	18.2
6	21	4	10.5	5	17.2	4	15.4	4	20.0	1	6.7	3	27.3
7	19	3	7.9	3	10.3	7	26.9	3	15.0	2	13.3	1	9.1
8	17	7	18.4	0	0.0	3	11.5	5	25.0	1	6.7	1	9.1
9	85	20	52.6	17	58.6	18	69.2	13	65.0	12	80.0	5	45.5
10	28	6	15.8	6	20.7	8	30.8	1	5.0	4	26.7	3	27.3

Note. [@] number of individual age groups providing a correct response to the question; [(1)] percentage of correct responses within the 10-19 age group; [(2)] percentage of correct responses within the 20-29 age group; [(3)] percentage of correct responses within the 30-39 age group; [(4)] percentage of correct responses within the 40-49 age group; [(5)] percentage of correct responses within the 50-59 age group; and [(6)] percentage of correct responses within the ≥ 60 years of age group

Table 4.13. Comparison of mean number of correct responses by age

Age	*Correct responses*							
	Subgroup 1				*Subgroup 2*			
	Epidemiology		*Clinic*		*Taeniasis*		*Neurocysticercosis*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Overall (n=139)	1.26	.90	1.21	1.00	1.29	.97	.51	.67
10-19 (n=38)	1.03	.92	1.00	.99	1.00	.90	.45	.69
20-29 (n=29)	1.31	.76	1.07	.75	1.21	.86	.34	.48
30-39 (n=26)	1.54	.91	1.54	1.17	1.50	.95	.77	.91
40-49 (n=20)	1.25	.97	1.30	.92	1.45	1.15	.55	.51
50-59 (n=15)	1.60	.99	1.33	.98	1.87	.83	.53	.64
≥ 60 (n=11)	.82	.75	1.18	1.25	1.00	1.00	.45	.69

Table 4.14. Description of correct responses in different formal education groups by questions

Question number	*Number of participants providing a correct response to the question*	*Formal education level*					
		No schooling (n=24)		*Primary school (n=93)*		*High school + Other (n=22)*	
		# of people providing a correct response to the question	*% (n/24) **	*# of people providing a correct response to the question*	*% (n/93) **	*# of people providing a correct response to the question*	*% (n/22) **
1	43	5	20.8	31	33.3	7	31.8
2	7	1	4.2	4	4.3	2	9.1
3	75	11	45.8	49	52.7	15	68.2
4	37	6	25.0	23	24.7	8	36.4
5	31	8	33.3	16	17.2	7	31.8
6	21	3	12.5	15	16.1	3	13.6
7	19	3	12.5	10	10.8	6	27.3
8	17	2	8.3	14	15.1	1	4.5
9	85	11	45.8	56	60.2	18	81.8
10	28	5	20.8	14	15.1	9	40.9

Note. * Number of participants providing a correct response to the question

In Table 4.14, it can be observed that participants with any level of high school or above formal education provided more correct responses than people with lower levels of formal education. It also showed that the increase of the percentage of correct responses is paralleled with participants' formal education level.

Table 4.15 shows the mean across all formal education groups on subgroup 1 and 2 questions. Regardless of different formal education levels, a comparison demonstrated the slightly greater mean on epidemiological questions than on clinical questions and far greater mean on taeniasis questions than on NC questions. Meanwhile, a comparison among different formal education groups demonstrates that with an exception of high school or above education group, the means were greater on epidemiological questions than clinical questions in the other two education groups. Additionally, among all three formal education groups, the means were higher on taeniasis questions than on NC questions, which are depicted in Table 4.15. Statistical analyses conducted also by One-Way ANOVA, identified significant differences in the total number of correct responses [F (2, 139) = 4.07, $p < .05$] and in the number of correct responses on clinical questions [F (2, 139) = 3.27, $p < .05$]. However, ANOVA did not find the significant differences in the number of correct responses on epidemiological questions [F (2, 139) = 1.84, $p > .05$], taeniasis questions [F (2, 139) = 1.45, $p > .05$] and NC questions [F (2,139) = 2.79, $p > .05$].

Table 4.15. Comparison of mean number of correct responses by formal education

Formal education level	*Correct responses*							
	Subgroup 1				*Subgroup 2*			
	Epidemiology		*Clinic*		*Taeniasis*		*Neurocysticercosis*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Overall (n=139)	1.26	.90	1.21	1.00	1.29	.97	.51	.67
No schooling (n=24)	1.25	1.03	1.00	1.10	1.13	1.08	.46	.66
Primary school (n=93)	1.18	.87	1.15	.94	1.27	.92	.45	.62
≥ High school (n=22)	1.59	.85	1.68	1.00	1.59	1.01	.82	.85

PREVALENCE OF MAJOR INTESTINAL HELMINTHS

In total, 123 persons provided fecal samples that were tested for *Taenia* sp. and other intestinal helminths by Kato-Katz concentration technique. The prevalence rate of *Taenia* sp. was 2.4%. Besides *Taenia* sp., fecal samples were examined for another two helminths (i.e., *Ascaris lumbricoides* and *Trichuris trichiura*), which are two common and important human parasites. The infectious eggs of these 2 human parasites are also found in soil; therefore; they are important indicators of environmental contamination. The prevalence rates of these two parasites were 39.8% (49/123) for *Ascaris lumbricoides* and 43.9% (54/123) for *Trichuris trichiura.*

Specific information about the three persons diagnosed with *Taenia* sp. is summarized in Table 4.16. All 3 persons were females and completed primary school. As well, all reported drinking untreated water and two reported eating undercooked pork meat.

Table 4.16. Summary of three tapeworm carriers detected by Kato-Katz examination

	Subject 1	*Subject 2*	*Subject 3*
Gender	female	female	female
Age	31	35	19
Formal education level – Complete primary school	yes	yes	yes
Feces disposal system in household	none	none	toilet
Treatment of drinking water in household	chlorine	none	chlorine
Recognition of tapeworm	yes	yes	no
Reported passing tapeworm segments	yes	yes	no
Reported passing tapeworm by family member	yes	yes	no
Reported having a history of NC in family members	yes	no	no
Reported having neurological symptoms in family members	headache	epilepsy	none
Reported eating undercooked pork meat	yes	no	yes
Serology results by EITB	positive	positive	negative

SEROPREVALENCE OF ANTI-*TAENIA SOLIUM* ANTIBODIES

All 139 participants provided blood samples and were tested for anti-*T. solium* antibodies by EITB. The results revealed that 26 serum samples had specific antibodies to *T. solium*, accounting for a seroprevalence rate of 18.7%.

Demographic characteristics (i.e., gender and age) and seropositive status of participants are summarized in Table 4.17. Seropositive participants had a wide range of age distribution from 10 to 72, with a large proportion falling in the category of 10-49 years of age. Individual characteristics are shown in Table 4.17, of the 26 seropositive participants, 76.9% (20/26) were females, accounting for 20.2% (20/99) of all female participants in this study. However, no statistical difference was found between seropositivity and gender (OR = 1.43, CI = 0.51-4.40, $p > .05$). Moreover, 84.6% (22/26) of seropositive subjects were younger than 50 years of age, especially in with 50% (13/26) falling between the ages of 30- 49. Furthermore, a significant difference (OR = 2.42, CI = 0.94-6.32, $p < .05$) between those aged 30-49 and the remaining age groups was found. Under the age of 50, the number of EITB positive subjects increased with the age, but the tendency in the population older than 50 was not obvious. Other characteristics of seropositive subjects are summarized in Table 4.18.

Table 4.17. EITB results of subjects by gender and age (n=139)

Items		*Number (%) of subjects*	
		Seropositive subjects (n=26)	*Seronegative subjects* (n=113)
Gender			
Female	(n=99)	20 (20.2%)	79 (79.8%)
Male	(n=40)	6 (15.0%)	34 (85.0%)
Age (year)			
10-19	(n=38)	5 (13.2%)	33 (86.8%)
20-29	(n=29)	4 (13.8%)	25 (86.2%)
30-39	(n=26)	7 (26.9%)	19 (73.1%)
40-49	(n=20)	6 (30.0%)	14 (70.0%)
50-59	(n=15)	2 (13.3%)	13 (86.7%)
≥ 60	(n=11)	2 (18.2%)	9 (81.8%)

Table 4.18. Summary of 26 seropositive participants by EITB technique

Items	*Results*	
	n	%
Formal education		
No schooling	5	19.2
Primary school (any level)	15	57.7
High school (any level)	5	19.2
Other	1	3.9
Type of feces disposal system		
Toilet	8	30.8
Latrine	10	38.4
None	8	30.8
Access to water		
Indoor tap	11	42.3
Well	13	50.0
Neither	2	7.7
Treatment of drinking water		
Directly drinking without treatment	13	50.0
Chlorinated	9	34.6
Boiled	4	15.4
Suggestive NC compatible symptoms		
Intense headaches only	6	23.1
Dizziness only	2	7.7
Intense headaches + vertigo	3	11.5
None	15	57.7
Passing proglottids currently		
Yes	2	7.7
No	24	92.3
Kato-Katz examination results		
Positive	2	7.7
Negative	23	88.5
Not provide fecal sample	1	3.8
Knowledge score		
Pass	1	3.8
Fail	25	96.2

Though, these characteristics are not identified to be significantly associated with serological results, they are still theoretically important characteristics associated with *T. solium* transmission. These characteristics include that 19.2% of participants reported not having any schooling; 30.8% reported not having latrine or toilet in their households; 7.7% reported no access to water and 50% reported drinking untreated water; 42.3% reported having some suggestive neurological symptoms (i.e., intense headaches, dizziness, and vertigo). Additionally, two participants (7.7%) reported passing tapeworm segments currently and were also identified positive by Kato-Katz technique, which will be discussed in the next chapter. Besides, results from the knowledge questionnaire show that only 3.8% (1/26) of seropositive participants received a pass score.

RISK FACTORS ASSOCIATED WITH SEROPOSITIVITY OF EITB TECHNIQUE

EITB seropositivity is an indicator of exposure and therefore active *T. solium* transmission. Thus, for statistical analysis, the EITB result was considered the dependant variable and individual risk factors as independent variables. Bivariate statistical analyses (chi-square statistic) were conducted and odds ratios with 95% confidence interval were calculated for potential individual risk factors and seropositivity.

Forty-two potential risk factors were analyzed by several bivariate statistical analyses, and six of them were found to be statistically significant, which are age (people at 30-49 years old); lack of handwashing before eating, the ability to recognize tapeworms, the presence of tapeworm carrier(s) in household, the presence of a NC patient in household, and knowledge regarding clinical importance of taeniasis. The bivariate statistical results are grouped by content area and shown in eight tables (Table

4.19 - 4.26) for further multivariate analyses.

To identify important personal demographic factors, three independent variables, namely gender, age, and formal education, were included in this subset as indicated in Table 4.19. Age (people at 30-49 years old) was found to be a statistically significant risk factor associated with seropositivity [x^2 (1, N = 139) = 4.13, p = .04, OR = 2.42, 95% CI = 0.94-6.31].

Table 4.19. Bivariate analysis of potential risk factors on demographic characteristics

Independent variables	*df*	x^2	*OR*	*95% CI*	*p*
Gender					
Female : male	1	0.51	1.43	0.51-4.40	0.48
Age					
10-19 : 20-29 : 30-39 : 40-49 : 50-59 : ≥60	5	4.35	---	---	0.50
30-49 : other ◄	1	4.13	2.42	0.94-6.32	0.04
30-39 + 50-59 : other age groups	1	0.40	1.34	0.49-3.60	0.53
50-59 : other age groups	1	0.32	0.64	0.09-3.31	0.57
Formal education					
None : primary-level : high-level : other	3	5.18	---	---	0.16
Low (none+primary) : High (high+other)	1	1.26	0.55	0.17-1.80	0.26
None : primary + high + other	1	0.09	1.18	0.34-3.87	0.77

Note. ◄ Statistically significant independent variable

To reveal significant risk factors regarding household environment, eight potential factors were analyzed by bivariate analyses as shown in Table 4.20. These variables are number of family members, number of bedrooms, duration for living in Jalaca, type of floor, feces disposal facilities, disposal method for sanitary paper, access to water, and treatment method for drinking water. However, none of them were identified as a significant risk factor.

Table 4.20. Bivariate analyses of potential risk factors regarding household environment

Independent variables	*df*	x^2	*OR*	*95% CI*	*p*
Number of family members					
>5 members : ≤5 members	1	0.78	1.47	0.58-3.76	0.38
>8 members : ≤8 members	1	1.37	0.41	0.06-2.04	0.24
Number of bedrooms					
1 : 2 : 3 : 4	3	0.16	---	---	0.98
1 bedroom : > 1 bedrooms	1	0.13	1.18	0.44-3.15	0.72
>2 bedrooms : ≤2 bedrooms	1	0.01	0.95	0.34-2.59	0.91
4 bedrooms : < 4 bedrooms	1	0.04	0.86	0-4.62	0.85
Duration for living in Jalaca					
Always : <1 year : ≥1 years	2	3.26	---	---	0.20
Always : immigrated (<1year + ≥1 years)	1	3.16	3.03	0.79-13.65	0.08
Always + ≥1 years : <1 year	1	0.47	?	?	0.49
Type of floor					
Earthen : cement : tiles : mixed	3	1.05	---	---	0.79
Earthen : cement + tiles + mixed	1	0.90	0.54	0.12-2.14	0.34
Earthen + mixed : cement + tiles	1	0.00	0.98	0.38-2.58	0.97
Dispose of sanitary paper					
Latrine or toilet : burns : dump	2	0.72	---	---	0.70
Dump : latrine or toilet + burns	1	0.34	1.51	0.30-6.80	0.56
Latrine or toilet : burns + dump	1	0.46	0.59	0.09-3.01	0.50
Feces disposal system					
Toilet : latrine : none	2	0.61	---	---	0.74
None : toilet + latrine	1	0.53	1.42	0.50-3.95	0.47
Access of water					
Tap : well : neither	2	1.82	---	---	0.40
Tap : well + neither	1	0.56	0.72	0.28-1.84	0.45
Neither : tap + well	1	1.55	3.06	0.33-24.33	0.21
Treatment of drinking water					
Directly drink : chlorinated : boiled	2	0.57	---	---	0.75
Directly drink : chlorinated + boiled	1	0.00	1.02	0.40-2.59	0.97
Boiled : directly drink + chlorinated	1	0.47	1.53	0.37-5.82	0.49

Note. ? Undefined

To recognize significant risk factors regarding domestic pig husbandry, four variables were analyzed by bivariate statistics, namely whether or not raising pigs, number of pigs raised in household, where pigs were kept, and a history of porcine CC. No significant risk factors were revealed from this subset as shown in Table 4.21.

Table 4.21. Bivariate analyses of potential risk factors regarding pig husbandry

Independent variables	*df*	x^2	*OR*	*95% CI*	*p*
Pig-raising					
Yes : no	1	0.60	1.43	0.53-3.96	0.44
Number of pigs raised					
1 : 2 : 3 : 4 : 6 : >6	5	4.63	---	---	0.46
≥5 : <5	1	0.05	0.83	0.11-4.84	0.83
>2 : ≤2	1	0.45	0.69	0.20-2.29	0.50
Where pigs were kept					
House : town : backyard : pig-pen : tied	4	3.53	---	---	0.47
Free-roaming : not free-roaming |	1	0.07	1.16	0.35-4.01	0.79
History of porcine CC					
Yes : no	1	1.99	0	0-3.03	0.16

Note. | free-roaming = houses/ backyards or village; not free-roaming = pig-pen or tied

To identify the association between person hygiene and serological results, three variables regarding handwashing practices at specific conditions were under bivariate analyses as indicated in Table 4.22. These three variables are washing hands before eating, after toilet or latrine, and before cooking. Lack of handwashing before eating was found to be a significant risk factors from this subset [x^2 (1, N = 139) = 4.38, p = .04].

Table 4.22. Bivariate analyses of potential risk factors regarding personal hygiene

Independent variables	*df*	x^2	*OR*	*95% CI*	*p*
Handwashing before eating					
Not washing hands : washing hands ◀	1	4.38	?	?	0.04
Handwashing after the toilet or latrine					
Not washing hands : washing hands	1	0.11	1.47	0.03-19.10	0.74
Handwashing before cooking					
Not wash hands: wash hands	1	0.24	0	0-77.38	0.63

Note. ◀ Statistically significant independent variable

Bivariate analyses were conducted to identify significant risk factors in the subset regarding taeniasis, which includes four variables (i.e., the ability to recognize tapeworm, passing tapeworm segments by participants, passing tapeworm segments by a family member, and the history of taeniasis in a family member). Two significant variables, that is, the ability to recognize tapeworm [x^2 (1, N = 139) = 8.15, p = .004, OR = 3.55, 95% CI = 1.32-9.59] and passing tapeworm segments by a family member [x^2 (1, N = 139) = 8.59, p = .003, OR = 6.49, 95% CI = 1.36-32.08], were significantly associated with seropositivity through bivariate analyses as shown in Table 4.23.

