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Review Article

Epidemiology and Control Strategies Against Cysticercosis (due to *Taenia solium*) with Special Reference to Swine and Human in Asia

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ABSTRACT

Cysticercosis is regarded as one of the most important zoonotic diseases in world affecting approximately 50 million people world wide including Asia. It is caused by the larval stage of a taeniid tapeworm *Taenia solium* which is cyclically transmitted between human and pigs. Man acts as a definitive as well as an intermediate host of the parasite. Adult parasite present in the intestine is not so harmful and produces non-specific symptoms. However, the cysticerci lodge in the central nervous system, eye, subcutaneous tissue and skeletal muscles and produce the organ-related symptoms. In the present report, the prevalence of cysticercosis in various Asian countries has been reviewed with emphasis on swine and human cysticercosis. Control strategies have been discussed which include general public awareness, improvement of sanitation and provision of facilities for proper disposal of human faeces. A combined strategy utilizing both anthelmintic treatment of tapeworm carriers and vaccination of pigs may pave a way for elimination of the parasite.

Key Words: Asia, cysticercosis, epidemiology, human, pig, *Taenia solium*

INTRODUCTION

Human and swine cysticercosis is a serious helminth infection caused by larval metacestode stage of a taeniid tapeworm *Taenia solium* (Flisser, 1994) which is cyclically transmitted between humans and pigs and is prevalent in various countries of Asia, Latin America and Africa. Cysticercosis is classified as a List B disease by the Office International Epizootics and is one of the most important zoonotic diseases in the world. Approximately 50 million people are infected with the parasite and some 50,000 die of cysticercosis annually (Willingham and schantz, 2004; Sarti et al., 2000). Swine cysticercosis affects carcass quality that results in heavy economic losses (Acevedo, 1982; Flisser et al.,1986).

The disease was first described in pigs by Aristophanes and Aristotle in the third century BC but Paranolia is credited with first human account in 1550 (Nieto, 1982). The adult *T. solium* measures 3 to 5 m in length and occurs in the small intestine of man.

Life cycle involves two hosts, one definitive (man) and one intermediate (pig) and three developmental stages (adult tapeworm, egg and metacestode). The larval stage is found in pigs and wild boars, sheep, deer, dogs and cats are less frequently infected (Kumar and Guar, 1994). The eggs or proglottids,. excreted by the definitive host, are ingested by a susceptible intermediate host (Pearse et al., 1987; Flisser et al., 1986; White, 1997). After their escape, oncospheres attach

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themselves to the intestinal mucosa via hooks (Canedo et al., 1990) and mature to cysticerci over a period of three weeks to two months (White, 1997). The fully developed cysticercus measures upto 20 x^{10} mm and contains an invaginated scolex. In pigs, cysticerci are mainly found in the muscles of neck, shoulder, thigh, tongue, heart and brain (Kumar and Guar, 1994; Pramanik et al., 1985). In heavily infected cases, cysts are also found in the liver, lungs and intercoastal muscles (Kumar et al., 1991). Ocular and orbital cysticercosis has also been reported in pigs (Cardenas et al., 1984). The life cycle is completed when man ingests raw, semi or under cooked infected "measly" pork (Varma, 1991; Madeley, 1984).

Man can also act as intermediate host and can result in the development of cysticercosis by ingestion of *T. solium* eggs (Nash and Neva, 1984) through faecal oral route. The *T. solium* eggs are sticky and are likely to be transmitted either by direct contact with a tapeworm carrier or food prepared by the carrier (White, 1997). Cysticercosis in man can also be acquired through ingestion of vegetables irrigated with contaminated sewage water (Flisser, 1994). *T. solium* transmission has been associated with poverty, lack of sanitary services and practices of rearing backyard pigs with free access to the areas that villagers use as toilets, and cultural behavior (Flisser et al., 2006).

In man, cysticerci lodge themselves in the central nervous system (CNS), eye, subcutaneous tissues and skeletal muscles (Flisser, 1994). The most serious effects are attributed to localization of cysts in the CNS resulting into neurocysticercosis (NCC).

