

Experimental infection of pigs and cattle with eggs of Asian *Taenia saginata* with special reference to its extrahepatic viscerotropism*

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Abstract: Asian *Taenia saginata*, tentatively called *Taenia saginata taiwanensis*, has been described to be infected in its metacestode stage only in the liver of intermediate host animals. Experimentally, however, we found that the metacestodes of the Asian *Taenia saginata* are also infected in other viscera than the liver of pigs (Landrace-Duroc-Hampshire) 4 days to 4 months postinoculation (PI). Viscerotropism of cysticercosis was apparent because a majority (70.7%) of the non-calcified cysticerci were found in the livers while a minority were found in extrahepatic organs such as the omentum (19.2%), lungs (8.1%) and serosa of colon (2.0%). When experimentally infected to cattle, Asian *T. saginata* cysticerci were also observed calcified in the livers. On the other hand, classical *Taenia saginata* metacestodes infected the muscles and viscera of the Holstein-Friesian cattle whereas no infection was observed in experimental pigs. Extrahepatic metacestodes of Asian *T. saginata*, which were obtained from an experimental pig were confirmed to be infective to a male volunteer. This extrahepatic viscerotropism of Asian *T. saginata* metacestodes in experimental pigs explains well the transmission modes of Asian *T. saginata* among people considering the eating habits.

Key words: Asian *Taenia saginata*, viscerotropic cysticercosis, experimental infection, cross bred pigs of Landrace-Duroc-Hampshire, Holstein-Friesian cattle

INTRODUCTION

Asian *Taenia saginata*, unlike classical *Taenia saginata* or *T. solium*, is known to infect humans by way of the internal organs of intermediate host animals. Of these internal organs,

only the liver has been considered by researchers in Asian countries such as Taiwan, Korea, Thailand and Indonesia (Chao *et al.*, 1979; Fan *et al.*, 1986, 1987, 1988b, 1989a, 1990a & b; Chung *et al.*, 1987; Eom and Rim, 1988; Kosman *et al.*, 1990) as a source of infection. Infectivity to human was proved with the metacestodes obtained from the liver of an experimentally infected cattle in Taiwan (Chao *et al.*, 1988) and with metacestodes obtained

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from the liver of naturally infected domestic pigs in Korea (Eom and Rim, 1992a).

One epidemiological problem, however, that should be properly evaluated, is the significance of liver as a source of human infection. From naturally infected pigs in Korea, 98.8% of the metacestodes in the liver were either calcified or highly degenerated although the pigs were only 6 months-old (Eom and Rim, 1992b). In experimental study, metacestodes matured in 43 days and the majority of them (96.0%) were dead or calcified within 72 days (Fan, 1987). Most Asian *T. saginata* metacestodes will probably have died before the domestic pigs have reached slaughtering age, 6 months or more. This fact led us to question whether the metacestodes are maintaining patent infection in other tissues for a longer period.

In this experimental study, we searched for the infected organs of Asian *T. saginata* metacestodes in visceral organs other than liver of pigs as well as the infectivity of extrahepatic metacestodes in a human host. As a comparative observation, infection of classical *T. saginata* metacestodes were also observed experimentally in pigs and cattle.

MATERIALS AND METHODS

Eggs of Asian *T. saginata* were collected from a Korean volunteer experimentally infected per os (p.o.) with metacestodes from the liver of naturally infected pigs. Eggs of classical *T. saginata* were collected from a Belgian who was infected in Africa.

Sixteen cross bred pigs of Landrace-Duroc-Hampshire strain, 4 days to 4 months-old, were inoculated p.o. with 25,000~90,000 eggs of Asian *T. saginata*. Two pigs of the same strain and age were inoculated p.o. with 30,000 classical *T. saginata* eggs. Another two pigs were used as a non-infected control group. Two Holstein-Friesian calves, 4 to 7 days old, were inoculated p.o. with 360,000~890,000 eggs of Asian *T. saginata*, and another calf with 125,000 eggs of classical *T. saginata*.

The pigs were killed 30, 45, 53, 60, 90, 120, 165 days PI and the calves 30~45 days PI. The liver, omentum, lung, serosa, brain, spleen, kidney, stomach, heart and muscle of all the animals were examined for *Taenia* metacestodes. Collected specimens were observed by the naked eyes or sometimes with helps of a light microscope.

A man was experimentally infected p.o. with a live extrahepatic cysticercus of Asian *T. saginata*, obtained from the serosa of colon in a pig, and he was treated 3 months PI to confirm the patent infection.