To identify risk factors from NC presentation subset, four variables were analysed by bivariate statistics (Table 4.24). These variables include participants' history of NC, family members' history of NC, participants' NC-related symptoms, and family members' NC-related symptoms, of which the family members' history of NC was revealed to be a significant risk factor in this subset [x^2 (1, N = 139) = 4.38, p = .04].

Table 4.23. Bivariate analyses of potential risk factors regarding taeniasis

Independent variables	*df*	x^2	*OR*	*95% CI*	*p*
Recognition of tapeworm					
Yes : no ◄	1	8.15	3.55	1.32-9.59	0.004
Passing tapeworm by participant					
Yes : no	1	0.88	2.27	0.27-15.73	0.35
Passing tapeworm by a family member					
Yes : no ◄	1	8.59	6.49	1.36-32.08	0.003
History of taeniasis in a family member					
Yes : no	1	1.35	2.33	0.42-11.64	0.24

Note. ◄ Statistically significant independent variable

Table 4.24. Bivariate analyses of potential risk factors on NC and its related symptoms

Independent variables	*df*	x^2	*OR*	*95% CI*	*p*
History of NC in a participant					
Yes : no	1	1.31	4.48	0.0-170.88	0.25
History of NC in a family member					
Yes : no ◄	1	4.38	?	?	0.04
NC-related symptoms in a participant					
Headaches : dizziness : headaches+vertigo : headaches+vertigo+dizziness : none	4	1.15	---	---	0.96
None : any symptoms	1	0.24	0.81	0.31-2.09	0.63
Headaches (alone or combined) : other groups	1	0.13	1.18	0.44-3.15	0.72
NC-related symptoms in a family member					
Epilepsy : headaches : both : none	3	2.19	---	---	0.53
Epilepsy alone : other groups	1	1.31	4.48	0-170.88	0.25
Epilepsy (alone or combined) : other groups	1	0.11	1.47	0.03-19.10	0.74
Headaches (alone or combined) : other groups	1	0.19	1.23	0.44-3.40	0.66
None : epilepsy + headaches + both	1	0.53	0.71	0.26-1.95	0.46

Note. ◄ Statistically significant independent variable; ? Undefined

In the subset about pork consumption practices, there are five potential risk factors analyzed by bivariate statistics. These five variables are whether or not consuming pork meat, frequency of consuming pork meat, source of pork meat, type of pork meat for consumption, and cooking preference of pork meat; however, none of them was identified to be significantly associated with seropositivity, and the statistical results are shown in Table 4.25.

Table 4.25. Bivariate analyses of potential risk factors on pork-consumption practices

Independent variables	***df***	x^2	***OR***	***95% CI***	***p value***
Consumption of pork meat					
Yes : no	1	0.08	0.84	0.23-3.34	0.78
Frequency of pork-consumption					
≥ 1/wk : 1/2wks : 1/m : <1/m : other	4	8.57	---	---	0.07
≥ 1/wk : other groups	1	0.99	0.58	0.17-1.87	0.32
≥ 1/wk + 1/2wks : 1/m + <1/m + other	1	0.09	1.15	0.42-3.21	0.76
<1/m : ≥ other groups	1	3.95	3.31	0.82-13.12	0.05
Source of pork meat					
Self-owned : neighbour's : town's : other town's : other sources	4	1.68	---	---	0.79
Self-owned : other groups	1	0.40	1.56	0.30-7.21	0.53
Self-owned + neighbour's + town's : other town's + other sources	1	0.77	2.50	0.30-54.92	0.38
Type of pork meat					
Fresh : frozen	1	0.69	?	?	0.41
Cooking preference of pork meat					
Well-cooked : medium : raw	2	2.14	---	---	0.34
Raw : well-cooked + medium	1	2.10	2.94	0.50-15.96	0.15
Raw + medium : well-cooked	1	1.51	2.20	0.50-9.08	0.22

Note. ? Undefined

Table 4.26. Bivariate analyses of potential risk factors on subjects' knowledge

Independent variables	*df*	x^2	*OR*	*95% CI*	*p*
Number of correct answers					
Pass (≥ 6) : fail (< 6)	1	0.43	2.22	0.0-33.18	0.51
0 : 1 : 2 : 3 : 4 : 5 : 6 : ≥7	7	5.48	---	---	0.60
0 : >0 (1 + 2 + 3 + 4 + 5 + 6 + ≥ 7)	1	0.10	0.77	0.11-4.09	0.75
Question 1: Acquisition of taeniasis					
Correct answer : all wrong answers	1	0.0	0.99	0.36-2.71	0.98
Question 2: Acquisition of NC					
Correct answer : all wrong answers	1	0.09	0.71	0.03-6.49	0.76
Question 3: Acquisition of porcine CC					
Correct answer : all wrong answers	1	3.00	2.21	0.82-6.08	0.08
Question 4: CC of other animals					
Correct answer : all wrong answers	1	0.89	0.60	0.18-1.89	0.34
Question 5: Epidemiological importance of taeniasis					
Correct answer : all wrong answers	1	0.17	0.80	0.24-2.54	0.68
Question 6: Clinical importance of taeniasis					
Correct answer : all wrong answers ◀	1	6.12	3.42	1.11-10.52	0.01
Question 7: Clinical importance of NC					
Correct answer : all wrong answers	1	0.08	1.19	0.30-4.36	0.78
Question 8: Causes of epilepsy					
Correct answer : all wrong answers	1	0.30	1.40	0.35-5.25	0.59
Question 9: Treatment of taeniasis					
Correct answer : all wrong answers	1	1.91	1.93	0.69-5.55	0.17
Question 10: Treatment of NC					
Correct answer : all wrong answers	1	0.91	1.61	0.53-4.76	0.34

Note. ◀ Statistically significant independent variable

To identify the association between subjects' relevant knowledge on *T. solium* and seropositivity, eleven variables were analyzed using bivariate statistics, in which one variable is the number of correct answers, and the other ten variables are corresponding to the ten knowledge questions individually as demonstrated in Table 4.26. Only one variable (i.e., the knowledge regarding clinical importance of taeniasis) was revealed to be significantly associated with seropositivity [x^2 (1, N = 139) = 6.12, p = .01, OR = 3.42, 95% CI = 1.11-10.52].

Although only six variables were statistically significant in the bivariate analysis, some independent variables that did not show statistical significance, but are relevant to the life cycle and transmission of the parasite were also selected to perform logistic regression model. The statistically significant factors by bivariate analysis and some theoretically important potential risk factors were categorized by content areas and analysed in eight individual logistic regression models. The process of running logistic regression models is shown in Table 4.27.

In total, three independent variables were identified as significant from the eight logistic regression models (Table 4.28) and the previous bivariate statistical analysis. Included are being 30-49 years of age [x^2 (1, N = 139) = 4.81, p = .028, OR = 2.73, 95% CI = 1.11-6.70]; the ability to recognize adult tapeworm [x^2 (1, N = 139) = 4.49, p = .034, OR = 2.90, 95% CI = 1.08-7.77]; and the presence of knowledge on the clinical importance of taeniasis [x^2 (1, N = 139) = 5.40, p = .02, OR = 3.41, 95% CI = 1.21-9.58]. None of the relevant risk factors, which were not significant in the bivariate analysis, were found significant in the multivariate analysis.

Table 4.27. Procedure of performing logistic regression models

Procedure	***Independent variables in the equation of logistic regression***
Personal variables	Age* Gender Formal education level
Household variables	Feces disposal system Discard of sanitary paper Treatment of drinking water
Pig-farming variables	Number of pigs in household Place to keep pigs History of porcine cysticercosis
Hygienic habit variables	Handwashing before eating* Handwashing after toilet or latrine Handwashing before cooking
Tapeworm carrier variables	The ability to Recognize tapeworm* Passing tapeworm segments (family members)* History of passing tapeworm segments (family members)
NC presentation variables	History of NC (participant) History of NC (family members)* Past NC symptoms (participant)
Pork consumption variables	Frequency of pork-consumption Ways to cook pork meat
Knowledge variables	Knowledge relevant to *T. solium* Knowledge on clinical importance of taeniasis*

Note. * Statistically significant variables in bivariate analysis

Table 4.28. Significant variables in the individuals and final logistic regression models

Independent variable	*B*	*S.E.*	x^2	*df*	*p*	*O.R.*	*95% C.I. for O.R.*	
							Lower	*Upper*
Individual logistic regression								
Age								
30-49 : other ages	1.00	0.46	4.81	1	0.03	2.73	1.113	6.699
Recognition of tapeworm recognize : cannot	1.07	0.50	4.49	1	0.03	2.90	1.083	7.768
Knowledge on clinical importance of taeniasis correct : wrong	1.23	0.53	5.40	1	0.02	3.41	1.211	9.579
Final logistic regression								
Recognition of tapeworm recognize : cannot	1.28	0.50	6.64	1	0.01	3.61	1.360	9.596
Knowledge on clinical importance of taeniasis correct : wrong	1.42	0.56	6.56	1	0.01	4.14	1.396	12.287

To conduct the final logistic regression model, the three significant risk factors were included simultaneously. The final results (Table 4.28) show that only two of them were statistically significant risk factors for *T. solium* transmission in Jalaca, which are the ability to recognize adult tapeworm [x^2 (1, N = 139) = 6.64, p = .01, OR = 3.61, 95% CI = 1.36-9.60] and presence of knowledge on clinical importance of taeniasis [x^2 (1, N = 139) = 6.56, p = .01, OR = 4.14, 95% CI = 1.40-12.29].

CHAPTER FIVE: DISCUSSION

DEMOGRAPHY AND EPIDEMIOLOGY OF THE STUDY

General Characteristics of Subjects

Response Rate

The household-level response rate was 93.3% (56/60), similar to a response rate of 96% reported from an urban community of Honduras.[30] From those 56 households, 139 participants responded to both questionnaires and provided blood samples. Of the139 participants, 16 did not provide fecal samples, which may be because fecal samples had to be brought back to the local public health centre the day after the interview; as well due to embarrassment or collecting difficulties technically or physically.

Demographic Characteristics

The population in this study had a mean age of 33 years. According to the Honduras population pyramid, more than 73% of population is less than 30 years of age,[193] which indicates that the mean age of the whole country should be lower than the mean age revealed in this study. Two reasons could explain this finding. One is because the age for sample selection was set as at least 10 years old, which increased the mean age to a certain extent. The other is that most children were in school when this study was performed (daytime). Additionally, the mean age was slightly older than similar studies from other Latin American countries, in which the mean ages ranged from 20 to 27.[17,42,43,49,76,158]

More than 71% of studied participants were females, which is not consistent with the natural gender distribution (49.9% of females and 51.1% of males) in

Honduras.[193] The most probable explanation for this gender imbalance is that the study was performed during the daytime when adult males were working in the fields or outside of the village, which is a common phenomenon in rural communities due to the traditional division of labour.[196,197] In addition, being the main caregivers of the family, women are involved in food preparation, feeding all family members, being on charge of family health, raising livestock and poultry, etc. and may make women more motived to participate in activities that bring benefits to the family.[42,198]

As described in Table 4.1, the majority of subjects were native-born Jalaca residents and could be a representative of Jalaca population. Except for 2 participants, all were permanent residents or relocated to Jalaca more than 1 year ago. Local residents in Jalaca had higher formal education levels when compared to other studies. The adult formal education rate in people aged 15 years or over in this community was 86% (101/117), which was higher than the nationwide rate of 75%.[199] Moreover, almost 16% of participants reported some levels of the high school education or above, which was greater than the reported 12% in a previous study in another Honduran rural community.[30] The higher education level could be explained by the existence of primary and junior high schools in the village, and the sample selection which involved, excluding all preschool and part of the primary school population. An increase in formal education level may indicate more knowledge, but as will be explained later, this was not the case in Jalaca.

General Characteristics of Households and Personal Practices

Household Overcrowding and Taenia solium Transmission

Among the participants in the study, on average there were a 5.4 persons living in 2 bedroom homes. In the 56 households studied, no family had more than 4 bedrooms. A prior study in a Honduran rural community conducted by Sanchez et al. (1997), defined overcrowding as more than eight family members in a household, and 14.3% (8/56) households met that criterion. Previous studies reported that overcrowding enhances domestic transmission should a tapeworm carrier lived in the household.[20,110] Interestingly, one individual in the most crowded household mentioned in the previous chapter (13 family members sharing only 1 bedroom) was identified as a tapeworm carrier by Kato-Katz; and a family member had a positive immunological result. In addition, overcrowding may be a marker for poor socioeconomic conditions and hygiene, so further investigation of overcrowded households is needed.

Environmental and Hygienic Conditions and Practices in Households

The type of floor present in households is an important environmental factor for parasite transmission and infection. Earthen floors pose the greatest opportunity for transmitting *T. solium* eggs to humans and pigs than other types of floor, mainly because it can be potentially contaminated with tapeworm carriers' feces and the floor is difficult to clean after contamination. Two previous studies carried out in 1997 and 1998 reported 73% of households had earthen floors,[20,51] compared to about 20% in the present study. This indicates that Jalaca had higher economic conditions than towns examined in other studies.

In Jalaca about 21% of households had no toilet or latrine, this is similar to the findings of a study carried out in another Honduran rural community that 22% had no toilets or latrines.[51] Several studies conducted in Mexico and Bolivia also reported a wide range (7.8% - 83%) in the percentage of households that reported not having toilets or latrines.[15,44,51,105,200] Lack of feces disposal facilities could be directly associated with both human and porcine cysticercosis, and indirectly related with human taeniasis. The transmission chain would happen, when household sanitary systems are absent or poorly maintained, and feces are easily accessible to pigs. Tapeworm carrier's feces would contaminate open places (such as backyard, grass field, etc.), which would increase the opportunity for disseminating and ingesting the infective eggs by pigs, and occasionally by humans. If infected pigs are slaughtered and meat is ingested undercooked, it would result in intestinal taeniasis.

Although 78.6% (44/56) households reported having either a latrine or toilet, only 7 households disposed sanitary paper in them. An explanation from the local residents was that sewage pipes were narrow and easy to be blocked by sanitary paper. Four households reported dumping sanitary paper to public places outside of their houses, which is a potential contamination source, as sanitary paper may contain the parasite's eggs in tapeworm carriers' feces. Many studies have revealed that most households in rural areas deal with sanitary paper by dumping, or in the best case, burning it in their backyards. This could result in environmental contamination and *T. solium* transmission and infection during the process. For instance, 97% of residents living in a Mexican rural village reported burning their sanitary paper and other waste; similarly, 97% of inhabitants in a Chinese community reported disposing fecal matter improperly.[19,98]

About 48% of studied households had no indoor tap water, so outdoor well water or other natural sources of water were used. Many studies also investigated the source of water as a potential risk factor for *T. solium*,[19,21,40,44,45,98,110] and among them, only one conducted in Mexico reported a comparable percentage with this study (i.e., about 52% households were using well or other natural sources of water).[110] Other studies reported a wide range of usage of piped water (6% - 98%).[19,21,40,44,45,98] These studies also revealed that outdoor well water and other natural sources carried an increased risk for transmission of the parasite when compared to indoor tap water. However, in these studies, there is no mention of the actual socioeconomic status (SES) of the household. It is well known that the lack of potable water in the household is a key indicator for low SES.[201] As well, it is also known that *T. solium* transmission is rooted in poverty.[202] Therefore, an accurate assessment of *T. solium* transmission and SES is still necessary.

Though source of water is an important transmission factor, water treatment practices in the household may be more directly linked to transmission, because properly treated water can eliminate parasites and other microorganisms contained in water regardless of the sources. The current study showed that 14.3% of subjects drank boiled safer water, this rate is similar to the 15% reported in a prior study from a rural village of Mexico.[45] Besides, other three studies conducted in Mexico also revealed a wide variation that 4.6% - 70% of subjects preferred to drink boiled water.[19,44,45,177]

Handwashing Practices

Since *T. solium* eggs may adhere to hands by accidentally touching tapeworm carrier's feces, handwashing practices after toilet or latrine usage or before eating and cooking can prevent the transmission and infection of *T. solium* to a certain extent. The majority of participants of this study (i.e., 99% before eating, 99% before cooking, and 97% after latrine or toilet) reported always washing their hands. These high rates of handwashing practices may reflect Jalaca's population true good hygiene habits. As demonstrated in Table 4.2, water sources were accessible to the majority (> 96%), so that hand washing could be done frequently. Therefore, the rates for handwashing practices and the rate for access of water were consistent. However, high rates of handwashing may also be an artifact due to participant's desire to provide a socially acceptable response. This phenomenon has been recently described in a study undertaken in the US and Canada. In this study, 95% of people interviewed by telephone reported always washing their hands after using public restrooms. In contrast, only 78% of people that were observed at public restrooms, did actually washed their hands.[203] This difference between participants' response in the survey and the actual observed behaviour, points to the existence of social acceptable response patterns that may have been at work in Jalaca. Interestingly, in the four participants who reported not washing their hands in the present study were males. This may indicate that these males have a lower awareness of personal hygiene practices or that they were less inclined to satisfy the interviewer.