Clinical Signs

Clinical signs of *T. solium* cysticercosis in pigs are usually not seen and animals appear to be perfectly healthy despite heavy infection. Noticeable clinical manifestations are found in those cases in which cysticerci get lodged in the eye and brain (Kumar and Gaur, 1994). The presence of one or more adult worms in man may cause non-specific symptoms although there may be vague abdominal pain, with diarrhea, constipation and slight eosinophilia. Possible infection of man with cysticerci lead to a serious disease in the form of dermal, muscular, ocular or even neurocysticercosis (Cruz et al., 1989). Cysticerci in the subcutaneous tissues and muscles are usually asymptomatic or well tolerated probably because they are found in small numbers. Muscular pseudohypertrophy has been reported in cases that have large number of parasites (Rum and Joo, 1989). Ocular cysticercosis may result in a generalized decrease in visible acuity, retinal edema, hemorrhages or visual field defects if cysts occur on the optical tract. Human neurocysticercosis is a complex disease, which sometimes may remain asymptomatic or have a pleomorphic clinical presentation (Escobar and Nieto, 1983; Rabiela et al., 1989). Its major manifestations depend not only on the number, location, stage and type of parasites lodged in CNS but also on the extent of the inflammatory response induced by the parasite and the condition of the host (Cook, 1988; Botero, 1988; Takayanagui, 1990). Seizures are the most frequent clinical manifestation (Flisser, 1994) and late onset epilepsy shows a strong association with cysticercosis (Vazquez and Satelo, 1992). Less common manifestations include headache, symptoms of elevated intracranial pressure and altered mental status (Subianto et al., 1978; White, 1997).

Epidemiology of Swine Cysticercosis

There is a wide variation in the prevalence of cysticercosis in different regions and socio-economic groups in the same country.

***China*:** China has 4.6 billion pig population (Anonymous, 1998). Survey in rural portions and the Shandong province revealed that pigs were rarely housed in pigpens, human

defecation was a common problem. Awareness regarding the use of infected pork meat was little (Cao et al., 1997). A sero-epidemiological survey of human cysticercosis by means of an IHAT in 6 villages of Nehe county of Heilongjiang Province revealed that out of 9832 residents examined 83 cases (0.8%) were found positive (Xu et al. 1986).

Another epidemiological study in 12 villages of 3 townships in Yucheng county and 9 villages of 2 townships in Yanzhou county revealed an infection rate of 0.3% and 0.71% of taeniosis and cysticercosis respectively among 11296 persons examined. The prevalence rate of porcine cysticercosis ranged from 0.73% to 6.21% with 5.1% of 215 blood samples collected from swine testing positive (Cao et al., 1995). A similar study carried out in Shandong Province, reported an infection rate of 0.1% and 0.107% of adult worm and metacestode, respectively in 35512 persons surveyed in 56 village of 5 counties (Liu et al., 2000). However, a prevalence rate of 0.032% and 0.051% of adult worms and cysticerci was reported in another survey carried out in 1999 in Shandong Province, China (Miao et al., 2000). The seroprevalence of specific anti-cysticercosis IgG4 was 2.24%. The prevalence of porcine cysticercosis ranged from 0.12 to 0.48% and the seroprevalence was 4.41% (Miao et al., 2000).

House to house interviews in the field, faecal examination and serological tests indicated that the prevalence of *Taenia* infection and cysticercosis in the human population were 0.048% and 0.057%, respectively and the prevalence differed among occupations and from region to region, but there was no significant difference between men and women, city and suburb (Liu et al., 2000). Unhealthy eating and unhygienic habits were commonly practiced among residents. About 92.3% of the families have latrines connected to pigsties. The surrounding sanitation and the disposal of faecal material were poor. The detection rate of porcine cysticercosis was 0.06% and the positive rate of anti-cysticercosis antibody in pigs was 1.99% (Liu et al., 2000).

***Hong Kong and Singapore*:** A survey in three different ethnic communities using an anticysticercus ELISA demonstrated an overall prevalence of 8% in human beings, among individuals of Chinese origin (13%) than of India (5%) or Malaysia (3%) origin (Coker-Vann et al., 1981). Singapore is considered `at-risk' for *T. solium* cysticercosis due to the tourists to and from this country. Hong Kong imports pork from China and thus local cases of cysticercosis result from the consumption of imported pork (Ko, 1991).

***India*:** In India, an unimaginable disparity exists in the geography, ethnicity, religion, food, personal habits, level of education and standards of living within the country. These factors have direct bearing on the frequency of *Taenia solium* infection and consequently the geographical distribution of infection varies in different states of India (Singh et al., 2002). The average infection rate found during last 45 years was 10.22 % ranging from 1.75 % to 36.7 %. The prevalence rate of *T.solium* in man varies from 0.75% to 1.00% in certain communities, particularly in rural areas where contact of human beings with pig populations is frequent. Out of 4858 pigs slaughtered at a bacon factory in Uttar Pradesh, 123 (2.53%) were found positive for the parasite (Varma and Ahluwalia, 1981). In northern India the prevalence of metacestodes and *Cysticercus cellulosae* was 20.8% pigs (Deka et al., 1985). *C. cellulosae* was detected in 477 (4.24%) of 11,237 pigs of various ages examined at the Tangra (Calcutta) pig abattoir (Pramanik et al., 1985). Prevalence was higher in crossbred than in indigenous animals, but was not affected by age or sex. In Uttar Pradesh State presence of cysticerci is 9.3% in pigs (Pathak et al, 1984).

