ASIAN *TAENIA SAGINATA*: SPECIES OR STRAIN?

PC Fan

Department of Parasitology, National Yangming Medical College, Taipei, Taiwan.

Abstract. Asian *Taenia* has a special epidemiological pattern. Many people eat raw and/or undercooked pork and pig viscera more often than that of cattle and acquire a *T. saginata*-like tapeworm infection. The pig has been found to be the most favorable laboratory intermediate host for four geographical strains of Asian *Taenia*. Numerous pinpoint cysticerci have been found in naturally infected livers of one wild boar and six domestic pigs in Taiwan. It is likely that pigs are the natural intermediate host of Asian *Taenia* in endemic areas other than Taiwan. Moreover, the cysticerci of Asian *Taenia* are only found in the livers of the infected animals and have similar morphological characteristics, which are distinguishable from the cysticerci of *T. saginata* and *T. solium*. These cysticerci are small in size and armed with two rows of rudimentary hooklets and can develop to maturity in as short a period as 4 weeks. It is possible that Asian *Taenia* is a different species or at least a different strain.

INTRODUCTION

Taenia saginata has a cosmopolitan distribution and man is the only definitive host. The relationship between the adult parasite of man and bladder worms of cattle was established experimentally by Leuckart in 1861 who fed several gravid proglottids to two calves and obtained the larval stage, *Cysticercus bovis*. Subsequently, Mosler (1864) succeeded in infecting man with cysticerci from cattle. Safronow (1960) reported that reindeer could also be an intermediate host.

In East Asian countries some people are fond of eating raw or undercooked meat and viscera of domestic and wild animals. These eating habits are important in the transmission of taeniasis. Although meat and viscera of pigs are commonly eaten and *C. cellulosae* is frequently found, *T. saginata* rather than *T. solium* is the dominant species (Cho *et al*, 1967; Huang, 1967; Kosin *et al.* 1972; Arambulo *et al*, 1976; Kim, 1985). This paradox leads to questions regarding the intermediate host (Huang, 1967; Cho *et al*, 1967; Arambulo *et al*, 1976) and evidence being accumulated leads us to question the identity of Asian *Taenia*.

TAENIASIS IN ASIA

Taiwan

Since the first report of human taeniasis by Oi (1915), the causative agent of taeniasis among the aborigines was believed to be *T. saginata*. In 1967, Huang questioned the identity of the parasite because beef was seldom eaten and cattle were not raised in the mountainous area.

Korea

On Cheju Island, raw pig liver is reported to be frequently consumed (Park and Chyu, 1963). However, 0.2–7.4% of pigs were infected with *C. cellulosae*, but it was extremely rare to find *C. bovis* in cattle (Kim, 1985). The causative agent of taeniasis on Cheju Island would appear to be *T. solium*. On the contrary, *T. saginata*-like tapeworms predominate over *T. solium* (Cho *et al*, 1967).

Indonesia

In 1972, Kosin *et al* reported a prevalence of 9.5% among 285 inhabitants in Ambarita Village on Samosir Island in Lake Toba, North Sumatra, Indonesia. Cross *et al* (1976) reported an infection rate of 2% in the same village. After mass treatment in Ambarita, 93 *T. saginata*-like tapeworms were recovered. However, the inhabitants have very little opportunity to eat beef, and it was suggested that the intermediate host may be animals other than cattle (Kosin *et al*, 1972).

Thailand

In 1957, Vajrasthira and Harinasuta reported that 2.5% of 263,703 persons were infected

with *Taenia* species. The infection rate was highest in the northeast region (3.4%), followed by the north (1.2%) and the central regions (0.2%). No *Taenia* eggs were detected in 41,337 stool specimens obtained from southern Thailand. Although pork is more commonly consumed than beef, taeniasis in Thailand is mainly due to *T. saginata* (Harinasuta and Charoenlarp, 1971).

The Philippines

In the Philippines, 0.12% of 246,398 persons in 77 provinces and locations examined were infected with *T. saginata*, 0.02% with *T. solium*, and 0.49% with *Taenia* of indistinguishable species (Hinz, 1984). Although *T. saginata* is the dominant species, cysticercosis was found in 0.167% of 4,956,422 pigs, 0.002% of 332,910 carabaos, and 0.003% of 494,968 cattle (Arambulo *et al*, 1976). Therefore, the relationship between *Taenia* infection and intermediate hosts is unclear.