Pig Husbandry

The breeding of domestic pigs is part of the culture and economy of the local inhabitants of Jalaca. Pork meat is an important source of protein and contributes to basic nutrition, especially in the rural undeveloped regions. In addition, domestic pig husbandry in Honduras is an important source of income for rural families due to pigs' ease of maintenance and low-cost. More than half of households (54%) in Jalaca reported raising pigs. Other towns in Honduras studied previously had higher rates of 67% and

61%.[20,30] However, a lower rate of 41% was reported from a study conducted in 1995.[20] The reason for the latter, as explained by Sanchez et al. (1997) was that at the time of conducting the study, several diseases had increased mortality rates among animals, including pigs, and had an effect on the number of pig-raising families. There are two similar findings from other Latin American countries: one was from Mexico reporting 50%, and the other was from Bolivia reporting 49% of pig-raising household.[15,105] Besides, other 12 studies from surrounding countries (i.e., Mexico and Guatemala), South American countries (i.e., Brazil, Bolivia, and Peru), and China have reported wide rates of pig-raising households ranging from 11% to 64%, which demonstrated that household pig husbandry is a common practice throughout the developing countries.[21,24,40,42-45,63,98,110,177,204]

The mean number of pigs per household was 2.4 in Jalaca, similar to that reported from two studies in Mexico.[45,204] A previous study conducted in another Honduran rural community reported the mean number of 1.6, which is the lowest mean reviewed in this thesis.[20] Similar studies from other Latin American countries also reported means of 2.4 - 3.8 in Mexico, 2.2 - 2.8 in Guatemala, 4.0 in Brazil, and 10.8 in Bolivia.[15,21,24,43,44,110] An interesting finding in this study is that the mean number of pigs per family was greater than a prior study in Honduras but lower than most of studies from other countries. It may be because the poverty in Honduras does not allow people to maintain large numbers of pigs for there may not have enough food leftover to feed pigs. The aim for the majority of pig-raising households in Jalaca was to provide protein sources for family members and to increase family income.

In the current study, 70% of the households reported allowing their pigs to freely roam and feeding on any garbage they could access. Such feeding method not only affect meat quality, but subsequently result in the transmission of human CC in the community as the pigs help to disseminate parasite eggs throughout the environment. The conditions found in Guatemala were very similar to the current study with 77% of households letting their pigs range freely.[24] Other reported findings from Mexico and Peru were lower (ranging from 11% to 43%), which reflects that the situation of free pig-roaming in the Honduran rural community is a quite common phenomenon and more severe than in the rural communities of other endemic countries. The local residents explained that allowing their pigs to range freely would decrease the cost of raising them, because they could avoid building a place for pigs, also pigs could be fed on household garbage, especially kitchen waste and human feces.[20]

Three households reported a history of having a pig with CC in the past. Due to this experience, one of them was not raising pigs at the time of performing the current study. As to the remaining two households, one family reported raising only one pig presently and confined it in the pigpen, which showed that this family realized and corrected their problem for raising pigs. The other family reported that they were raising three pigs currently and allowed their pigs to freely roam within their household area, which implied that this particular family did not associate free roaming with increased risk of infection and health education would be beneficial. Additionally, none of them reported current or past presence of tapeworm carriers that may imply that pigs could acquire infection either domestically or elsewhere.

Pork-consumption Practices

More than 86% of participants reported consumption of pork meat as their main protein source. Of them, 32% reported eating pork meat more than once a week; 98% reported consuming fresh pork meat (without being frozen after local slaughter); 91% reported getting pork meat from their own community; 89% reported eating well-cooked pork meat and only 7% and 4% reported eating uncooked and medium-cooked meat, respectively.

Since pork consumption was reported in the majority of Jalaca's households, and conditions that increase the potential for pig infection were present, it may be expected that taeniasis would be prevalent in the community. A previous study conducted in Honduras also reported that 93% of the rural and 86% of the urban individuals consumed pork meat.[51] It is important to understand in *T. solium* cycle that although non-pork consumption reduces to zero the risk of acquiring taeniasis, CC/NC could still be acquired by accidental ingestion of food or water contaminated with infective eggs from tapeworm carriers' feces, or by direct contamination.

Thirty-two percent of Jalaca's participants reported eating pork meat at least once a week, but higher consumption has been reported in Mexico (43%, 70%, 77%, and 90%).[44,45,105,110] Nevertheless, as will be discussed later, the prevalence of taeniasis in Jalaca was higher than that was reported in Mexico, which may indicate that the infection rates of porcine CC are higher in Jalaca. Alternatively, this finding may suggest that Mexicans from those studies cooked pork meat more thoroughly.

With the exception of 3 participants, the majority reported eating fresh pork meat, which may be due to the lack of electricity and refrigerators in those households.

Fresh pork carries more risk than frozen pork does, and according to a scientific research, deep-freezing at -10ºC for 4 days can kill *T. solium* cysticerci.[134] If freezers were available in endemic areas, it would be appropriate to recommend that people freeze their pork before consumption.

In this study, the majority of participants (67.5%) reported that they obtained pork meat from somewhere else in their community, and 10% from their own families, which is similar to what was reported from a study in Guatemala (70% - 81% from community and 5% - 7% from their self-households).[24] All three participants who had positive fecal samples reported obtaining pork meat from somewhere inside Jalaca, which means they were potentially infected from locally raised infected pigs. This confirms that the existence of infected pigs keeps the transmission cycle and therefore endemicity persisting in a community.

Although only 7% and 4% of participants reported eating uncooked and undercooked pork meat, respectively, it is important to note the significance of this risk for acquiring taeniasis is. In fact, of the 8 participants who reported such habit, two were identified as tapeworm carriers.

In addition to proper cooking of meat, recognition of infected meat is also important to prevent taeniasis.[15,19,40,51,98] Therefore, a health education program should incorporate these two factors to maximize prevention measures.

Recognition of Tapeworms, Current and Lifetime Taeniasis

Recognition of Intestinal Tapeworm

Almost 75% of participants were not able to recognize a tapeworm when shown a fixed sample to them, which indicated that they would not be able to identify it in their own or others' feces and taeniasis would go untreated. This creates a contamination source for the community. Nevertheless, more people could recognize the tapeworm in this study than in a prior Honduran study, which reported that only 7% of rural and 6% of urban participants recognized adult tapeworms.[51] This comparison shows better awareness on the parasite among Jalaca's residents.

Current Taeniasis in Participants and Their Family Members

Six (4.3%) participants reported passing tapeworm proglottids at the time of the study, two of which could also recognize the tapeworm shown in a jar. Moreover, Kato-Katz parasitologic examination was positive for *Taenia* sp. eggs in these two persons, which demonstrated that they were aware of being infected before attending the study. The remaining 4 persons that claimed being infected had a negative Kato-Katz result. Among the reasons for this discrepancy are confusion of tapeworms with other helminths and Kato-Katz sensitivity not enough to identify all tapeworm carriers. Questions were not asked about why these participants who reported passing tapeworm proglottids, had not looked for anti-parasitic treatment, therefore it could be only speculated that they did not consider it a serious infection. Since 2 of 6 participants identified with taeniasis reported passing tapeworm segments, asking participants if they are passing tapeworm proglottids could be a good indicator for diagnosing *T. solium* infection.[44,45]

Nine (6.5%) participants reported that a family member was currently passing tapeworm proglottids. Two of them had positive Kato-Katz results and were the same persons mentioned above for passing tapeworm segments currently. It could be assumed that there were at least two tapeworm carriers in their families at that moment of the study, and the infection tended to be clustered in their households. It also indicates that domestic infection may be a common source of infection in Jalaca's households.

History of Neurocysticercosis and Its Related Signs and Symptoms

Participants' History of Neurocysticercosis

Two participants reported that they had been clinically diagnosed with NC, but did not specify for how long. Additionally, both of them had negative fecal results. Linking the history of NC with the laboratory results and questionnaire information, the possible interpretation is as follows.

One person, who was 24 year-old male, reported having a history of NC without any symptoms and signs at the moment of the study. Since his questionnaire information showed that he had good personal and household hygiene and practices, and did not report observing any taeniasis infection in his family, no obvious potential risk factors were revealed by the interview. The possibility of autoinfection and infection within his households could be ruled out since there was no current or lifetime taeniasis in him or other family members. It is assumed that this person probably was infected somewhere outside his household.

The other person, who reported having been diagnosed with NC, was 23 year-old female. She reported symptoms of intense headaches and fainting. Her questionnaire information did not reveal any obvious risk factors, because she reported good personal and household hygiene practices, and beside her NC history, no other *T. solium* infections were observed in this household. However, she did report that a family member also had a history of intense headaches, but no further information about how NC had been diagnosed was available. Since current or lifetime tapeworm carriers in the household were not detected, the participant's NC was probably acquired outside her family. In addition, questionnaire answers showed lack of relevant knowledge about *T. solium*. Further investigation is required for this person.

It is interesting to note that epilepsy and seizures were not present in either person, which is the most common manifestation of NC (in up to 70% of cases).[126] Thus, confirmation of these cases is needed

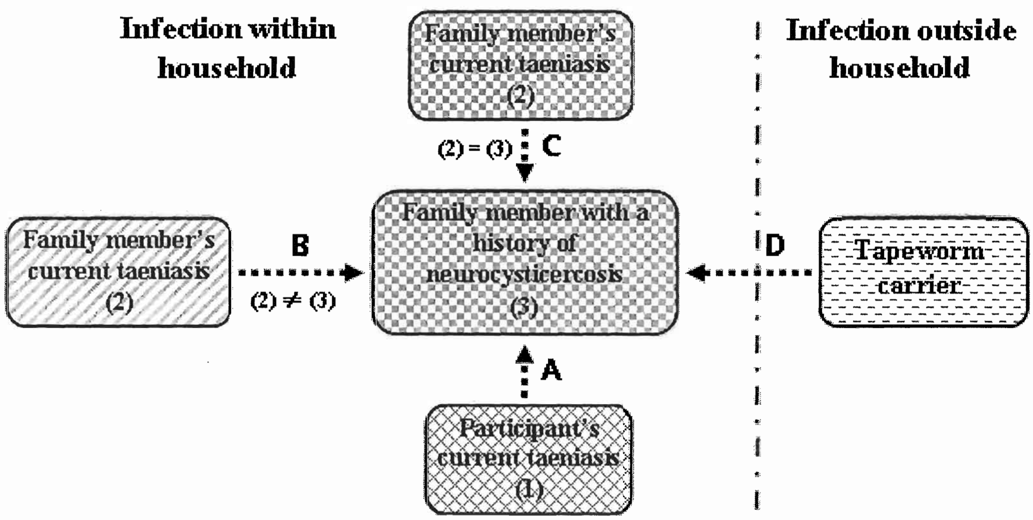
Lifetime Neurocysticercosis in Family Members

Only one participant (31-year-old female), who was seropositive and a tapeworm carrier, reported a history of NC in a family member. Other relevant characteristics of the participant included poor household hygiene and practices (i.e., overcrowding; no feces disposal system; no indoor tap water, not drinking boiled water; raising up to 9 pigs); frequent consumption of undercooked pork meat; personal history of *T. solium* infection (i.e., current tapeworm infection); and a history of NC compatible symptoms (i.e., intense headaches).

The above description shows that there were several potential risk factors existing in her family, resulting in infection and continuous transmission. Since the participant also reported current taeniasis in her family and herself simultaneously, a diagram considering four possibilities that may have lead to the family member's lifetime history of NC is depicted in Figure 5.1.

In total, there exist four possibilities for this family member's history of NC, which are depicted as four bold capital letters (i.e., A, B, C, and D). If possibilities A, B, and C happened, then infection occurred within the household; and if D, the only infection happened outside of the household. The Arabic digitals with parentheses (i.e., (1), (2), and (3)) represent family members involved in this infection. This NC patient has been infected from the subject or from another family member. However, two possible infections could happen on person (2) and (3): if (2) and (3) is the same person, it must be autoinfection; otherwise the infection would happen similar to A.

Figure 5.1. Four possible infection methods for the person having a history of NC



Neurocysticercosis Related Neurological Signs and Symptoms

In total, 38% (53/139) of participants reported having neurological symptoms that might be associated with NC. Moreover, 83% (44/53) of these symptomatic participants reported having intense headaches alone or combined with other symptoms (i.e., vertigo and/or dizziness), and the rest 17% (9/53) reported having a symptom of dizziness only. Although intense headache is the second common symptom of NC, it not only presents on cases of NC, but can present on other disease or non-disease conditions. Also due to the lack of relevant medical knowledge, they may have difficulty on distinguishing intense headache with other kind of headaches, which might lead to a false-positive result of intense headaches. None of the interviewed participants reported suffering a history of epilepsy or seizures, which is commonly used as an indicator of the presence of NC in a community.[5,8,48] No reports of epilepsy or seizures from the participants most likely indicate the true absence of those conditions at the time of the study. However, it may also indicate that most people are not aware that there are different kinds of epilepsy, and that epilepsy not just manifests itself with generalized seizures (e.g. absence epilepsy). As well, there maybe an unwillingness to report epilepsy or seizures due to the related social stigma.

About 3% of participants (4/139) reported having a family member with a history of epilepsy alone, or in combination with intense headaches. Among these four, one was detected as tapeworm carrier by Kato-Katz, and one did not provide fecal sample. Moreover, the person having positive results also reported that her family member was passing tapeworm proglottids at the time of the study. Family members having a history of epilepsy should be suspected as NC and further clinical examination (e.g., immunological assay, CT or MRI) should be done. If suspected NC was confirmed, the presence of tapeworm carriers in this household should be investigated in Jalaca.

PARTICIPANTS' KNOWLEDGE ASSOCIATED WITH *TAENIA SOLIUM*

Overview of 139 Subjects' Knowledge Associated with *Taenia solium*

Of 139 participants, only four (≈ 3%) correctly answered six or more questions of the ten-item knowledge questionnaire. The non-passing score of the vast majority (97%) demonstrates that this population would benefit immensely from a health education program, should *Taenia solium* intervention measures be implemented in Jalaca. Regardless of age, gender, or formal education level, participants generally showed more knowledge on epidemiological aspects than clinical aspects of *T. solium* infections and more about taeniasis than NC.

Further Impressions about the Results of the Knowledge Questionnaire

Epidemiology Questions

The mechanisms of transmission for taeniasis or CC were not understood by the participants as evidenced by the low rate of correct responses to Questions 1 and 2 (31% and 5%, respectively). Nevertheless, it seems that to understand the connection between eating pork meat and acquiring taeniasis (Question 1) is easier than to understand the relationship between fecal contamination and NC (Question 2). This dual mechanism of infection leading to two different conditions by the same parasite is a theoretical concept difficult to understand even by health care professionals. It is no surprise that inhabitants of a rural community in Honduras would have this rate of correct response without active and direct health education programmes in the community.

The mechanisms of porcine infection, on the other hand, were better understood as shown by high correct response rates to Question 3. Fifty-four percent of interviewed participants knew that pigs get infected by scavenging garbage containing human feces. Some participants that answered this question correctly also admitted having had pigs with CC in the past. Thus, learning how pigs get infected is more straightforward when pigs are found to be infected upon backyard slaughtering. However, the sole fact of knowing how infection occurs is not enough to change husbandry practices. Among persons knowing the correct answer, about 69% were raising pigs at the moment of the study, and about 15% reported that they let their pigs roam free around the community.

In the cycle of *T. solium*, human tapeworm carriers are at the centre of the transmission chain, and timely diagnosis and treatment is the key to interrupt transmission. Of the interviewed participants, 22% (31/129) were able to correctly answer that a tapeworm carrier is the source of CC for humans and pigs (Question 5). However, correct responses were not found among the three tapeworm carriers identified by stool examination, nor the 8 of 9 participants who reported a possible tapeworm carrier in their household, or the 5 of 6 participants who reported passing tapeworm segments at the time of the study. This finding is of crucial importance, as it provides evidence that health education targeting this particular aspect of the parasite's life cycle is urgently needed in Jalaca.

Clinical Questions

Table 4.9 shows that most local inhabitants knew the cure for intestinal taeniasis, but a few participants did not know the cure for NC. Additionally, only 12% - 15% of participants were aware of the clinical importance of taeniasis and NC and the causes of epilepsy or seizures. Comparing the correct responses of epidemiological questions, the correct responses were lower for clinical questions, which indicated that local residents in the community of Jalaca had better realization on epidemiological knowledge regarding the parasite.

Of particular importance is the fact that only 12% of participants knew that NC and epilepsy have a strong association. Being that both conditions are common in Honduras, it seems important that Hondurans realize that epilepsy has many causes, among which NC is of major importance. Finally, knowing that there are adequate treatments for both taeniasis and NC is important for people to seek medical care when aware of passing tapeworm segments or being diagnosed with a form of CC.

The majority (85/139) of interviewed persons in this study answered correctly that there is indeed treatment for tapeworm carriers. However, out of the 3 tapeworm carriers found by coproscopic examination, and the other 3 that reported passing proglottids but whose fecal examination were negative, only 1 subject did not know that there is treatment for taeniasis. However, the reasons why people that were aware of being infected and knowing the cure but did not seek treatment were not explored during the interviews, and should be addressed in further field studies in order to understand the obstacles people face in seeking and obtaining immediate treatment.