RESULTS

Experimental infection in pigs

Asian *T. saginata* metacestodes were recognized in both the hepatic and extrahepatic organs of pigs. Each pig was infected with 9~3,941 metacestodes. A total of 5,512 metacestodes was collected from 8 pigs. Of them, distribution and status of 1,540 metacestodes were microscopically examined, and shown in Table 1. Of the 1,540 cysticerci, calcification was observed in both hepatic (92.1%) and extrahepatic (1.4%) cysticerci. Live cysticerci were observed both in hepatic (0.13%) and extrahepatic (0.32%) cysticerci. 99.1% calcification was observed in older pigs (4 months old when inoculated). The size of the host tissue capsules was greatest in those from the omentum, followed by the lung and the serosa (Table 1). Host tissue capsules from livers were smaller than those from other organs. But in the live ones, capsules measured up to 2.0~2.5 mm. Rudimentary hooklets were observed in 9 of the 99 metacestodes. These were countable in only 2 metacestodes which had 8 and 9 rudimentary hooklets.

In experimental pigs, a total of 99 non-calcified metacestodes were observed. Majority (70.7%) of them were found in livers and a minority (29.3%) from extrahepatic organs such as the omentum (19.2%), the lung (8.1%) and the serosa (2.0%) (Figs. 1~5). Hepatic cysticerci were distributed randomly (20.3~33.1%) in

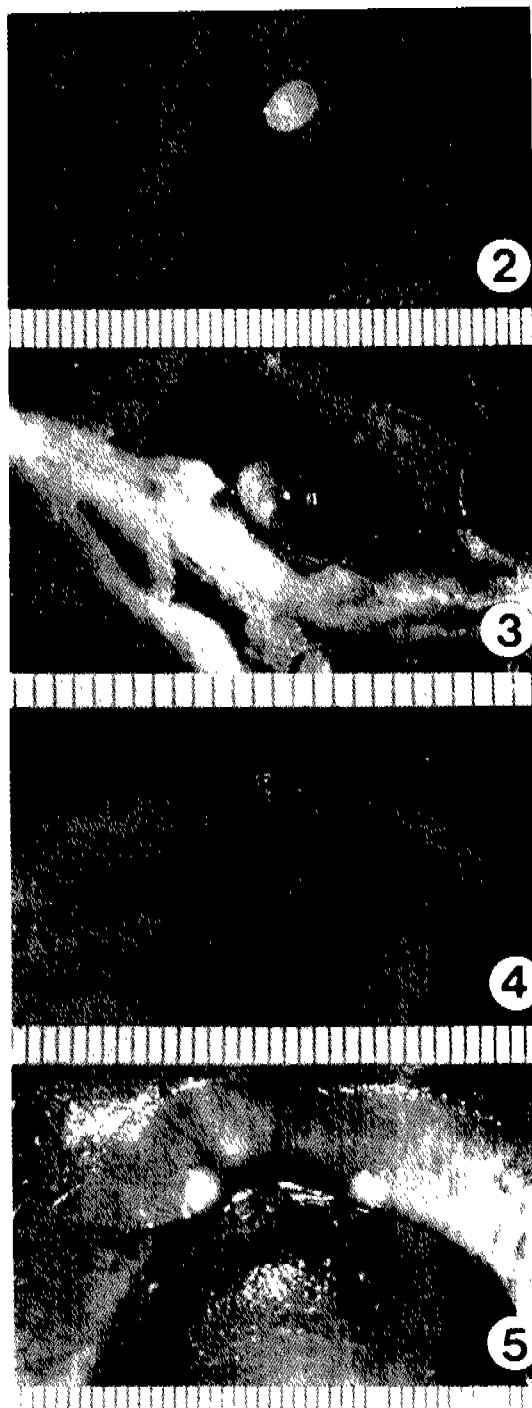
each lobe of the liver. Most of hepatic cysticerci (88.9%) were collected from the parenchyme, the remainder (11.1%) coming from the liver surface. Two non-infected control pigs were found to be free of any Asian *T. saginata* metacestodes in the liver and other internal organs 2 months PI. Eggs of classical *T. sagi-*

Table 1. Hepatic and extrahepatic distribution of Asian *Taenia saginata* metacestodes according to size of the host tissue capsules in 8 experimental pigs (microscopically examined only)

	Hepatic	Extrahepatic		Total	
		Omen- tum	Lung		Serosa
Number of metacestodes					
Live	2	2	1	0	5
Dead	1487	21	19	8	1535
<i>degenerated</i>	68	17	7	2	94
<i>calcified</i>	1419	4	12	6	1441
Total	1489	23	20	8	1540
Size of host tissue capsules (in mm)					
Mean	1.30	3.46	2.88	1.40	
Range	1.0~ 3.5	3.0~ 4.0	2.5~ 3.5	1.0~ 2.0	
S.D.	0.45	0.37	0.48	0.55	
number measured	292	14	4	5	



Fig. 1. Asian *Taenia saginata* metacestode collected from the serosa of colon in pigs (carmine stained, scale: one mm).