Experimental infections

In Taiwan, Yokogawa (1935) attempted to infect three cattle, eight pigs and three goats by feeding each one 50,000 to 100,000 *Taenia* eggs from proglottids obtained from Taiwan aborigines, but no cysticerci were recovered when the animals were sacrificed 221–754 days post-infection. In 1967, Huang succeeded in infecting two out of three calves, after giving each animal approximately one million *Taenia* eggs obtained from Taiwan aborigines. The infected calves were 2 and 7 days of age and were sacrificed 2 and 4 months post-infection. The third calf was 30 days old and sacrificed 3 months after infection.

In the Philippines, Arambulo *et al* (1976) experimentally infected 6 calves (*Bos taurus*), 6 carabaos (*Bubalus carabanensis*), 3 pigs (Sus-scrofa) and 4 goats (*Capra hircus*) with 5–40 proglottids of a *T. saginata*- like tapeworm. However, no cysticerci were recovered when sacrificed 71–561 days after the infection. In addition, 7 pigs of the local strain on Leyte Island were infected by feeding with 15–49 proglottides of *T. saginata*. Thirty *C. cellulosae* were recovered from one of these pigs. However, this experimental study was conducted in the endemic area. The pigs were allowed to root and roam freely and were raised together.

EPIDEMIOLOGICAL SURVEYS AND FIELD TRIALS

Current status of taeniasis in Taiwan

From 1979 to 1989, 20,810 aborigines from three tribes were examined for taeniasis and 12% were found to be infected: Atayal tribe (13%), Bunun tribe (11%) and Ami tribe (4%). The infection rate of males was slightly higher (13%) than that of females (11%). The rate increased with age, from 3% among children under 10 years of age, to a peak of 28% in the 41–50 age group, and then declined to 19% in those over 60 years of age (Fan *et al*, 1990a).

Infection with Taiwan *Taenia* is a family disease as well as a multiple infection. Of 1,207 families infected, the numbers of infected individuals ranged from 1 to 6 in decreasing order of frequency: 71%, 23%, 4%, 1%, <1% and <1%. By giving chemotherapy to 407 infected persons, 748 worms were recovered, ranging from 1–24 worms (average 1.8) per person. One third of the infected persons were found to have multiple infections (Fan *et al*, 1990a).

In our surveys, all of the 1,468 infected aborigines had eaten raw meat and viscera of 18 species of animals: wild boar (domestic pig for Yami tribue) 77%, flying squirrel 69%, wild goat (domestic goat for Yami tribue) 68%, muntjac 58%, wild rat 50%, monkey 47%, hare 39%, civet-cat 22%, pheasant and wease 18%, squirrel 14%, grouse 4%, deer and snake 1%, bamboo partridge, bear, frog and dog <1% (Fan *et al*, 1990a).

In different endemic areas, 12 wild boars, 46 domestic pigs, 3 squirrel, and 8 muntjacs were examined for cysticerci of *Taenia* species. Numerous tiny pinpoint milk-white cysticerci were observed on the surface of a liver from a wild boar in a mountainous area in Central Taiwan. Nine cysticerci (2 viable, 3 degenerated, and 4 calcified) were found on the livers of six domestic pigs in Lanyu District, Taitung County (an offshore island). These findings indicate that pigs can be a natural intermediate host for

Taiwan *Taenia* in the endemic area (Fan *et al*, 1990a).

Taeniasis in Korea

Of 1,102 inhabitants in 2 villages on Cheju Island examined, 7% were found to be infected with *Taenia*. Infected cases were most common in the 51–60 age group. More males (8%) than females were infected (5%). Among 58 infected persons, 53 ate raw pork and 47 ate raw beef. However, 15 tapeworms expelled from 12 cases after treatment were all *T. saginata*-like tapeworm (Soh *et al*, 1988).

Taeniasis in Indonesia

Of 465 inhabitants in Ambarita, Lake Toba, North Sumatra, 21% were found to be infected with *Taenia*. Thirty-two percent of the infected persons were in the 41–50 age group (24% male and 18% female). Nine of 15 infected persons ate partially cooked pork, five ate partially cooked pork and dog meat, and only one ate partially cooked beef and dog meat. Twenty-two *T. saginata*-like tapeworms were recovered from 10 infected persons after treatment (Kosman *et al*, 1988).