The prevalence of *C. cellulosae* (*T. solium*) in Chitoor, Krishna, West Godavari and Guntur districts of Andhra Pradesh were 8.66, 8.00, 6.00 and 43.3 percent, respectively (D'Souza, 1998). Prevalence was found to be 5.36% a bacon factory in Gannavaram. The prevalence of *C. cellulosae* was investigated in 279 pigs slaughtered at different abattoirs in Greater Guwahati, (Assam) which was found to be 3.22 percent Sharma et al. (2004). The prevalence rate of 1.70 and 6.35 per cent was reported in Ludhiana city of Punjab state on post-mortem examination (Avapal et al., 2003; Sharma et al., 2004). Human neurocysticercosis is regarded as the second most common intracranial space occupying lesions following tuberculosis in India (Mahajan, 1982) and the most common cause of epilepsy (Sawhney et al., 1996). Computed Topography (CT) scan reports of children and adolescents after first seizure revealed that single small enhancing CT lesion is a most common radiological abnormality occurring even after the first seizure (Garg et al., 2000) and the commonest radiological abnormality in Indian patients with new onset of partial seizures (Puri et al., 1991). Childhood NCC (Neurocysticercosis) is now well recognized clinical entity (Garg et al., 2000) and 5.47 % of children with subacute and chronic meningitis have revealed the presence of anti cysticercal antibody in cerebrospinal fluid (Chandermukhi and Nayak, 1990).

***Indonesia*:** About 88% of the population is Muslim; the remaining 12% consists of Christians, Hindus and Buddhist (www.geographic.com). Improper cooking of infested pork and reliance upon traditional sanitary practices are the major cause of higher incidence of *T. solium* taeniosis and cysticercosis in Indonesia. People generally defecate in their house yards and garden and allow free ranging of pigs to clear the excrement at night time. In Bali traditional dish lavar is made of minced raw pork mixed with coconut and spices. In Moslem dominated regions of Indonesia human and porcine cysticercosis is infrequent. However, they constitute major health and economic problem in other community people in which the estimated prevalence varies between 2% in Bali and 48% in Irian Jaya, which is being one of highest reported figures in the world (Simanjuntak et al., 1997; Margono et al. 2003). Approximately 8.6% of the local population in Kama, harbour adult *T. solium* (Margono et al., 2003). Intestinal taeniosis is common in Bali and three instances of *Taenia* spp. infections were reported among 415 faecal samples surveyed in Bali (Sutisna et al., 1977). Several workers have recently examined the intestinal *T. solium* infection in Irian Jaya which varied from 8 to 51% (Margono et al., 2003). Some recent studies using serological markers suitable for human and swine have been demonstrated serological evidence of exposure among dogs in Indonesia. A prevalence of 21% anticysticercus antibodies in sera based upon ELISA among inhabitants of Bali was found Coker-Vann et al., (1981) and an immunoblot based seropositivity to be 13% (Theis et al., 1994).

***Korea*:** During the last few decades, *Taenia* infection was decreased steadily in Korea. The egg positive rate has always been the highest in Cheju province although the infections were found throughout the country. Porcine infection with *T. solium* metacestodes had been as high as 70% in Cheju province where pigs have been reared in pig pens in each household. After 1986, no more swine infections were found when the Governor of Cheju province banned the use of pigpens. Of 3799 pigs slaughtered at 54 abattoirs in nine regions, 12 pigs (0.3%) from three regions were infected with *C. cellulosae* (Jang and Kang, 1989), nine of these were from Cheju Island. Of 190 live pigs examined for *C. cellulosae* from 54 farms on Cheju Island, five (2.6%) from 3 farms were found infected.

***Myanmar*:** An earliest Coker-Vann et al. (1981) performed a serological study in a local population using an ELISA found anticysticerus antibodies in 6% of the samples surveyed.

***Malaysia and Bangladesh*:** *T. solium* is infrequent in this country as most of the Malaysian are Muslim. Similarly main religion in Bangaldesh is Muslim. Hence indigenous cases of *T. solium* taeniosis and cysticercosis do not occur (Singh et al., 2002).

***Nepal*:** In Nepal, pork contributes about 7% of the meat consumed. Previously, pork was consumed only by people belonging to low castes, however, in recent years, the consumption of pork has increased in higher castes. *T. solium* cysticercosis is a major health hazard in the country as (Amatya and Kimula, 1999; Shrestha et al., 1999). Data indicate that NCC is the commonest cause of seizure in Nepal. Both solitary and multiple form of cerebral cysticercosis are seen though the former predominates.