A general conclusion that can be drawn from the results of the knowledge assessment of this population is that even though there is some understanding in some aspects of *T. solium* transmission and clinical importance, this knowledge is fragmented and not really working for the community. Two obvious examples discussed above are: one of the three households reported a history of having a pig with CC, but still allowed their pigs roaming freely; two of the three subjects having the positive Kato-Katz result reported knowing their infection before this study and knowing the cure for taeniasis as well, but still did not seek treatment. These two instances are the evidence for this general conclusion. Therefore, adding more knowledge by deliberate health education could help filling the knowledge gap and bridging knowledge to action on behaviour changes. To create behaviour changes of rural population, an effective approach should be a combination of educating individuals to (1) perceive themselves to be exposed under *T. solium* transmission; (2) to understand how serious *T. solium* infection is both for family member's health and wealth and for public health and social economy; (3) to convince that treatment and prevention activities (e.g., good personal hygiene and practices) are effective yet not overly costly in terms of money, time, or pain; (4) to believe that behaviour changes will have a positive effect in their lives.

Analysis of Knowledge Questionnaire by Gender

There was no statistical significance between genders on the results of knowledge questionnaire. However, 3 of the 4 participants who had a passing score were females, demonstrating that females had more knowledge related to *T. solium* than males did.

Analysis of Knowledge Questionnaire by Age

Although lack of knowledge was found across all ages, in general, people at 30-39, 40-49, and 50-59 age groups answered slightly more questions than other age groups. The two age groups with more highest response rates were the 30-39 and 50-59, but the statistical difference was observed across all ages in the general knowledge on *T. solium* and the specific aspect of knowledge on taeniasis.

Analyzing the knowledge questionnaire results was a complicated process. Knowledge (as indicated as the number of correct responses) was distributed very irregularly among the age groups. For instance, although the $\geq$ 60 years of age group had the lowest average in correct responses, people belonging to this group knew more about the clinical aspects of *T. solium* infections than epidemiological aspects (M=1.18 versus M=.82). Furthermore, of the 4 people that had a passing score, one was 63 years old. Additionally, people belonging to the age groups of 10-19 years and 30-39 years seemed to have balanced knowledge on both epidemiological and clinical aspects of the infections. The differences in knowledge distribution are difficult to explain, but may be related to life experience. Finally, all age groups showed better understanding regarding taeniasis than NC, which may be directly related to the differences in transmission, localization and manifestation of infection of each. Taeniasis is acquired by a straightforward mechanism, (i.e., ingestion of infected pork meat) that results in a more obvious intestinal infection, whereas NC is acquired by ingestion of microscopic eggs, which results in a hidden chronic infection that can go unnoticed for years.

Analysis of Knowledge Questionnaire by Formal Education

Formal education was statistically associated with increased general and clinical knowledge regarding *T. solium*. People with any level of high school or above obtained the highest correct response rates on 6 of the 10 questions. Nevertheless, as it will seen later in this chapter (entitled "Factors associated with seropositivity"), having more knowledge was not a protective factor for seropositivity. In other words, knowing more about the parasite did not prevent people from infection, as indicated by a seropositive status. These findings are of crucial importance for the community of Jalaca for they revealed an evidently urgent need to increase the general educational level as well as the specific *T. solium* knowledge. Moreover, since the mere presence of knowledge does not necessarily translate into action, a health promotion program that encourages behaviour changes and modification of practices would be extremely beneficial. For instance, such a program could include aspects on pig husbandry, personal and household hygiene, protection of environment and water sources, safe treatment approaches for food and drinking water. Therefore, such a comprehensive program could help rural Hondurans not only integrating the seemingly fragmented knowledge on *T. solium*, but also understanding how to incorporate changes to protect them without infection.

PREVALENCE OF MAJOR INTESTINAL HELMINTHS

Prevalence of Intestinal Tapeworms

In total, 123 people provided fecal samples for testing intestinal helminths by using Kato-Katz concentration technique. Three individual samples were positive for detecting tapeworm eggs, indicating a prevalence of human taeniasis of 2.4%. Since pork was the major meat consumed by more than 81% of households in the community; and swine were raised by about 54% of households and cattle were rarely found to be raised by households, these *Taenia* sp. segments were likely *T. solium* tapeworm proglottids.

All the three tapeworm carriers were females, aged 15, 31, and 35. They were living in different households. Two females belong to the age group of 30-39 and were probably homemakers, involved in food handling, children care, livestock and poultry raising, and entire family members' health care. Due to the small sample size, statistical analyses were not conducted to identify any potential risk factors associated with taeniasis. However, a previous study conducted by Allan et al. (1996) in Guatemala, the neighbouring country of Honduras, confirmed that gender (female) and age (30-39 years old) were important risk factors. Women as main tapeworm carriers have not been studied extensively though, and more studies are necessary.

Two of the three tapeworm carriers reported that their households did not have either toilet or latrine, which would indicate an occurrence of environmental contamination. People passing tapeworm segments outside toilet or latrine is a fateful risk for transmission of the parasite, as infective eggs will be spread within or even outside community. Additionally, the 3 tapeworm carriers all reported not boiling the drinking water in the household. If these tapeworm carriers contaminate the water, the risk for the rest of the family members is increased.

One of the tapeworm carriers reported a family member with a history of NC and intense headaches. It is possible that this NC patient acquired the infection from the tapeworm carriers in the household. The second tapeworm carrier reported a family member suffering of epilepsy. Since epilepsy is the most common symptoms of NC, more studies should be done to determine whether NC is the cause of epilepsy in this case. Ideally, in-depth investigations should be undertaken for all tapeworm carriers' households.

The type of parasitological technique and stool collection approach used for taeniasis detection is very important when drawing conclusions on the endemic status of a community, and determining whether the prevalence rate found is accurate, or if an underestimation may have occurred. Stool examination of a single sample is less sensitive than that of a series of samples obtained in different days from the same person. In Jalaca, due to budgetary constraints, a single sample was collected from each participant and even when Kato-Katz technique was used to concentrate the sample and increase the probabilities of finding *Taenia* sp. eggs, the prevalence rate of 2.4% found is probably an underestimation. Nevertheless, any prevalence above 1% is considered to be hyperendemic.[16] Other Honduran studies using more sensitive methodology found lower or similar prevalence rates in other rural communities,[20,30,51] suggesting that Jalaca is a very important focus for *T. solium* transmission in Honduras. Other Latin American countries show lower prevalence rates by using parasitologic examination (1.3% in Bolivia, 1.6% in Ecuador, 1.0% in Guatemala, 0.1% - 1.5% in Mexico, and 0.8% in Peru).[15-17,19,21,24,44,45,59,60,64] The use of coproantigen technique increases the probability of finding cases.[24,62,63] In fact, the higher prevalence rates of 4.5% in Brazil, and 2.7%, 2.8%, and 3.5% in Guatemala have been reported with this technique.[24,62,63,112]

In summary, the present study has confirmed that Jalaca is a hyperendemic area of transmission for taeniasis or CC. Considering the low sensitivity of the parasitological technique used in this study, it can be concluded that the real prevalence would be higher. It also points to a need for treating taeniasis and establishing control measures to reduce the impact of *T. solium* transmission and infection in Jalaca.

Prevalence of Other Intestinal Helminths

Intestinal helminths are a group of parasitic worms, including *Taenia* sp., *Trichuris trichiura*, *Ascaris lumbricoides*, etc. Infections due to these predominant helminths are widespread and could result in disease, which represents a health and economic problem.[205] Determining helminth infections in a region, particularly caused by predominant helminths, is considered as an important indicator of local environmental contamination, also indirectly implicating the infection of *T. solium*.[205]

About 61% (75/123) of the 123 subjects tested positive by Kato-Katz for at least one intestinal helminth. This was slightly lower than reported in a prior study (77%) in a Honduran rural community,[20] which indicated that helminth infections in the community of Jalaca was not as severe as in another Honduran community of Agua Caliente. Another four studies from Mexico also investigated the infections of other intestinal helminths, and one showed that 62% of subjects were infected with at least one helminth.[45] The other three studies reported helminth infection rates of 50%, 67%, and 50%, respectively.[19,44,177] All of these studies indicated widespread helminth infections in Latin America.

The infections with *Trichuris trichiura* and *Ascaris lumbricoides* are common in rural areas of developing countries.[205] The prevalence rates in the current study were identified as 44% for *T. trichiura* and 40% for *A. lumbricoides*, which were higher than almost all previous epidemiological studies for *T. solium* in Honduras. In those studies, the prevalence rates of *T. trichiura* and *A. lumbricoides* were ranging 19% - 61% and 8% - 28%, respectively.[20,30,51] Besides, similar epidemiological studies conducted in Mexico also reported findings with a wide range of variation: 0.5% - 29% for *T. trichiura* and 0.7% - 41% for *A. lumbricoides*.[19,35,44,45] Compared with the prevalence rates in the present study, it was found that the infection of *T. trichiura* in the rural community of Jalaca was far more serious than all those investigated communities in Mexico; meanwhile the infection of *A. lumbricoides* in this study was also parallel to the highest infection level in Mexico. These comparisons show that helminth infections in the community of Jalaca were extremely severe, indicating heavy environmental contamination, an essential element for the persistence of *T. solium* transmission.

SEROPREVALENCE OF ANTI-*TAENIA SOLIUM* ANTIBODIES

A high seroprevalence rate was found in the studied community. In total, 139 participants provided blood samples for detecting anti-*Taenia solium* antibodies by using EITB technique. Twenty-six serum samples were identified positive, indicating a seroprevalence of 18.7%, and therefore suggesting that the *T. solium* transmission is very high in this rural area of Honduras. Few other studies have been carried out in Honduras and showed similar or higher seroprevalence rates (i.e., 15.6%, 17%, and 34%).[20,30,51] The high seroprevalence rates are perhaps due to the fact that these studies have been conducted in selected communities, where there was reported high epilepsy levels and raising pigs was common practices. Other studies are needed to confirm that high transmission is occurring throughout the country. For instance, studies in other known endemic countries show wide variations: 3.3% - 12.2% in Mexico and 7.0% - 26.9% in Peru, 14% and 22.6% in Ecuador, 10% and 27% in Guatemala, 2% - 22% in Bolivia, and 1.6% and 2.1% in Brazil. [5,15,17,19,24,42-45,47-49,59,62,64,69,70]

As explained earlier in an epidemiological study, seropositivity is taken as an indicator of transmission. A seropositive status may indicate a variety of instances: true NC or CC cases, current tapeworm infection, or immunological memory from a past infection or simple exposure. In fact, 2 of the identified tapeworm carriers were seropositive. As well, 11 of the 26 seropositive participants reported suffering of headaches, which has been suspected to be associated with NC.[12,132,133] However, no clinical examination was performed in the seropositive persons; they were referred to the local public health center for further clinical assessment.

FACTORS ASSOCIATED WITH SEROPOSITIVITY

Statistical analyses were performed to determine whether any specific individual or household characteristics were associated with seropositivity, which is an indicator of transmission. Bivariate analysis showed that seropositivity was strongly associated with six potential risk factors, namely, age (people at 30-49 years old); lack of handwashing before eating; the ability to recognize tapeworms; the presence of tapeworm carrier(s) in household; the presence of a NC patient in household; and knowledge regarding clinical importance of taeniasis. However, after logistic regression analysis, only two factors retained statistical significance, the ability to recognize tapeworms and the presence of knowledge regarding the clinical importance of taeniasis. Other potential factors, albeit obvious from the biological point of view, showed weak or no statistical significance. The lack of statistical association between obvious factors and seropositivity is likely due to the small sample size. In addition, socioeconomic conditions and therefore the probability of exposure were very homogeneous throughout this community, thus reducing the probability of revealing risk factors. Moreover, since *T. solium* transmission is rooted in poverty, which is prevalent in Jalaca, identifying risk factors becomes a more difficult task, particularly with a small sample size. Further studies comparing communities with different socioeconomic status may help to identify additional risk factors associated with *T. solium* transmission. The following is a discussion of the factors assessed for association with seropositivity.

Individual Factors

Residence

The time of residence in Jalaca was not associated with seropositivity. This finding is understandable since *T. solium* infections tend to be chronic. For instance, untreated taeniasis can persist up to 25 years due to the tapeworms' longevity,[58] and CC (including NC) is often diagnosed many years after infection, making the time and place of infection impossible to determine, especially in endemic countries.

Gender

Twenty of the 26 seropositive individuals were female. However, no statistical significance was demonstrated between genders. Few studies have demonstrated female gender as a risk factor associated with seropositivity. One study in a Peruvian community[42] and another in Guatemala[39] showed the statistically significant association between seropositivity and females. In contrast, studies in other Latin American countries (such as Mexico, Bolivia, Ecuador, Brazil, etc.) did not find such statistical association. Although some studies have shown that tapeworm carriers are more likely to be females,[39,42] the vast majority of studies have not found an association between gender and seropositivity.

Age

Eighty-five percent (22/26) of the seropositive subjects were under 50 years of age, of which 50% belonged to the age group 30-49. A significant association between age distribution (30-49 years group compared to other age groups) and antibody seropositivity was established by bivariate statistical analysis. As stated earlier, this factor was not determined statistically significance in the multivariate analyses. However, the significance found in the bivariate analysis shows that the number of seropositive persons increased with age, which may be explained as the cumulative exposure during people's lifetime. Many studies performed in Peru, Bolivia, and Ecuador confirmed the statistically significant and positive association between age and antibody seropositivity.[15,17,41,42,98,107]

Formal Education

In the present study, formal education levels were not associated with seropositivity. Contrary to what other studies have found in Bolivia, Peru, Ecuador, and Mexico,[15,43,51,105,107] the results from the present study suggest that an increased level of schooling does not necessarily translate into specific knowledge of health issues. In the case of *T. solium*, health education should be designed and delivered within specific intervention programs. The formal education levels of the target population should, of course, be taken into account when designing such programs.

Handwashing Practices

Handwashing practice is an indicator of personal hygiene, especially after toilet or latrine and before eating and cooking. If there is a tapeworm carrier in the household, the lack of or inappropriate handwashing before eating would pose a risk for that individual and the rest of household members for acquiring cysticercosis. The importance of handwashing has been recently stressed by the WHO in an intensive programme of handwashing education and promotion.[206] A conclusion from this programme is that vigorous public promotion of handwashing, particularly among the areas without reliable clean water supplies, could have a major impact on health. In Jalaca, the significant association between lack of handwashing before eating and seropositivity found in the bivariate analysis also reveals the importance of handwashing practices. This association, however, was weakened in the logistic regression and found not significant. A study in China looked at this same association and did not find a significant difference either.[40]

Pork-consumption Practices

The frequency of pork consumption was not found to be significantly associated with seropositivity. This finding is in contrast with other studies that have found the association to be significant.[44,108] The most likely explanation for this discrepancy is that pork consumption in Jalaca was extremely high, when compared to reports in other studies. Therefore, the comparison group was so small that the sample lost some power.

A trend between the consumption of uncooked pork meat and seropositivity was found; however, no statistical association was identified. This trend shows as 4 of the 8 participants, who reported eating uncooked pork meat, were positive for antibodies.

Ability to Recognize Intestinal Tapeworm

Recognition of intestinal tapeworm may be used as indicative of having been infected or having been exposed to someone who was tapeworm carrier. In the present study, the ability to recognize a tapeworm in a glass jar was revealed as a significant risk factor associated with seropositivity by both bivariate and multivariate statistical analyses. This result is consistent with several studies that revealed the trend but did not show a statistical association.[19,44,51,60] This finding suggests that individual's high familiarity with tapeworms may indicate the presence of tapeworm infections in communities where no health promotion interventions have been implemented.

Current and Lifetime Taeniasis in Family Members

Passing tapeworm proglottids by participants' family members at the time of the study was found statistically associated with seropositivity by bivariate analysis, but no association after multivariate analysis. This result demonstrates the importance of living in close proximity with a tapeworm carrier, which may result in exposure to *T. solium* eggs and future cysticercosis. Several larger studies from Peru and Mexico have also revealed this important association.[17,19,106]

Conversely, no significant association was revealed between the report that a family member had expelled proglottids in the past and the individual's serological status. Previous studies conducted in Honduras, Mexico, Guatemala, Peru, and China, report that having a history of passing tapeworm proglottids by either participants themselves or their family members was the significant risk factors associated with antibody seropositivity.[20,17,24,40,41,44,46,105]

Family Member with a History of Neurocysticercosis

A history of NC from participants' family member was revealed as a statistically significant risk factor for seropositivity by bivariate analysis only. Though theoretically the presence of a person with NC in a household will not initiate any transmission, it may be used as an index case to investigate whether a source of infection in the household exists. It is much easier, however, to demonstrate this association in non-endemic countries where exposure, if any, is restricted to limited sources. The existence of NC cases in the localized area of New York is a good example.[35] But in endemic countries where contamination is widespread and exposure persistent, it becomes more difficult to discover the source of transmission.