EXPERIMENTAL INFECTIONS

Susceptibility of laboratory animals to different strains of Asian *Taenia*

In addition to epidemiological surveys, a known number of eggs from *T. saginata*-like tapeworms from Taiwan, Korea, Indonesia, and Thailand, were inoculated into different species of domestic and wild animals. Infections were established in 39 pigs, 3 calves, 5 goats, and 2 monkeys with Taiwan *Taenia*; 8 pigs, 1 calf, and 1 goat with Korea *Taenia*; 6 pigs and 2 calves with Thailand *Taenia*; and 9 pigs with Indonesia *Taenia*. Pig of the small-ear-miniature (SEM) strain were found to be the most favorable experimental intermediate host for the four geographical strains of Asian *Taenia* (Fan *et al*, 1990b).

Distribution of cysticerci in livers of experimentally infected animals

A total of 87,524 cysticerci from *Taenia* from Taiwan (63,354), Korea (19,219), Indonesia (4,922), and Thailand (29) were recovered from livers of only 76 infected animals. The cysticerci were located in the parenchyma (67%) more often than on the liver surface (33%) (Fan *et al*, 1990b), and were different from the classical *C. bovis* and *C. cellulosae*, which are usually large in size and found mostly in the muscles of infected cattle and pigs, respectively.

Development of different strains of *Taenia* cysticerci in livers of experimentally infected animals

Taiwan *Taenia*

Pigs: Thirty-six immature cysticerci were first observed on day 14 in 2L-SEM pigs. In SEM pigs, 9 immature cysticerci were found as long as 79 days post-infection, but in L-SEM pigs none were found after day 37. Mature cysticerci first appeared on day 27 in SEM, on day 28 in L-SEM, and on day 43 in DYL pigs. Degenerated/calcified cysticerci were first recovered from the livers of L-SEM, SEM, and DYL pigs on days 21, 27 and 43 after inoculation, respectively. On and after day 85, all cysticerci were found degenerated/calcified in the L-SEM pigs, but the mature ones were still found on and after day 97 in the SEM pig. The percentages of immature and mature cysticerci were inversely proportional to the duration of infection, while those of degenerated/calcified cysticerci were directly proportional to the age of the pig and the number of eggs inoculated.

Calf, monkey and goat: Mature (74%) and degenerated/calcified (26%) cysticerci were recovered from the livers of three calves 85 to 91 days post-infection. Only degenerated/calcified cysticerci were recovered from the liver of two monkeys and five goats.

Korea *Taenia*

A total of 187 mature and 37 immature cysticerci were found in the livers of 4 L-SEM pigs on 29, 34, 41 and 55 days after feeding 1,000 eggs each. No degenerated/calcified cysticerci were observed.

From the livers of two of three SEM pigs, each fed 380,000 eggs, 10,270 immature cysticerci were recovered 16 and 21 days post-infection,

and 6,517 degenerated/calcified cysticerci were also recovered. On day 30, 248 immature, 687 mature and 1,234 degenerated/calcified cysticerci were found in the liver of one SEM pig.

From a 5-day old DYL pig, 17 mature cysticerci were recovered from the liver 77 days after inoculating 30,000 eggs. Only degenerated/calcified cysticerci were found in the livers of an 8-day-old Holstein calf and a 5-day-old Sannean goat, 72 days and 101 days, respectively, after feeding each 30,000 eggs.

Indonesia *Taenia*

Six L-SEM pigs became infected 61–195 days after feeding each 30,000 Indonesia *Taenia* eggs, and most (99.9%) of the cysticerci recovered from the livers were degenerated or calcified. However, 78% of the cysticerci from 3 SEM pigs were mature and only 22% were degenerated or calcified 45–76 days after feeding each 3,000 eggs.

Thailand *Taenia*

Sixteen cysticerci were recovered from the livers of six SEM pigs after inoculating each with 3,000 eggs: 10 cysticerci were mature and 6 were immature. One of the immature cysticercus was recovered from a 36-day SEM pig on day 12 after inoculation. This is the earliest record of immature cysticerci in the liver of an infected pig.