Figs. 2-5. Asian *Taenia saginata* metacestodes observed in various visceral organs such as the liver (Fig. 2), the omentum (Fig. 3), the lung (Fig. 4) and the serosa of colon (Fig. 5) of pigs (scales in mm).

nata were found to be not infective in two pigs when observed 2 months PI.

Experimental infection in cattle

When challenged with Asian *T. saginata* eggs, two calves became infected with the metacestodes in their livers. One calf was infected with 786 cysticerci and the other with 507 cysticerci after 4 and 6 weeks respectively. All the cysticerci collected were calcified, measuring 1.5 mm(0.3~3.5) (n=201).

When classical *T. saginata* eggs were challenged, a calf was infected in the muscles of the upper and lower limbs, trunk, jaw, tongue, diaphragm and heart, and also in visceral organs such as lung and omentum (Table 2). A total of 1,944 *T. saginata* metacestodes were collected.

Infectivity of extrahepatic form of

Asian *T. saginata* metacestode in a man

Extrahepatic cysticercus of Asian *T. saginata*, obtained from the serosa of colon in a pig was infective to a volunteer. An adult worm, 290 cm in body length without scolex, was recovered 3 months PI by niclosamide treatment.

Table 2. Infected organs of Asian *T. saginata* and classical *T. saginata* metacestodes in pigs and calves

Intermediate hosts	Infected organs by metacestodes	No. hosts infected/ No. hosts challenged	
		Asian <i>T. saginata</i>	classical <i>T. saginata</i>
Pigs	liver	8/16	0/2
	viscera*	2/16	0/2
	muscle	0/16	0/2
Calves	liver	2/2	0/1
	viscera*	0/2	1/1
	muscle	0/2	1/1

* Extrahepatic viscera such as omentum, lung and serosa

DISCUSSION

Asian *T. saginata* is a species closely related to the eating habits of humans in its life cycle. Some rural Koreans, like many other rural Asian people, like to eat raw foods, including the internal organs of pigs. In Korea, Cheju Province has been known as a highly endemic area of

T. saginata (what we now consider to be Asian *T. saginata*). The people of Cheju usually eat the viscera of pigs at 'Churyum.' 'Churyum' was a common rural practice of slaughtering pigs for parties, marriages and funerals. The pig liver is the most popular part to be eaten raw, followed by the intestines or stomachs. Some people eat the lung, spleen, kidney and pancreas raw, too. The custom of eating raw viscera of pigs among people in Cheju Island varies from 19.2% to 52.3% in the past (Park and Chyu, 1963; Kang *et al.*, 1965; Kim, 1982). The popularity of the organs eaten varied: liver (19.2~49.9%); intestines (2.1~19.9%); lung (10.2~19.6%); and spleen 0.1~6.5%).

What draws our attention is the fact that old people of Cheju calls eating 'raw viscera' as 'Semmai' (or Senmai). The term 'semmai' originated from the 13th century Mongolian, [Senezi(n)] which means fat around the intestines; epiploon, fatty skin around the intes-tien of animals, fat of the epiploon; thin layer of fatty tissue on the cud pouch or rumen, semeze=semezi (Park, W.K., 1991, pers.). This Mongolian term has been used in Cheju Island, because Mongolian soldiers temporarily ruled the Island during the 13th~14th century. Retrospectively, the habit of eating raw semmai alone or together with the stomach, spleen or other visceral organs may cause the infection of Asian *T. saginata*. In our study, the omentum and fat tissues around the stomach, spleen and intestine harbored many hidden, hard to be recognized, transparent metacestodes. Thus the custom of eating raw spleen itself has no meaning; but eating the omentum or fat tissues around the organs together has a meaning, and we can say that the same is true for the other visceral organs such as the stomach, intestine, kidney and pancreas.

Another site for the infection of metacestodes in pigs is the serosa of abdominal organs. The infectivity of the extrahepatic cysticerci, obtained from serosa of a colon in this study, led us to confirm evidently the importance as a source of Asian *T. saginata* infection. Despite our recog-

dition of the extrahepatic tissues as infection sources, however, we do not underestimate the importance of the liver as a source of this infection in humans, because 71% of the non-calcified cysticerci were infected in the liver.