History of Neurocysticercosis Related Signs and Symptoms

In *T. solium* endemic areas the report of neurological signs and symptoms, especially epilepsy and seizures may be used as indicative that a case of NC may exist. In fact, studies done in Peru and Mexico have shown a significant association between seropositivity and a history of epilepsy and or seizures and confirmed it is a strong indicator of NC in endemic countries.[17,41,44-47,105,177]

In the present study, none of the interviewed participants reported suffering of epilepsy or seizures, but 53 individuals reported other signs and symptoms such as intense headaches, dizziness and vertigo, none of which was found statistically associated with seropositivity. The same lack of association was observed between seropositive individuals and the report of such signs and symptoms in their family members.

Participants' Knowledge Regarding Taenia solium

A significant association between participants' understanding of the clinical significance of taeniasis and antibody seropositivity was revealed by both bivariate and multivariate statistical analyses. However, overall knowledge on *T. solium* (as indicated by passing or failing scores in the knowledge questionnaire) was not associated with seropositivity. Other studies have found that there is a strong relationship between illiteracy or low education levels and the probability of exposure to the parasite as indicated by seropositivity.[15,43,51,105,107] No other studies have explored the presence of specific knowledge on *T. solium* in endemic communities with serological status, and the present study is the first attempt to do so. The fact that participants' understanding of the clinical significance of taeniasis and seropositivity were associated and indicates that people may be more aware of the importance of an infection if they had experienced or witnessed it. Intervention programs should consider health education as a crucial component to provide an opportunity to increase awareness to promote prevention of infection.

Household Factors

Household Overcrowding and Clustering

Some studies have found that probabilities of seropositivity increase when there is a large number of people living in a household.[20,207] The rationale for this is that a tapeworm carrier in an overcrowded household places other family members at an increased chance of exposure. In the present study, using a similar definition of overcrowding to that reported in a previous Honduran study (at least 8 people in the household), only 8 of 56 households met the definition. No significant relationship between overcrowding and antibody seropositivity was found in this study; however, a trend for clustering was observed: five (25%) seropositive households had more than one seropositive subject, four of which had two and one had three seropositive subjects. Statistical analysis of this trend was not performed due to the irregular number of participants from each household. For the study, 56 households were randomly selected and the 139 subjects that participated were unequally distributed, with variations of 1-7 subjects per households. For instance, 1 family of 10 and another family of 7 persons were underrepresented with only one participant each. The irregular number of participants, particularly more than one participant per household, makes it difficult to identify risk factors because participants are not independent from each other as they are exposed to similar conditions. This is an obvious limitation and should be avoided in further investigations. On the other hand, including all member of the household in a study would be necessary for assessing household clusters of infection.

Other Household Environmental Characteristics and Seropositivity

The socioeconomic characteristics of the population in Jalaca were very homogenous; hence, the living conditions were fairly similar from household to household. Due to this, (combined with the small sample size), household characteristics such as type of floor, feces disposal facilities and source of water were not statistically associated with seropositivity.

These characteristics have been found relevant in other studies in which varied socioeconomic conditions existed throughout the studied communities,[6,20,41,45,51,84,110] demonstrating that *T. solium* transmission is closely associated with poverty.[202]

Pig Husbandry

Although several studies have found an association between the presence of antibodies and domestic pig husbandry,[17,40,41,43,51,98,105] no statistical association between these two variables was determined in the present study.

In summary, in the present study, it was not possible to find statistical significance between seropositivity and many socioeconomic conditions previously reported as risk factors. Three main explanations can be offered:

Firstly, socioeconomic conditions among Jalaca's population are fairly homogenous and it may be difficult to unravel any particular risk factor due to the multitude of underlying confounding factors. Moreover, since *T. solium* transmission is rooted in poverty and associated conditions, comparison of individuals within the same hyperendemic community may be futile.

Secondly, the relatively small sample size of the present study may account for weak statistical associations. In many cases, a trend was observed, but the final statistical analysis showed not significance. Moreover, bivariate analyses showed some factors as significant risk factors that lost significance in the multivariate analysis by logistic regression.

Finally, although the EITB has been shown the most specific serological tool for determination of serum antibodies against *T. solium*, [68,115,151,154] the assay's sensitivity is widely variable.[68,146,149,152-155] Therefore, many subjects may have had a false seronegative result, affecting the quality of the statistical analyses. In addition, it may be possible that due to the hyperendemic status of Jalaca, high transmission levels will account for temporary seropositivity in some individuals,[65-67,157,158] thus confounding the statistical analyses. This is because transient antibodies may be detected on people who have been exposed to, but did not develop an active infection of *T. solium*; or people who have had CC or NC, but have self-cured.[65]

In summary, this study has confirmed that *T. solium* transmission is rooted in poverty. Moreover, poor socio-economic conditions and low levels of formal education are strongly associated with the presence of this parasite discovered.

In the following diagram (Figure 5.2) depicts the complexity of factors at play in *T. solium* transmission, where health outcomes (i.e., the presence of taeniasis and cysticercosis seroprevalence) are directly linked to low SES. In turn, low SES provides a fertile ground for *T. solium* transmission with the existence of factor, such as:

a) household factors

b) Individual factors

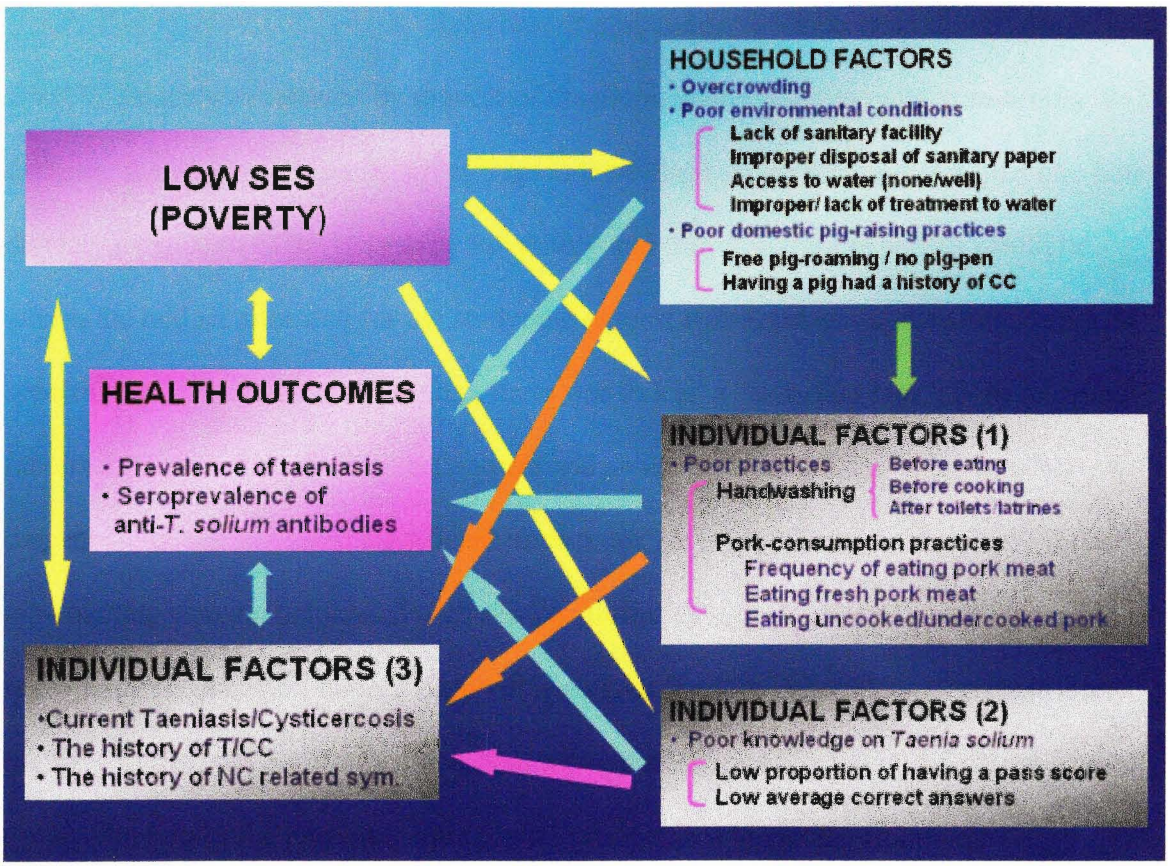
  b.1 Poor personal practices

  b.2 Poor knowledge on *Taenia solium*

b.3 Presence of taeniasis and neurocysticercosis and NC related symptoms

Once *T. solium* transmission is established in a community, it will affect the health economy and aggravate the low SES, therefore perpetuating the poverty cycle in the community.

Figure 5.2. The poverty cycle among low SES, health outcomes, and potential risk factors



LIMITATIONS

Every study has limitations and researchers work at the best of their abilities to decrease the impact of those limitations in their investigations results so correct interpretation and extrapolation (transferability) can be achieved.

Some characteristics have identified as *potential limitations* in the present study, and although they do not affect the quality of results, it is worth to acknowledge them offer a brief discussion, as follows:

Selection of community

Jalaca was selected by request of the municipality's mayor who was aiming to decrease the number of free-roaming pigs in the village. Since Jalaca was at just one-hour driving distance from the university laboratory and transportation expenses would be within the budget allocated for the study, the request was granted and the study designed specifically for this village. Although there was indeed a "selection bias", both selection factors are common in field investigations and as shown by statistical analysis of the present study, neither had a significant impact: the participation rate was not 100%, and pig-roaming was not associated with seropositivity. Finally, Jalaca is a good representative of any Honduran rural village where families are dedicated to small-scale pig husbandry, with similar practices that include allowing animals run freely throughout towns. Therefore, the present results can be extrapolated to similar Honduran communities.

Sample size

The sample size for the study was calculated appropriately so the number of participants represented the entire population. However, since Jalaca is a small town with a small of population, as expected, a small number of participants were identified as seropositive. Since in this type of studies, seropositivity is used as the dependant variable to conduct statistical analyses, the strength of associations was decreased by the small number of seropositive individuals (n=26). However, the seroprevalence rate (18.7%) obtained in Jalaca is similar to what other Honduran studies (larger and smaller) have found in Honduras[30,51] which supports the argument that the sample size was appropriate.

Lack of assessment of porcine cysticercosis

Assessment of porcine CC by tongue inspection and serology provides more complete information on the status *T. solium* transmission in a community, but budgetary constraints did not allow for incorporating this assessment into the study design. The lack of this data in the present study does not affect the quality of results but makes the study incomplete. Further studies should aim to be more comprehensive and assess CC in both natural hosts (humans and pigs).

General survey questionnaire

The general survey questionnaire used to collect information was comprehensive and piloted. Nevertheless, it was found that it would have been useful to have included more questions, especially clinical and follow-up questions, including: a) for how long participants or their relatives have had taeniasis (if aware) and the reasons why they have not sought treatment; b) for how long participants or their relatives have been diagnosed with NC, what studies were done to diagnose it and what treatment was prescribed (if any). Though this information is valuable, its absence does not affect current research findings.

Taeniasis detection technique

To detect tapeworm carriers, coproantigen detection is more sensitive than microscopic examinations. [58,112,115] It has been reported that the former can detect 2.6 times more cases of taeniasis than direct microscopic examination.[112] Since the coproantigen test has not been commercialized, it is only available to certain research groups and could not be accessed for this study. Kato-Katz (a concentration technique recommended by the WHO for helminth infections[194]) was used instead. Considering that the prevalence rate of taeniasis, ascariasis, and trichuriasis obtained in Jalaca are very similar to those reported in other studies,[20,30,51] it can be said that Kato-Katz was efficacious. Furthermore had the coproantigen test been used, the taeniasis prevalence in Jalaca would have been only higher.

Besides the potential limitations mentioned above, there are three important limitations that need to be acknowledged for the present study, namely irregular number of participants per household, gender imbalance, and the format of knowledge questionnaire (Q2). Each will be discussed separately.

More than one participant per household

In the present study, more than one individual participated per household (ranging from 1-7 subjects/household). It is well known that statistical associations between outcomes and exposures are weakened whenever subjects are not independent from each other and are exposed to similar conditions. This is what happened in the present study, and risk factors for seropositivity were difficult to identify. This limitation could be corrected by reanalyzing the present data randomly selecting only one person from each household, and will be done after this thesis is published.

Additionally, taking advantage of the participation of more than one person per household, a more sophisticated analysis could be used to determine the household clustering of *T. solium* infections, because clustering has been revealed as a significant indicator of transmission in several studies.[16,44,105,200,208]

Gender imbalance

As introduced earlier, comparing to nationwide gender distribution in Honduras, females were over-represented in this study. Statistical analyses showed there was not a significant difference between gender and knowledge questionnaire and risk factors related with seropositive results. This indicates that gender imbalance did not obviously affect the study findings. Nonetheless, since intervention measures may be designed differently for males and females, it would be desirable to keep genders equally represented.

Format of knowledge questionnaire

The knowledge questionnaire was standardized and piloted previous to the study. Although all precautions were taken to obtain reliable responses in this questionnaire, it has to be acknowledged that having only multiple choice questions may allow for chance correct responses. Therefore, subsequent studies should include a variety of formats of questions to increase the consistency of correct responses. However, care should be taken into not making the interview process too long as to discourage participation. Since this study is the first study in Honduras to explore *T. solium* related knowledge, further studies have ample room for improvement and are faced with the challenge of creating an improved instrument for knowledge data collection.

CHAPTER SIX: CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

CONCLUSIONS

I. The present study was able to meet the objectives proposed and answer the research questions posed for the study

II. In Jalaca, population's practices and households' environment and practices provide great potential risk for transmission of *Taenia solium*

II. It was demonstrated that Jalaca was a hyperendemic community for *Taenia solium.* The prevalence of intestinal taeniasis of 2.4% was higher than in other Latin American countries and similar to what other studies have found in Honduras

III. The seroprevalence of 18.7% for human anti-*Taenia solium* antibodies in the rural community of Jalaca was high when compared to other studies from known endemic countries in Latin America

IV. The population in the community of Jalaca lacked relevant knowledge regarding *Taenia solium* both in the aspects of transmission and the clinical importance of the infections it causes. However, knowledge about transmission was relatively higher than the clinical knowledge, and knowledge about taeniasis was generally higher than that of NC

V. The ability to recognize adult tapeworm and the presence of knowledge on the clinical importance of taeniasis were identified to be significant risk factors associated with the transmission of *Taenia solium*

In general, this study shows for the first time that despite the high frequency of infections and the constant transmission, taking place in the community, general knowledge regarding *Taenia solium* is low in a Honduran rural population. The present study can be regarded a guide to plan health education program as a cost-effective control strategy to reduce *T. solium* transmission.

The findings from this study show that Honduran rural areas are indeed important foci for *T. solium* transmission and that a control program should be considered as a priority for the country. In view of the general situation of rural regions, health education as a cost-effective measure could be first performed individually or in company with other control measures.

FUTURE RESEARCH DIRECTIONS

Sufficient evidence has been provided by this and other studies, indicating that in Honduras *T. solium* is a parasite prevalent in comparable proportions to those reported by well-known endemic and hyperendemic countries. However, it is necessary not only to demonstrate the presence of *T. solium* infections, it is also crucial to demonstrate the impact of those infections in Honduras' population, in terms of both health and economy. This can be done through a specific project in disease burden and cost of disease. Such a study would provide solid justification for a national control program, and would attract funds to continue research and implement prevention and control measures.

Other research activities could aim to establish the efficacy of different control measures as implemented in different model communities. Health education should be regarded as an important part of these strategies. As well, porcine vaccination should be explored as a great tool to reduce infection in the intermediate host. Other control measures could also be involved in a comprehensive control program, such as treatment of taeniasis; treatment of infected pigs; and establishing strict inspection system for pork meat.

In addition to research activities, intervention program in high-prevalence areas should be established as soon as possible. Rural populations would benefit from programs that a) help them to integrate their fragmented knowledge about *T. solium*; b) guide them to implement changes in their practices, and c) provide alternatives to care for their environment. These programs would empower rural inhabitants to improve their health and economy.

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Appendix A - Invitation Letter (English Version)

Information - Invitation Letter
about the project
The Impact of Health Education in the control of *Taenia solium* infections

Dear Sir or Madam:

With this letter, we are inviting you to participate in the research study "The Impact of Health Education in the Control of *Taenia solium* infections"

This research study is supported by the National University of Honduras (UNAH) and Brock University, Ontario, Canada. The Project has been reviewed by, and received ethics clearance through, the Directorate of Scientific Research (DICU) (File # 015-DICU), and Brock University's Office of Research Ethics Board (File #_____)

The study is being supervised by Dr. Ana L. Sanchez, as Principal investigator (Assistant Professor, Department of Community Health Sciences, Brock University, Phone (905) 688-5550 ext. 4388) and conducted by co-investigator and Master student Ms. Maritza Canales de Garay, Instructor, Microbiology Dept., UNAH, telefono 232-5836).

The objective of the study is to assess the beneficial effects of an educational campaign as intervention measure against the tapeworm parasite, *T. solium*, which cause both taeniasis and cysticercosis (*semilla*). During this campaign, basic concepts on the parasite's life cycle will be taught to the community population, a portion of which will be approached -like in your case-, and interviewed to determine the knowledge gained during the process.