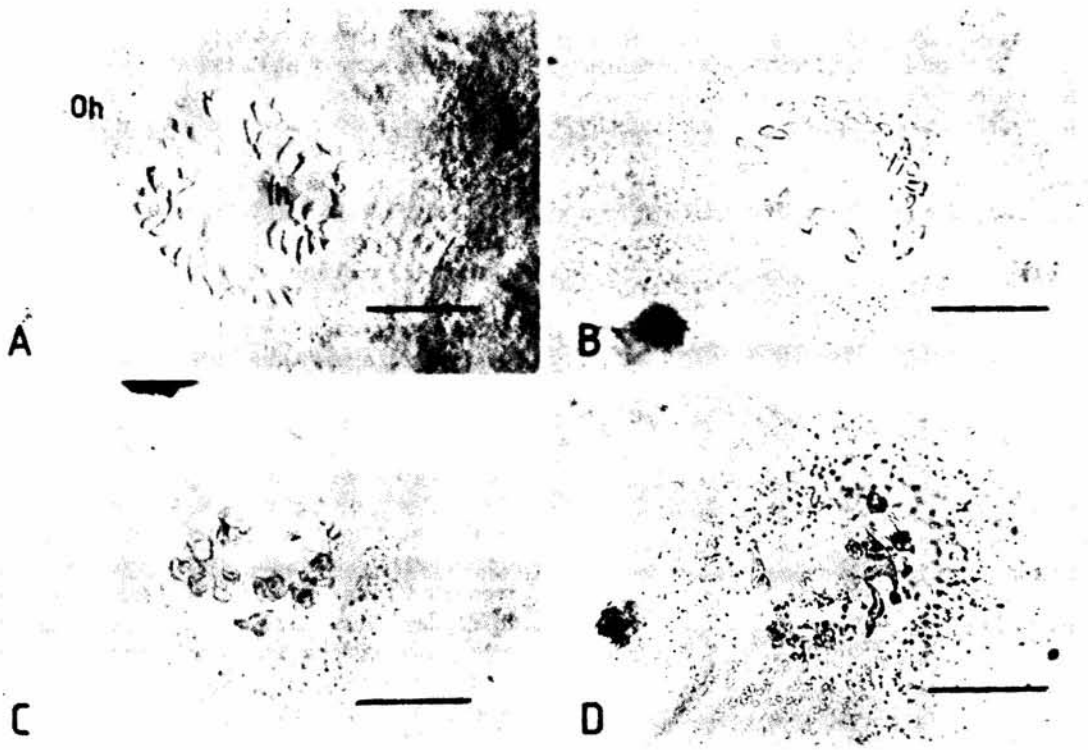

Fig 1 – Rudimentary-hooklet pattern on scolex of *Taenia saginata* cysticercus in Asia
A. *Taenia saginata* cysticercus (Taiwan strain).
B. *Taenia saginata* cysticercus (Indonesia strain).
C. *Taenia saginata* cysticercus (Korean strain).
D. *Taenia saginata* cysticercus (Thailand strain).
Ih = Inner hooklet; Oh = Outer hooklet;
Scale bar = 50 μm.

Measurements of cysticerci in livers of experimentally infected pigs

The length, width and diameters of protoscolex, rostellum and sucker of all 1,491 cysticerci of Taiwan *Taenia* (788), Korea *Taenia* (403), Indonesia *Taenia* (290), and Thailand *Taenia* (10) were 1,531 μm, 1,383 μm, 566 μm, 93 μm, and 203 μm, respectively, with the size increasing with the duration of infection. However, the size of cysticerci became smaller when the liver of the host animal harbored a large number of cysticerci. Moreover, the corresponding figures were smaller than those of both *T. saginata* and *T. solium*.

Hooklet pattern of cysticerci in livers of experimentally infected animals

All 1,491 cysticerci of the four Asian *Taenia* were found to have two rows of hooklets. The hooklets in the outer row were numerous and small. The means (and ranges) of the number and the length of the inner-row hooklets are as follows: Taiwan *Taenia*, 18 (2–51), 11 μm (5–25 μm); Korea *Taenia*, 16 (1–76), 11 μm (2–28 μm); Indonesia *Taenia*, 2 (1–40), 11 μm (3–20 μm); and Thailand *Taenia*, 17 (3–44), 11 μm (6–16 μm) (Fig 1).

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