The custom of eating raw viscera is popular in other Asian countries such as Taiwan and Thailand where Asian *T. saginata* is endemic (Cross *et al.*, 1971; Fan *et al.*, 1989b; Chan *et al.*, 1981; Vajrasthira and Harinasuta, 1957). Usually the small intestines and the flesh of wild or domestic animals are eaten raw together with liver in these countries. The infected animals include pigs, cattle, wild boars, flying squirrels, wild goats, muntjacs, monkeys, wild rats, wild hares, pheasants, weasels and cats (Vajrasthira and Harinasuta, 1957; Chan *et al.*, 1981).

Most other experiments reported the liver as the only infected organ of Asian *T. saginata* metacestodes (Fan *et al.*, 1986, 1987 & 1990a). In the present study, we proved the extrahepatic viscera are also infected in experimental pigs. This extrahepatic, viscerotropic cysticercosis seems not due to strain differences of experimental pigs or cattle. The pigs we used were cross breeds of Landrace-Duroc-Hampshire strains rather than the Lanyu strain of Taiwan. In the cattle, all cysticerci were recovered in calcified states, producing no different results from Fan *et al.* (1989a) who used Korean strain eggs in Holstein calves. On the other hand, Fan *et al.* (1986) observed live cysticerci 89 days after infection with Taiwan strain eggs in Holstein-Friesian calves. One of the clear features observed in this study was that the organotropism and the host animal tropism of the metacestodes were different between Asian *T. saginata* and classical *T. saginata*. Asian *T. saginata* metacestode had no musculotropism while classical *T. saginata* metacestode had no pig-host-tropism.

Combination swine pen and human latrines have been used in Cheju Island, Korea, until 1985. This swine pen/latrine system had also been found in China, Taiwan, the Philippines,

Okinawa and some other areas in Asia (Park and Chyu, 1963). This system has been thought to play a major role in the transmission of *T. solium*; but retrospectively, we believe that the system also has contributed to the transmission of Asian *T. saginata*.

Based on our experience, 'Cysticercus viscerotropica' for the metacestode of Asian *T. saginata* is proposed as a term corresponding to 'Cysticercus cellulosa' of *T. solium* or 'Cysticercus bovis' of classical *T. saginata*. We also record the existence of the similar term 'Cysticercus visceralis Gmelin, 1790' (Synonym. *Cysticercus visceralis hominis* Rudolphi, 1810; *Cysticercus visceralis simiae* Rudolphi, 1810; *Cysticercus tenuicollis* Rudolphi, 1810), which is a name for the larval stage of *Taenia hydatigena* Pallas, 1766 (Synonym. *Taenia visceralis* Goeze, 1782; *Taenia visceralis treulneri* Slavikowski, 1879), a different kind of cestode.

In conclusion, Asian *T. saginata* caused 'viscerotropic cysticercosis' in many visceral organs as well as in the liver of pigs and other animals and we confirmed experimentally the infectivity of the extrahepatic metacestode in a human host as well. This new infection mode seems an important supplement in the transmission modes of Asian *T. saginata* infection in Asian people.

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＝국문초록＝

**Asian *Taenia saginata* 條蟲의 중간숙주내
內臟型囊尾蟲症 유발에 관한 실험적 관찰**

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한국산 돼지 간에서 기원한 Asian *Taenia saginata*의 충란을 돼지 (Landrace-Duroc-Hampshire)에 감염시키고 4일~4개월 후 부검하여 감염 장기를 조사한 결과 석회화되지 않은 낭미충의 71%가 간장(肝臟)에서 회수되었으나 대망막 (19.2%), 폐장 (8.1%), 장막 (2.0%) 등의 간의장기 (extrahepatic organ)에서도 발견되어 이 조충이 중간숙주에서 內臟型囊尾蟲症(viscerotropic cysticercosis)을 유발한다는 사실을 관찰하였다. 송아지 (Holstein-Friesian)에서는 실험적 감염후 석회화된 낭미충이 간에서만 발견되었다. 반면에 무구조충의 낭미충은 간을 제외한 송아지 근육 및 내부장기에 감염되었고 돼지에는 감염되지 않았다. 돼지의 간의장기에서 얻은 낭미충을 사람에게 시식시킨 결과 인체 감염이 성립됨을 확인하였다. 돼지의 간의장기도 낭미충에 감염되며 인체감염의 근원이 됨을 실험적으로 새로이 밝혔다.

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