T. solium tapeworm infects both humans and pigs. In humans, the parasite could localize as an adult worm in the small intestine and cause taeniasis, or in the brain and cause cysticercosis (*semilla*). One of the main symptoms of the latter is epilepsy. In swine, *T. solium* causes only cysticercosis in skeletal muscles (pork meat). When humans eat infected undercooked pork meat, they get the intestinal tapeworm, thus completing the parasite's life cycle. *T. solium* therefore, produces not only medical problems but also economic losses due to condemnation of infected meat. In communities such as the one you live in, where the parasite is prevalent, it is necessary to implement control and prevention measures. Previous research has shown that health education is a main component of any program targeted to control and reduce *T. solium* prevalence. Knowledge about the parasite's transmission greatly facilitates the implementation of such control measures.

You have been randomly selected to participate in the evaluation of a Health Education Program soon to be conducted in your community. If you decide to participate, we would require: firstly, that you participate in the campaign activities, and secondly, that you answer a one hour questionnaire previous to, immediately after and 4-6 months after the campaign.

If you decide to participate and answer the questionnaire, you will be free to answer only those questions you feel comfortable with. Although most questions will be about how

much you know about the parasite, some personal questions will be asked, like your name, age, and some household conditions, and if you raise pigs in your home. The type of questions you will be asked will be similar to the following:
"How do you think a person acquire intestinal tapeworm:
a) by eating cysticercotic pork meat
b) by drinking unsafe water
c) by eating unwashed vegetables
d) by accidental contamination with human or animal feces"

At the end of the second interview, you will be asked to let us take a blood sample and provide us with a stool sample, both to be analyzed at the UNAH's clinical laboratory.
Your participation in this study does not pose more than minimal risks. The research team members are well trained in collecting blood samples, and will use only sterile disposable material for their safety and yours. As well, they will observe standard precautions in handling any biological sample. However, you might experience temporary physical discomfort when your blood sample is drawn. As well, some persons feel some embarrassment when providing a stool sample. To avoid this, we will make sure this process in done in a confidential way. Some persons sometimes experience anxiety when waiting for laboratory results. We will do all we can to provide you with your results as soon as possible.

All these laboratory tests are totally free of charge, and at no point of the study you will have to incur in any expense by participating, nor will you have any monetary compensation in doing so. If after the samples are collected you decide to withdraw from the study, we will still analyze them and provide you with the results.

A benefit you will receive by participating in this study is gaining health education that will help you to prevent and control *T. solium* infections. This might result in better health for you and your family. It could also represent a future economic benefit by raising healthier non-infected pigs. Another benefit of your participation is having laboratory tests done, which might reveal you are infected with treatable parasites. The Primary Health Centre will provide you anti-parasitic treatment in this case.

If you decide to participate, all personal information you will be asked during the interviews will remain confidential. All information from all participants will be aggregated. Therefore your name will not appear in any report or publication produced as a result of this study. A database will be created in which your name will be removed upon completion of the study. We will store this database indefinitely in a secure place not accessible to anyone except the research team.

We would like to make special emphasis in the fact that this letter is an invitation for your voluntary participation in the study, and that your selection was made randomly and therefore not based in any personal characteristic.

Sincerely

Dra Maritza de Garay
Instructor y Master in Public Helath student
Microbiology Dept, UNAH
4to piso del edificio CB,

Ciudad Universitaria, Tegucigalpa
Teléfono 232-5836

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Appendix A - Invitation Letter (Spanish Version)

Carta De Invitacion E Informacion Sobre El Proyecto "Impacto De La Educación Sanitaria En El Control De Las Infecciones Por *Taenia solium* (Solitaria)"

Sr./ Sra:

Por este medio lo estamos invitando a que participe en el estudio de investigación "IMPACTO DE LA EDUCACIÓN SANITARIA EN EL CONTROL DE LAS INFECCIONES POR *Taenia solium* (SOLITARIA)"

Dicho estudio de investigación es patrocinado por la Universidad Nacional Auntónoma de Honduras (UNAH) y la Universidad de Brock, Ontario Canada. El mismo ha sido revisado y aprobado por la Dirección de Investigación Cientifica de la UNAH, (oficio # 015-DICU) y por el comite de etica de la Universidad de Brock (expediente REB # 01-238).

El investigador principal del estudio es la Doctora Ana L. Sanchez, Profesor de la Universidad de Brock (teléfono en Canada # 905-6885550 ext 4388) quien actúa en calidad de asesora, y la co-investigadora principal es la Dra. Maritza Canales de Garay, Profesora del Depto. de Microbiologia de la UNAH (Telefono 232-5836). Cualquier informacion respecto a este studio la puede obtener con la Dra. Lourdes de Madrid en la UNAH y con el Dr. Doctor Ivàn Lanza, el en Centro de Salud, telefono 775 8329.

El propósito del estudio es el de documentar los efectos beneficiosos de una campaña de educación en la cual se enseñen los principios básicos de prevención y control del gusano conocido como solitaria, el mismo que causa la cisticercosis (o semilla) en los cerdos (científicamente llamados *Taenia solium* y cisticercosis respectivamente).

La solitaria es un gusano que afecta tanto a los seres humanos como a los cerdos. En las personas, la solitaria puede localizarse como gusano adulto en el intestino o en el cerebro como cistercerco, que es cuando puede causar serios problemas neurológicos especialmente epilpsia. En los cerdos, el gusano produce solamente cisticercosis (conocida como semilla), que se aloja especialmente en la carne. Cuando las personas comen carne de cerdo con cisticercosis adquieren el gusano intestinal y se completa el ciclo de vida del párasito. Este párasito produce problemas médicos en las personas y también pérdidas económicas por el decomiso de carne de cerdo infectada. En comunidades donde este parásito abunda, es necesario implentar medidas para prevenir y control su diseminación. Los estudios demuestran que la educación es un componente principal de toda programa destinado para tales efectos, pues teniendo conocimiento de como se transmite el parásito, es mas fácil implementar y sostener medidas de prevención y control.

Usted ha sido elegido al azar (por medio de una rifa) para participar en la evaluación de la campaña de educación que queremos implementar. Si usted decide participar voluntariamente en el estudio, su participación consistiría en participar en las las actividades educativas y colaborar respondiendo un cuestionario sobre la solitaria y algunos datos personales sobre su persona antes de la campaña, unos dias después y a los 4-6 meses después. Responder a las preguntas del cuestionario le tomaria aproximadamente una hora cada vez.

Si decide participar y contestar el cuestionario, usted es libre de no contestar preguntas que no le parezcan apropiadas. El tipo de preguntas que se harían son como la siguiente:
"Como cree usted que una persona le sale solitaria:
a) por comer carne de cerdo con semilla
b) Por tomar agua sucia
c) Por comer vegetales sin lavar
d) por contaminarse con excrementos humanos o de cerdo"

También se le pediría al principio del estudio que nos permita obtener una muestra de sangre, y nos provea una muestra de heces para ser analizados en el laboratorio de la UNAH.

Participar en esta investigación no convella riesgos para su persona. Pero podria experimentar alguna incomodidad pasajera cuando le tomemos la muestra de sangre. Proveer una muestra de heces no representa tampoco ningun rieso para usted si observa medidas de higiene normales y utiliza el material que le proveamos para ello. Algunas personas se sienten apenadas por proveer una muestra de heces, por lo que nos aseguraremos de que cuando usted la entregue sea de una manera confidencial.

En ningun momento tendrá usted que gastar dinero al participar en el estudio. Asimismo, no se le dara ninguna remuneración economica por participar.

Los beneficios que usted obtendria al participar serian ganar educación para contrarrestar un problema tan serio como es la solitaria en su comunidad. Ademas de ello, se le harán exámes de laboraortorio completamente gratis, y los resultados servirán para que se dé cuenta si tiene solitaria u otro parásito intestinal y reciba tratamiento antiparasitario en el centro de salud. Algunas personas podrian sentirse ansiosas mientras esperan los resultados de los exámens, por lo cual haremos todo lo posible por proporcionarle los resultados lo más pronto posible.

En cuanto a la información que usted provea, sera mantenida confidencial en todo momento del estudio, respetanto su privacidad y la de su familia. Los datos que usted nos proporcione formarán parte de una base de datos en la que su nombre e identificación personal seran removidos. La base de datos será guardada indefiidamente bajo condiciónes de seguridad.

Cualquier reporte o publicación con los resultados del estudio sera de naturaleza estadística colectiva y su nombre no será revelado en ninguna instancia.

Deseamos enfatizar que esta es una invitación para su participación voluntaria, y que el hecho que haya sido seleccionado no lo obliga a participar. Su selección para este estudio es puramente fortuito y no esta directamente relacionado con su persona o sus caracteristicas individuales.

Atentamente,

Dra Maritza de Garay
Instructor y estudiante de Maestria
Depto de Microbiologia, UNAH
4to piso del edificio CB, Ciudad Universitaria, Tegucigalpa
Teléfono 232-5836

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CODE #:

Appendix B - Informed Consent (English Version)

Authorization to participate in the research study "The Impact of Health Education in the Control of *Taenia solium* Infections"

1. I ___________ accept to participate (or authorize the participation of my minor child) in the research study "The Impact of Health Education in the Control of *Taenia solium* Infections" to be conducted in this community by research teams from the National University of Honduras and Brock University, Ontario, Canada. I understand that this is a research study approved by the Research Ethics Boards from both institutions and that it complies with all scientific requirements.
2. I have read the invitation/information letter, and I understand that that purpose of the present study is to assess the beneficial effects of an educational programme in which the basic principles of prevention and control for the tapeworm parasites *Taenia solium* will be taught to the population of this community.
3. I understand that I myself (or my minor child) have been randomly selected and invited to participate voluntarily in this study and that I am not under any obligation to accept.
4. I understand that the duration of the study is approximately six months, and that my active participation will be required only at the beginning and the end of the programme.
5. I understand that if I decide to participate I have the right to withdraw from the study at any moment.
6. I understand that I will not receive any monetary compensation by participating in the study, nor that I will have to pay for any expenses related to the study.
7. I understand that I myself (or my child) will be asked to answer questions during a one-hour interview prior to the campaign, to determine our knowledge about the parasite. I understand that my name and address, as well as literacy, household conditions and animal husbandry will be asked during this interview. I understand that I have the right not to answer any questions that I consider not appropriate.
8. I understand that at the end of the interview we will be asked to provide a blood sample (4 ml) to determine the presence of *Taenia solium* antibodies. I am aware that the researchers will use sterile and disposable materials and that there is no risk of infection for me or my child on having our blood sample taken. However, I am aware that during the process of blood sampling I could experience some physical discomfort and that after the blood is drawn, a few drops of blood might be visible in the puncture area and that this will stop as soon as normal blood clotting takes place. In some cases, I understand that a bruise may remain in the site of the puncture, which will disappear in a few days. I understand that the amount of blood to be taken is normal for that kind of testing and that there is no health risk in providing 4 ml of blood. I understand that my blood sample will not be used for any other type of test. If my child refuses to have his blood sample taken, I understand that his wishes will be respected even though I have given consent for his participation.
9. I understand that we will be required to provide a stool sample to determine the presence of *Taenia solium* and other intestinal parasites. I will be provided with materials and instructions to collect such sample and I understand that there is no risk in collecting the sample provided I take hygienic measures. I understand that I will take the sample to the health centre or any other place indicated by the researchers, and that the sample will be analyzed later at the university (UNAH) laboratory. The container in which I collect the stool sample will bare only a numeric code, and

confidentiality will be assured when I deliver the sample. I understand that I don't have to provide the sample if I feel too embarrassed to provide the sample, or if it is impossible for me to do so.

10. I understand that I will be provided with laboratory results after analyses are done and that I will be provided with an explanation of those results. I understand that if it is found that I have intestinal parasites I have the right to seek medical attention at the health centre for anti-parasitic treatment. I might be asked to collect tapeworm parasites expelled after treatment so species identification can be performed. In this case, I will be given detailed instructions to collect the tapeworms without causing contamination to my self or my family.
11. I understand that all these laboratory tests are free of charge and that I will be provided with the results even if I withdrew from the studies.
12. I understand that I will be interviewed for an hour a few days after the educational campaign and again after four to six months to compare the knowledge that I have gained during the programme.
13. I understand that there are some benefits associated with my participation in this study. The knowledge that I gain could be used to protect my health and the health of my family. Similarly, this knowledge will allow me to prevent future infections in the pigs I might raise, representing an economic benefit for the community and me.
14. I understand that all information obtained during the interviews and laboratory analyses will be aggregated and that my identity will remain anonymous throughout the studies.
15. I understand he researches will write a report or publication with the results of this study, but that no personal association to myself, my child or any other participant will be possible.
16. I understand that an electronic database will be kept indefinitely without any personal identification in a secure place only accessible to the researchers.
17. I understand that if I have any questions regarding the study, I can contact Mrs. Maritza Canales at the Microbiology Department, UNAH, CB Building, phone number 232 5836.
18. I understand that by signing this consent, I am expressing my understanding and acceptance to participating in this study. In case I am unable to sign, I understand that a witness will be asked to sign this form to validate my verbal consent.

Printed name and signature: ____
Printed name and signature of witness in case of verbal consent: ____

Printed name and signature of legal guardian if participant is under 18 years of age:

____

Relationship with minor:

____

Place and date:

____

Interviewed by:

____

Appendix B - Informed Consent (Spanish Version)

CODIGO:

CONSENTIMIENTO INFORMADO
Autorizacion Para La Participacion En El Estudio De Investigación "Impacto De La Educación Sanitaria En El Control De Las Infecciones Por *Taenia solium* (Solitaria)"

1. Yo, el abajo firmante, acepto participar (o autorizar la participacion de mi menor hijo o hija) en el estudio de investigación "Impacto de la educación sanitaria en el control de las infecciones por *Taenia solium* (solitaria)" realizado en esta comunidad por personal docente de la Universidad Nacional Autonoma de Honduras, Honduras, y la Universidad de Brock, (Ontario, Canada). Entiendo que este es un estudio de investigación aprobado por los comités de ética de las instituciones mencionadas y que cumple con todos los requisitos científicos de un estudio de este tipo.

2. He leido la carta de invitacion-informacion y entiendo que **el fin de la presente investigación** es documentar los efectos beneficiosos de una campaña de educación donde se enseñen los principios básicos de prevención y control del gusano conocido como solitaria, el mismo que causa la cisticercosis (o semilla) en los cerdos (científicamente llamados *Taenia solium* y cisticercosis, respectivamente).

3. Entiendo que yo (o mi menor hijo) he (hemos) sido hemos sido seleccionados al azar e **invitado (s)** a participar en el estudio de investigación antes mencionado en forma **voluntaria** y que no estoy obligado a aceptar participar en el mismo.

4. Entiendo que la duración del estudio es aproximadamente de 6 meses, siendo mi participacion requerida solamente al princio y al final del mismo.

5. Entiendo que si decido participar (o autorizar a mi hijo a participar), conservo del derecho de retirarme del estudio en cualquier momento que yo decida conveniente.

6. Entiendo que no recibire **ningun tipo de remuneración** económica por el hecho de participar en el estudio, y que tampoco tendre que gastar dinero por participar.

7. Comprendo que yo o mi hijo **seremos entrevistados** durante una hora para obtener información sobre nuestros conocimientos sobre la solitaria, antes de comenzar la campaña de educación. Entiendo que en la entrevista se registrará nuestro nombre y dirección y que se nos harán preguntas personales sobre nuestra edad, si sabemos leer y escribir, datos sobre nuestra casa, crianza de animales y otras condiciones de la vivienda. Entiendo que yo o mi hijo podemos negarnos a contestar algunas preguntas si no nos parecen apropiadas y que podemos retirarnos del estudio al momento de la entrevista.

8. Comprendo que al final de la entrevista se nos pedirá a mi o a mi hijo que nos dejemos tomar una **muestra de sangre** (una pequeña cantidad de 4 ml) para investigar en ella si tenemos o no anticuerpos contra la solitaria. Entiendo que los investigadores usarán exclusivamente material estéril y descartable, que no presenta para mi o mi hijo ningún riesgo de adquirir ningun tipo de infección.
   Es de mi conocimiento que los riesgos asociados a la extracción de sangre son **un**

poco de dolor al momento de insertar y extraer la jeringa, y que unas **pequeñas gotas de sangre** pueden fluir del lugar de la punción una vez retirada la aguja, hasta que la punción se coagule naturalmente. Entiendo que en algunos raros casos, puede quedar una **marca morada**, acompañada de dolor en el lugar de la extracción, la cual desaparecerá en pocos días.
Entiendo que mi salud no sufrirá por dar esa pequeña cantidad de sangre, que la normal que se extrae para la prueba de anticuerpos.
Entiendo que mi sangre no se utilizara para ningún otro tipo de prueba.
Entiendo que mi hijo puede rehusar que se le extraiga la sangre, en tal caso, se respetará la decisión de mi hijo aunque yo haya autorizado la extracción de la muestra.