***Sri Lanka*:** NCC including solitary cysticercosis granuloma, which occurs very commonly in several neighbouring countries, does not occur in Sri Lanka (Singh et al., 2002).

***Thailand*:** *T. solium* infection is quite uncommon in Thailand (Vejajiva, 1977). However, reports of sporadic cases have been made. A recent report from a provincial general hospital in Surin, in Northeast Thailand found frequent occurrence of solitary cysticercosis granuloma (Yodnopaklow and Mahuntussanapong, 2000).

***Vietnam, Cambodia and Laos*:** Cysticercosis is wide-spread in North Vietnam and is often seen in male adults aged 30 to 60 years, but not in children (Hoang and Nguyen, 2000). In 36 children convalescing from a flu like illness in Vietnam 3% of serum samples were positive for anticysticercus antibodies (Coker-Vann et al., 1981). A seropositivity of 5.7% among inhabitant of North Vietnam was reported (Brandt, 2000). A survey on cysticercosis infection in humans and pigs was carried out in the Bac Kan and Bac Ninh provinces (Vietnam) from 1999-2000. Results of faecal and serological examination of humans demonstrated that 1.00-12.6% were infected with *Taenia* and 2.2-7.2% with *Cysticercus*. Ten of 26 necropsied pigs were found to be infected with *C. tenuicollis*, but the infection by *C. cellulosae* was not observed. ELISA carried out on 323 pig serum samples showed a disease prevalence of 9.91%, varying from 6.06-15.49% (Nguyen et al., 2002).

Control Strategies

Control of cysticercosis is a difficult task because of local habits, traditions and practices. Control can be made by creating of an awareness of these infections among the general public, improvement of sanitation and provision of facilities to dispose human faeces. Cooking is the most effective means of prophylaxis. Cysticerci are killed at 45-50°C but pork should be cooked for at least one and a half hours for every pound, or until it becomes grey in color. Cysticerci are also killed by freezing below -20° C but at 0-2°C they survive for nearly two months and at room temperature for 26 days. Freezing at -10°C for > 4 days is an effective but expensive method (Brown and Belding, 1964). Prolonged cold storage or cooking to a core temperature of 70°C inactivates the parasites in meat and meat products. Pickling is not always effective whereas, both boiling and freezing (-20°C) kill the cysticerci (Flisser et al., 1986). *Taenia solium* cysticerci are more resistant to acid than to basic solutions. Infected pork carcasses can be rendered fit for human consumption by exposure to gamma radiation at doses between 20 and 60 K rads for 10 min (Hafeez, 2001).

Mass cestocidal treatment, aimed to cure of possible taeniosis and cysticercosis cases, has shown to be useful (Cruz et al., 1989; Sarti et al., 2000). It is a useful method of control but has certain disadvantages like generation of symptoms in a case of occult neurocysticercosis during mass treatment with praziquantel (Flisser et al., 1993). Chemotherapy should be provided only to those people previously identified or that have a high risk of being carriers. Albendazole and praziquantel have been reported to effectively eliminate cysticerci in pigs (Gonzalez et al., 1990) and oxfendazole leaves the pork with a clean appearance.

Health education has been shown to be highly effective since people become aware of the importance of human and porcine cysticercosis and the possibility of eliminating it (Sarti et al., 1997). Health education should be provided by trained personnel and is more effective as associated to the identification and treatment of tapeworm carriers. Restriction of the scavenging habit of the pigs that have access to human faecal material might help in controling of this condition. Health education programs should be associated for the improvement of sanitary facilities.

A less expensive option for control of human cysticercosis is to use vaccine. There has been substantial progress made in the development of recombinant antigen vaccines for protection against infection with a number of *taeniid* cestode species in their intermediate hosts (Lightowlers et al., 2003). Recently two candidate antigens TSOL 18 / TSOL 45 have been developed as vaccines against *Taenia solium* infection in pigs (Gauci et al., 1998). A combination of three recombinant *T. ovis* antigens (45W, 16K and 18K) was able to induce significant (upto 93%) protection against experimental challenge infection with *T. solium* in pigs (Plancarte et al., 1999).

Therefore, for control of *T. solium* cysticercosis a combined strategy utilizing both anthelmintic treatment of tapeworm carriers and vaccination of pigs may allow eradication of the parasite. The International Task Force for Disease Eradication suggested in 1992 that the eradication of cysticercosis could be achieved by using current technology. It is therefore, a political decision of especially developing countries to control this disease through a legislature framework, implementation of meat inspection and also through public information campaigns and the implementation of prevention programme.

It is important to identify the cysticercosis as one of the major public health problems in Asia that needs to be tackled vigorously by the governments and public health authorities of the region.

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