9. Entiendo que se nos pedirá a mi o a mi hijo que recojamos **una muestra de heces** para investigar si tenemos solitaria u otros parásitos intestianales. Se me proveerá con un recipiente limpio, con el código que me corresponde escrito en el recipiente, y se me darán intrucciones de cómo recoger la muestra de una manera limpia y segura. Entiendo que llevaré la muestra al centro de salud u otro lugar indicado, para que sea trasladada al laboratorio para su análisis. Entiendo que si me siento demasiado **apenado** por dar este tipo de muestra, o si es imposible para mí proveerla, no seré obligado o coarcionado para entregarla.
Entiendo que **no existe ningún riesgo** en la proporción de esta muestra de heces si lo hago de una manera cuidadosa e higiénica.

10. Entiendo que los investigadores me **proporcionarán los resultados del analisis de mi muestras** de sangre y de heces. Entiendo que ellos me explicarán el significado de los resultados y que dependiendo de si tengo parásitos intestinales ellos me pueden sugerir que visite el centro de salud para ser evaluado por el medico (o enfermera) y que me den tratamiento para expulsar los parásitos.
Entiendo que si tengo solitaria, los investigadores pueden pedirme que recoga los gusanos que expulse después del tratamiento para que ellos puedan hacer una investigación específica del gusano. En el caso de que tenga que recoger gusanos de solitaria, los investigadores me darán los recipientes e intrucciones adecuadas para que no represente ningún peligro de contaminación para mi persona o miembros de mi familia.

11. Entiendo que todos los análisis de laboratorio serán completamente **gratuitos** y que me seran entregados aunque me retire del estudio posteriormente.

12. Entiendo que después de la campaña de investigación, los investigadores me visitarán de nuevo a mi o a mi hijo dos veces más: unos dias después de la campaña y a los 4-6 meses después, y me harán otra vez preguntas durante una hora sobre la solitaria para verificar cuánto aprendí durante la campaña.

13. Entiendo que mi participacion o la de mi hijo en este estudio involucra ciertos beneficios, ya que podré aprender cómo evitar el gusano de la solitaria, el cual puede afectarme a mí, a mi familia y también a los cerdos que pueda criar ahora o en el futuro. Entiendo que si aprendo cómo se transmite este gusano, podré tomar acciones para evitarlo, lo cual redundará en beneficios de salud y economía.
Otro beneficio directo de esta investigación para mí o mi hijo es la posibilidad de que se descubra que tengo parásitos intestinales mediante el análisis de mi muestra de heces, que de otra manera no hubiera tenido conocimiento. Debido a que los

gusanos son malignos para mi salud, tendré un gran beneficio si debido al estudio puedo recibir tratamiento antiparasitario.

14. Comprendo que todos los datos personales que se obtengan durante las entrevistas y análisis de muestras, serán sólo del conocimiento de los investigadores y que ellos no divulgarán ningun tipo de informacion que pueda ser asociada con mi identidad o la de mi hijo.

15. Entiendo que los investigadores harán un reporte de los hallazgos del estudio, pero que en el mismo no aparecerán datos personales por los que personas ajenas al estudio puedan asociar mi identidad o la de mi hijo con la información.

16. Entiendo que los investigadores velarán por que toda la información se mantenga segura y confidencial.

17. Entiendo que si tengo alguna pregunta, podré recurrir a la Dra. Maritza Canales en el Depto de Microbiologia de la UNAH, y que ella puede ser localizada en el 4to piso del edificio CB de la ciudad Universitaria en Tegucigalpa, o que la puedo llamar al teléfono 232-5836 para cualquier cosa relacionada con el estudio.

18. Entiendo que firmando este documento acepto todo lo anterior para mí o para mi hijo, y que si por alguna razón no puedo firmar, daré mi consentimiento verbal una vez que se me haya explicado el contenido de este documento en un lenguaje que yo entienda. En caso de consentimiento verbal, otra persona designada por los investigadores servirá como testigo y firmará el documento.

Nombre y firma del **participante directo**:

____

Nombre y firma de **testigo** en caso que el participante directo sea adulto y no pueda firmar

____

Nombre y firma del **guardian legal** si el participante es menor de edad (menor de 18 años)

____

Relación con el menor:______________________________________

Lugar y Fecha:

____

Entrevistador:

____

Appendix C - General Survey Questionnaire (Q1) (English Version)

1. GENERAL INFORMATION
1.1 Date ________________
1.2 Interviewed by ________________
1.3 House code ________________
1.4 House address ________________
1.5 Name of Head of the family ________________

2. HOUSEHOLD CONDITIONS
2.1 Number of adults (>=15 years of age) living in your house ________________
2.2 Number of children (>=10 and <15 years of age) living in your house ____________
2.3 Total number of persons living in your house ________________
2.4 Total number of rooms in your house ________________
2.5 Total number of rooms used as bedrooms in your house ________________
2.6 What is the type of floor in your house?
1. earth 2. cement 3. tiles 4. others
2.7 What is the type of feces disposal system in your house?
1. toilets 2. latrine 3. none
2.8 If you have latrine, do you use it?
1. yes 2. no
2.9 Does everybody in your house use the latrine?
1. yes 2. no
2.10 Who in your house do not use the latrine? ________________
2.11 How do you discard the sanitary paper?
1. within latrine 2. into waste basket 3. burns 4. other
2.12 What type of water do you drink?
1. tap 2. river 3. well 4. others
2.13 How do you treat the drinking water?
1. directly drink as it is 2. chlorinated 3. boiled

3. PIG FARMING
3.1 Are there any pigs being raised in your household?
1. yes 2. no
3.2 If yes, how many pigs do your have? ________________
3.3 Where are the pigs kept?
1. free within the house 2. free within the town
3. backyard with other animals 4. pig-pen 5. tied
3.4 Have you ever had pigs with cysticercosis in this household?
1. yes 2. no

4. PERSONAL INFORMATION
4.1 Name ________________
4.2 Age ________________
4.3 Gender ________________
1. female 2. male
4.4 For how long have you been living in this town?
1. always 2. less than a year 3. more than a year
4.5 What is your literacy level?
1. none 2. know how to read and write but not schooling
3. elementary (primary) incomplete 4. elementary (primary) completed

5. highschool incomplete 6. highschool completed 7. others

5. HYGIENE

5.1 Do you wash your hands after going to the toilet/latrine?
1. yes 2. no

5.2 Do you wash your hands before eating?
1. yes 2. no

5.3 Do you wash your hands before cooking?
1. yes 2. no

6. TAPEWORM CARRIERS (actual worm shown in a jar)

6.1 Have you seen this tapeworm (*Taenia solium*)?
1. yes 2. no

6.2 Are you passing tapeworm segments similar to these?
1. yes 2. no

6.3 If yes, for how long you have been passing segments
1. less than a year 2. more than a year 3. more than two years

6.4 Is any body in your household passing segments like these?
1. yes 2. no

6.5 Has anybody in your household ever passed segments like these?
1. yes 2. no

7. PERSENCE OF NEUROCYSTICERCOSIS (NC)

7.1 Have you ever been diagnosed with NC ("trichina" in your brain)?
1. yes 2. no
If so, for how long you have been diagnosed with NC? ____________________

7.2 Has anybody in your household ever been diagnosed with NC?
1. yes 2. no

7.3 Have you suffered from any of these symptoms?
1. headaches (intense) 2. epilepsy 3. dizziness
4. faint 5. more than one of the above
If epilepsy is present, please provide detailed story, including onset time (early or late after 18 years of age), treatment, hospital or clinic, etc. ______________________

7.4 Has anybody in your household suffered from any of these symptoms?
1. headaches (intense) 2. epilepsy 3. both
If epilepsy is present, please provide detailed story, including onset time (early or late after 18 years of age), treatment, hospital or clinic, etc. ______________________

8. PORK MEAT CONSUMPTION

8.1 Do you eat pork meat?
1. yes 2. no

8.2 If yes, how frequently you eat pork meat?
1. once a week or more 2. every two weeks 3. once a month
4. once in a while 5. others

8.3 Where do you get pork to eat?
1. from my own pigs 2. from neighbours' pigs 3. from another village 4. others

8.4 Is the meat eaten fresh or has been frozen before consumption?
1. fresh 2. frozen

8.5 How do you like your pork meat cooked?
1. well done 2. medium 3. rare

Appendix C - General Survey Questionnaire (Q1) (Spanish Version)

UNIVERSIDAD NACIONAL AUTONOMA DE HONDURAS
PROYECTO IMPACTO DE LA EDUCACION EN EL CONTROL DE INFECCIONES POR *TAENIA SOLIUM*
SECCION PARASITOLOGIA

1. DATOS GENERALES

1.1. Fecha____________________
1.2. Entrevistado por ____________________
1.3. Código de casa______________________
1.4. Dirección de casa______________________
1.5. Nombre de Cabeza de Familia____________________

2. CONDICIONES DE LA CASA

2.1. Número de adultos que viven en la casa (>15)______
2.2. Número de niños (<15 años de edad) que viven en la casa________
2.3. Número total de personas que viven en la casa__________
2.4. Número de habitaciones que viven en la casa____________
2.5. Número total de dormitorios_________
2.6. Tipo de piso.
- ❖ Tierra________
- ❖ Cemento_____
- ❖ Ladrillo_______
- ❖ Otros_______________________________________

2.7. En la casa tiene
- ❖ Servicio sanitario________
- ❖ Letrina_______
- ❖ Ninguno______

2.8. Si tiene letrina, esta en uso SI ☐ NO ☐
2.9. Todos utilizan la letrina/ servicios sanitario SI ☐ NO ☐
2.10. Quienes no la utilizan____________________________________
2.11. Como descarta el papel sanitario.
- ❖ Dentro de la letrina________Quema_______
- ❖ En el basurero____________Otros_______________________

2.12. Tipo de agua que toma
- ❖ Llave_________
- ❖ Río___________
- ❖ Pozo __________
- ❖ Otros________

2.13. Como toma el agua
- ❖ Directamente de la llave o pozo_______
- ❖ Clorada_________
- ❖ Hervida _________

3. CRIANZA DE CERDOS

3.1. Tiene cría de cerdos en la casa SI ☐ NO ☐
3.2. Cuantos (#) ______

3.3. Donde están los cerdos
- ❖ Libres en la casa_______
- ❖ Libres en la calle_______
- ❖ En el patio con otros animales_______
- ❖ Chiquero _______
- ❖ Amarrados ______

3.4. Ha tenido algún cerdo enfermo con triquina o cepillo SI ☐ NO ☐

4. INFORMACIÓN PERSONAL

4.1. Nombre_________________________________
4.2. Edad____________________
4.3. Sexo: Femenino_______ Masculino________
4.4. Hace cuanto vive en esta aldea
- ❖ Siempre_______
- ❖ Menos de un año_______
- ❖ Mas de un año_________

4.5. Nivel de Educación
- ❖ Ninguno________ Sabe leer y escribir______
- ❖ Primaria incompleta__________
- ❖ Primaria completa___________
- ❖ Secundaria incompleta _______
- ❖ Secundaria completa_________
- ❖ Otros ____

5. HIGIENE

5.1. Se lava las manso después de usar la letrina o servicio sanitario
SI ☐ NO ☐
5.1. Se lava las manos antes de comer SI ☐ NO ☐
5.2. Se lava las manos antes de cocinar SI ☐ NO ☐

6. PORTADORES DE TENIASIS (Presentar gusano en frasco)

6.1. Conoce este gusano SI ☐ NO ☐
6.2. Esta eliminando o defecando pedazos de gusano parecidos a este
SI ☐ NO ☐
6.3. Hace cuanto usted eliminó pedazos de gusanos
- ❖ Menos de año__________
- ❖ Mas de un año_________
- ❖ Mas de dos años________

6.4. Sabe usted si alguien de la familia está eliminado de estos pedazos
SI ☐ NO ☐
6.5. Sabe usted si algún miembro de la familia estuvo eliminando estos pedazos
SI ☐ NO ☐

7. PRESENCIA DE NEUROCISTICERCOSIS

7.1 Ha sido diagnosticado de neurocisticercosis SI ☐ NO ☐
(Si es así obtener detalle de la Historia)
7.2 Algún miembro de la familia ha sido diagnosticado por neurocisticercosis
SI ☐ NO ☐
7.3. Ha sufrido o padecido de:
- ❖ Dolor de cabeza intenso_________
- ❖ Epilepsia_____________

- ❖ Vértigo, mareo________
- ❖ Desmayos ___________

7.4. Alguien de la familia a padecido alguno de estos síntomas

- ❖ Dolor de cabeza_________
- ❖ Epilepsia__________

(Si alguien ha padecido de epilepsia obtener detalle de la historia si es menor de 18 años tratamiento Hospital o Clínica)

8. CONSUMO DE CARNE DE CERDO

8.1 Come usted carne de cerdo SI ☐ NO ☐

8.2 Si es sí, con que frecuencia

- ❖ Una vez a la semana_______
- ❖ Cada dos semanas_________
- ❖ Cada mes______
- ❖ Pocas veces al año_____________
- ❖ Otro_____________________________

8.3 De donde obtiene la carne de cerdo

- ❖ Cerdos de la casa____________
- ❖ Cerdos del vecino____________
- ❖ Cerdos de la comunidad_______
- ❖ De otra aldea_______

8.4 La carne de cerdo que consume es

- ❖ Fresca_______
- ❖ Congelada _______

8.5. Como le gusta comer la carne de cerdo

- ❖ Bien cocida________
- ❖ Media cocida_______
- ❖ Chorizada ________

Appendix D - Knowledge Questionnaire (Q2) (English Version)

1. GENERAL DATA
1.1 Date ____________________
1.2 Interviewed by __________________
1.3 House code _______________
1.4 House address _______________
1.5 Name of Head of the family ________________

2. PERSONAL INFORMATION
2.1 Name ____________________ Code # [ ]
2.2 Age ____________________
2.3 Gender: Female ______ Male ______

Pre- or Post- Education Questionnaire to Assess Knowledge Changes About *Taenia solium* Transmission and Clinical Information

1. HOW IS THE INTESTINAL TAPEWORM ACQUIRED?
   A person who is passing PAJUELAS (tapeworm segments) in his/her feces, acquired the infection by:
   a) eating raw vegetables contaminated with tapeworm eggs
   b) eating undercooked pork meat with cysticercosis or “semilla”
   c) eating food contaminated by soil or other contaminants
   d) drinking dirty water
   e) do not know

2. HOW IS BRAIN CYSTICERCOSIS ACQUIRED?
   A person with SEMILLA in his/her brain acquired the infection by:
   a) eating raw vegetables contaminated with tapeworm eggs
   b) eating undercooked pork meat with cysticercosis or “semilla”
   c) eating food contaminated by soil or other contaminants
   d) drinking dirty water
   e) do not know

3. HOW PIGS ACQUIRE CYSTICERCOSIS?
   If a person is raising pigs and one of them turned out to have MAICILLO when slaughtered, what is most likely to have happened?
   a) the pig was born with MAICILLO passed on by mother
   b) the pig acquired MAICILLO from its siblings
   c) the pig has been eating garbage
   d) the pig ate human feces from someone with tapeworm
   e) do not know

4. WHAT OTHER ANIMALS CAN HAVE “SEMILLA” (CYSTICERCOSIS)?
   What animals other than pigs do you think may also have SEMILLA?
   a) cows
   b) dogs
   c) cats
   d) chicken

e) all of them
f) none of them

5. EPIDEMIOLOGICAL IMPORTANCE OF A PERSON WITH TAENIASIS
Why is it important for the rest of the household members that a person with tapeworm is diagnoses and treated?
a) because if someone is passing "PAJUELAS" others in the family are going to start passing PAJUELAS as well
b) because if someone with PAJUELAS defecates in the open and pigs eat those feces, they are going to get "SEMILLA"
c) because people with PAJUELAS is the source for other people and pigs to acquire "SEMILLA"
d) it is not important, because PAJUELAS are not transmissible to others
e) do not know

6. CLINICAL IMPORTANCE OF TAENIASIS
a) because tapeworms are dangerous and someone may die from the infection
b) because the tapeworm can go to your brain
c) tapeworms cause diarrhea and steal your food in your intestine
d) worms in your intestine may cause seizures
e) do not know

7. CLINICAL IMPORTANCE OF NEUROCYSTICERCOSIS
What symptoms are common when a person has brain cysticercosis?
a) headache
b) seizures or epilepsy
c) dizziness
d) all of them
e) do not know

8. CAUSES OF EPILEPSY
Which of the following do you believe do not cause seizures or epilepsy? (Which of the following is not correct?)
a) intestinal worms
b) SEMILLA in the brain (CNS)
c) head TRAUMA
d) genetic reasons
e) do not know

9. TREATMENT OF TAENIASIS
A person infected with intestinal tapeworm may be cured by
a) a purgative with ricin oil
b) eating garlic clove everyday before breakfast for 30 days
c) with special antiparasitic treatment
d) there is not cure for this parasite
e) do not know

10. TREATMENT OF HUMAN NEUROCYSTICERCOSIS
Do you think there is cure for a person diagnosed with TRICHINA (NC) in their brain?
a) yes, NC can be treated easily with medicines prescribed by the doctor

b) yes, there is treatment but it is only effective when the disease is starting
c) no, there is no cure for neurocysticercosis
d) do not know

[PLEASE BE AWARE THAT HONDURAN PEOPLE FROM RURAL AREAS DO NOT CALL PARASITES BY TECHNICAL OR SCIENTIFIC NAMES, so giving a Spanish transcript may not be useful. IN THE CASE OF *Taenia solium*, they call the worm "SOLITARIA" (solitaire) and the worm segments "PAJUELAS" (no translation). They call cysticerci "SEMILLA" (seed) or "MAICILLO" ("SORGHUM") because of its appearance in meat, or even "TRIQUINA" ("TRICHINA") which is totally incorrect, but somehow is a term used in much of Latin America, including Mexico (Trichinosis is caused by another parasite infecting same hosts)].

Appendix D - Knowledge Questionnaire (Q2) (Spanish Version)

UNIVERSIDAD NACIONAL AUTONOMA DE HONDURAS
PROYECTO IMPACTO DE LA EDUCACION EN EL CONTROL DE INFECCIONES POR *TAENIA SOLIUM*
SECCION PARASITOLOGIA

1. DATOS GENERALES
1.1. Fecha____________________
1.2. Entrevistado por ____________________
1.3. Código de casa____________________
1.4. Dirección de casa________________________
1.5. Nombre de Cabeza de Familia____________________

2. INFORMACION PERSONAL
2.1. Nombre______________________________ Código [ ]
2.2 Edad________________
2.3. Sexo: Femenino____ Masculino_____

PRE Y POS TES PARA VALORAR EL CONOCIMIENTO ANTES Y DESPUES DE LA CAMPAÑA DE EDUCACION

Código [ ]

1. Como se adquiere la teniasis ó solitaria?
   Cuando una persona está eliminando o excretando pedazos de gusanos en heces adquirió la infección por:
   a) Comer vegetales crudos contaminados con huevos de (solitaria)
   b) Comiendo carne de cerdo mal cocinada con triquina
   c) Comiendo comida contaminada con tierra
   d) Tomando agua sucia
   e) No sabe

2. Como se adquiere la Cisticercosis?
   Una persona, con triquina o cisticerco en el cerebro adquirió la enfermedad por:
   a) Comiendo vegetales crudos contaminados con huevos de solitaria
   b) Comiendo carne de cerdo mal cocida con triquina o cisticerco
   c) Comiendo comida contaminada con tierra
   d) Tomando agua sucia
   e) No sabe

3. Como adquiere el cerdo la cisticercosis o triquina semilla?
   Si una persona cría cerdos y uno de ellos aparece con triquina como se enfermo el cerdo.
   a) El cerdo nació con triquina pasada por la madre
   b) El cerdo adquirió triquina de otro cerdo
   c) El cerdo ha comido basura

d) El cerdo comió heces humanas de alguien con solitaria
e) No sabe

4. Que otros animales pueden tener cisticercosis o triquina?
   Que otros animales además del cerdo pueden tener triquina o cepillo
   a) Vacas
   b) Perros
   c) Gato
   d) Pollo
   e) Todos ellos
   f) Ninguno de ellos

5. Importancia epidemiológica de una persona con Teniasis ó solitaria. (Portador)
   Porque es importante, que una persona que tenga solitaria, sea diagnosticado y tratado.
   a) Porque si alguna tiene solitaria en la familia, otros familiares podían comenzar a eliminar pedazos de solitaria también
   b) Porque si alguno en la familia, defeca al aire libre, y tiene solitaria, los cerdos podrían comerse estas heces y así pueden obtener la triquina
   c) Porque una persona con solitaria es la fuente para que otras personas y cerdo adquiera triquina
   d) No es importante, porque la solitaria no se transmite a otras personas.
   e) No sabe

6. Importancia clínica de Teniasis
   Es importante saber sí una persona tiene solitaria, porque:
   a) Estos gusanos son dañinos y algunos pueden causar infección y la muerte
   b) Porque estos gusanos pueden llegar al cerebro
   c) Estos gusanos pueden causar diarrea, y roban sus alimentos que consume en el intestino.
   d) Los gusanos en el intestino pueden llegar a causar enfermedades
   e) Se desconoce.

7. Importancia clínica de la NCC
   Que síntomas son comunes en una persona con cisticercosis cerebral
   a) Dolor de cabeza
   b) Epilepsia o ataques
   c) Mareos, desmayos
   d) Todos los anteriores
   e) No se conoce

8. Causas de la epilepsia
   Cual de las siguientes, cree, causa epilepsia
   a) Solitaria en el intestino
   b) Triquina en el cerebro
   c) Un golpe en la cabeza
   d) Causas genéticas
   e) No sabe

9. Tratamiento de Teniasis
   Una persona infectada con solitaria puede curarse con:

a) Purgante de aceite de recino
b) Alimentarse comiendo dientes de ajo por 30 días en ayunas
c) Tomando antiparasitante
d) No hay cura para este parásito
e) No se sabe

10. Tratamiento de neurocisticercosis humana
    Como cree usted que se puede curar una persona diagnosticada con triquina en el cerebro (NC)
    a) Si N.C.C. puede ser tratada por medicina prescrita por un doctor
    b) Si ese tratamiento puede ser efectivo cuando la enfermedad es tratada al comienzo
    c) No hay cura para la neurocisticercosis
    d) No se sabe

Appendix E - Enzyme-Linked Immunoelectrotransfer Blot Technique

Enzyme-linked immunoelectrotransfer blot technique (EITB), developed at the CDC, Atlanta, Georgia, USA by Tsang, Brand and Boyer in 1989, is the most frequent method to be used for detection of antibodies to specific *T. solium* glycoproteins.

Reagents and Materials

Materials:

incubation tray

disposable pipettes and tips

forceps

rocking platform

micropipettes and tips

vacuum system (a water aspirator with a trap)

paper towel

small glassware

marker

Reagents:

wash buffer (0.05 *M* PBS; 0.2 *M* Tween and 0.2 *M* non-fat dry milk);

goat anti-human immunoglobulin-alkaline phosphatase conjugate;

distilled/deionized H_2O,

PBS buffer (140 m*M* NaCl, 2.7 m*M* KCl, 10 m*M* Na_2HPO_4 and 1.8 mM KH_2PO_4; pH 7.4)

Experimental Procedure

There are four main steps: a) preparation of parasite antigens; b) sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) and transfer; c) western blotting; and d) interpretation. The available commercial kits for diagnosis CC by EITB technique have already achieved the steps of a), b) and part of the c), so the emphasis of the procedure to be used in this study will be centralized to the remainder steps of c) and d). In brief, the whole procedure of EITB technique is performed as follows:

a) Preparation of parasite antigens

Antigens have been collected from the cysts of naturally infected pigs. After repetitious homogenization and centrifugation, the proteins are solubilized in urea/PMSF buffer and ultracentrifuged. Then, the extract (glycoproteins) has been purified by lentil lectin affinity chromatography.

b) SDS-PAGE and transfer; and c) western blotting

The lectin-bound antigens are detached using SDS-PAGE and transferred from the gel to a nitrocellulose membrane through electrophoresis. After SDS-PAGE, the membranes are blotted. The blotted membrane is then cut into 36-44 identical 3-mm strips and stored at -60°C as strip production for individual serum/CSF sample testing. A completely commercial kit includes preblotted antigen strips and all of the reagents needed for screening.

d) Interpretation

After the development with goat anti-human immunoglobulin-alkaline phosphatase conjugate to human IgG and substrate, those glycoproteins derived from cysts are designated to seven bands by their respective molecular weights in thousands as

GP50, GP39-42, GP24, GP21, GP18, GP14 and GP13. The EITB distinguishes inspected diluted samples (involving antibodies) to any one of the seven diagnostic bands. In 98% of the time, infected samples could act with one more bands. The proteins most frequently recognized are the GP39-42 complex (95%) and GP 24 (94%), GP14 and GP13 are identified the least.

The detailed experimental steps after buying commercial kits are described as follows:

1) Dispense 1 ml of wash buffer into each channel of the incubation tray.
2) Place one membrane strip face up into each channel of the tray by using forceps. Then mark each strip at the top of the upper side with a number and a black line.*
3) Place the tray on the rocking platform (10-15 cycles/minute) and incubator for 30 minutes to wet the strips thoroughly. Meanwhile, dilute serum samples to 1:50 or CSF samples to 1:10 by using PBS/milk solution.
4) Turn on the vacuum system (a water aspirator with a trap is sufficient).
5) Aspirate the liquid completely from individual channels using a disposable pipette tip connected to the vacuum system.
6) Load samples to be tested immediately in order to avoid drying of Western Blots.
7) Load 0.8 ml of diluted negative control sample into channel 1 and 0.8 ml of diluted positive control sample into channel 2 (other channels can be used if preferred).**
8) Load 0.8 ml of diluted serum/CSF sample into the appropriate numbered channel

corresponding to the sample sequence of every experimental project itself. ***

9) Incubate on the rocking platform for 60 minutes.

10) Aspirate liquid from each channel by vacuum as described in step 5).

11) Rinse Western Blot strips by adding approximately 1 ml of wash buffer to each channel, then aspirating the liquid by vacuum.

12) Repeat step 11) four more times and each time lasts 5 minutes.

13) Load 0.75 ml of 1 × Enzyme Conjugate into each channel and incubate on the rocking platform for 30 minutes.

14) Rinse strips using wash buffer for five times and then using wash buffer without the component of Tween for two times as described in step 11) and 12).

15) Add 0.8 ml of distilled/deionized H_2O to each channel.

16) Place the tray on the rocking platform to initiate color reaction. Then, allow the color reaction to develop on the rocking platform (10-15 cycle/minute) for 6-8 minutes, or until the positive control serum immunoreactive bands are visible. The duration of incubation should not be longer than 20 minutes.

17) Stop color development by rinsing the western blots with distilled or deionized water.

18) Transfer Western Blots to face up to a paper towel by using forceps, and let air dry approximately 3 hours.

19) Interpret results until blots are completely dry. To interpret data, compare the strip to the lot-specific immunostained Reference Strip included with every kit for band identification and the intensity of the bands is monitored by comparison to the Cysticercosis Positive Control.

* Before using stored strips, defrosting is needed to them at 37ºC, keeping moist. Once incubation, strips must be under the fluid surfaces.

** Step 7) is optional.

*** The tray must be gently rocked back and forth for completely submersing strip.

Appendix F - Kato-Katz Concentration Technique

Kato-Katz concentration technique, also called cellophane faecal thick-smear technique, has proved to be an efficient means of diagnosis of intestinal helminths, including *Taenia solium*.

Kato and Myurous introduced this technique in 1954 and the technique was initially published in English in 1966 by Komiya and Kobayashi. Many modifications of the original technique have occurred; in 1991 WHO published the modified technique, which has been accepted and used worldwide currently.

Materials and Reagents

Spatula (plastic) or applicator sticks (wooden)

Screen, stainless steel, nylon or plastic---60-105 mesh

Template, stainless steel, plastic or cardboard

Microscope slides

Cellophane, hydrophilic, 40-50 μm thick, strips 25 × 30 or 25 × 35 mm

Flat-bottomed jar

Forceps

Toilet paper or absorbent tissue

Newspaper

Glycerol-malachite green (or methylene blue) solution

Experimental Procedure

1) Soak cellophane strips in the 50% glycerol-malachite green (or methylene blue) solution for at least 24 hours before use.
2) Transfer a small amount of fecal material on to a piece of scrap paper or newspaper
3) Press a piece of nylon screen on top of the faecal sample so that some of the feces sieved through the screen and accumulated on top.
4) Using a flat-sided spatula or a applicator stick to scrape across the upper surface of the screen to collect the sieved feces.
5) Place a template on a clean microscope slide.
6) Add a small amount of the sieved feces with the spatula or applicator stick into the hole of the template and completely fill the hole.
7) Remove excess feces from the edge of the hole by using the spatula or applicator stick.
8) Remove the template carefully so that a cylinder of feces is left on the slide without leaving some fecal material sticking to the template.
9) Cover the fecal material on the slide with a pre-soaked cellophane strip.
10) Wipe off excess glycerol from the upper surface of the cellophane by using a small piece of toilet paper or absorbent tissue.
11) Invert the microscope slide and press the fecal sample firmly against the cellophane strip on a smooth surface (a piece of tile or flat stone is ideal) to spread the sample evenly.

12) Place the slide on the bench with cellophane upwards to enable the evaporation of water while glycerol clears the feces; do not lift the slide straight up; the cellophane may separate.
13) Keep the slide for one or more hours at room temperature to clear the fecal material, and then detect the eggs or gravid proglottid segments or both under microscopic examination.

Appendix G - Ethics Forms

Brock University Research Ethics Board

Brock University

artment of Community Health Sciences
St Catharines, Ontario
Canada L2S 3A1
Telephone (905) 688-5550 Ext. 4228
Fax (905) 688-8954

"Senate Research Ethics Board **Extensions 3205/3035, Room C315**

DATE: April 25, 2002

FROM: David Butz, Chair
Senate Research Ethics Board (REB)

TO: Ana Sanchez, Community Health Sciences
Maritza Canales, Microbiology, UNAH

FILE: 01-238 Sanchez/Canales

TITLE: The Impact of Health Education in the control of *Taenia solium* infections

The Brock University Research Ethics Board has reviewed the above research proposal.

DECISION: Accepted a s clarified. (Please provide us - as soon as possible - with the name and position of a local contact person participants will be referred to.)

This project has been approved for the period of **April 25, 2002** to **December 31, 2002,** subject to full REB ratification at the Research Ethics Board's next scheduled meeting. The approval may be extended upon request. ***The study may now proceed.***

Please note that the Research Ethics Board (REB) requires that you adhere to the protocol as last reviewed and approved by the REB. The Board must approve any modifications before they can be implemented. If you wish to modify your research project, please refer to www.BrockU.CA/researchservices/forms.html to complete the appropriate form ***REB-03 (2001) Request for Clearance of a Revision or Modification to an Ongoing Application.***

Adverse or unexpected events must be reported to the REB as soon as possible with an indication of how these events affect, in the view of the Principal Investigator, the safety of the participants and the continuation of the protocol.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and approvals of those facilities or institutions are obtained and filed with the REB prior to the initiation of any research protocols.

The Tri-Council. Policy Statement requires that ongoing research be monitored. A Final Report is required for all projects, with the exception of undergraduate projects, upon completion of the project. Researchers with projects lasting more than one year are required to submit a Continuing Review Report annually. The Office of Research Services will contact you when this form ***REB-02 (2001) Continuing Review/Final Report*** is required.

Appendix G - Ethics Forms

National University of Honduras, Directorate of Research

Universidad Nacional Autónoma de Honduras
Ciudad Universitaria
Dirección de Investigación Científica
Tegucigalpa, M. D. C., Honduras, C. A.

Oficio No. 015-DICU
27 de Febrero, 2002

Doctora
LOURDES ENRIQUEZ DE MADRID
Jefe Departamento de Microbiología
Presente

Estimada Doctora de Madrid:

En atención a su oficio DMU-No. 032 del 14 de febrero de 2002 con respeto a la probación del proyecto "The impact of health education in the control of taenia solium infections" de la Dra. Maritza Canales Garay, quiero manifestarle por su digno medio a la Dra. Canales Garay, que la Dirección de Investigación Científica de la UNAH respalda plenamente este proyecto que viene a contribuir a la solución de un problema ampliamente sentido por la gran mayoría de nuestra población, que se enmarca plenamente en las políticas de investigación de nuestra institución y que además no tiene implicaciones éticas desfavorables para la población objeto de estudio.

Para efectos de carga académica y los créditos que se otorgan según el Estatuto del Docente Universitario, instamos a la Doctora Canales a registrar su proyecto en está Dirección con la Doctora Dixiana Alvarado.

Sin otro particular más que agradecer su fina atención me es grato suscribirme.

Atentamente,

Lic. Pablo Domínguez
Director Investigación Científica

DIRECCION DE INVESTIGACION CIENTIFICA U. N. A. H.

CC: Archivo.

Appendix G - Ethics Forms

National University of Honduras, Directorate of Research (Free Translation)

" National Autonomous University of Honduras
University campus
Directorate of Scientific Research
Tegucigalpa, MDC, Honduras, Central America
File No. 015-DICU
February 27, 2002

Dr. Lourdes Enriquez de Madrid
Head
Microbiology Department
UNAH

Dear Dr. Madrid,

In response to your letter DMU No. 032 dated February 12, 2002, regarding our approval of the Research Project "The Impact of Health Education in the Control of *Taenia solium* Infections", to be conducted by Mrs. Maritza Canales Garay, I am glad to inform you **that this Directorate has decided to approve the project** and offer its full support. Such project will make a great contribution in finding solutions to a problem that affects our entire population. At the same time, the project is framed within our research policies and mandates, and it poses no ethical risks to the participating population.

I encourage Mrs. Canales to contact Dr. Dixiana Alvarado from this Directorate, so the project will be registered and a record established for her academic merits and load

Sincerely,

Signature (illegible) Lic. Pablo Dominguez,
Director
Directorate of Scientific Research,

Cc: file"