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

Keeseon S. Eom, Han-Jong Rim** and Stanny Geertsz***

Department of Parasitology, College of Medicine, Chungbuk National University, Cheongju 360-763, Department of Parasitology**, College of Medicine, Korea University, Seoul 136-705, Korea, Prince Leopold Institute of Tropical Medicine***, Nationalestraat, 155, B-2000 Antwerp 1, Belgium

Abstract: Asian *Taenia saginata*, tentatively called *Taenia saginata t'aiwanensis*, 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*, viscerotropism 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

*This paper was supported by the NON DIRECTED RESEARCH FUND, Korea Research Foundation, 1989.
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)

<table>
<thead>
<tr>
<th>Number of metacestodes</th>
<th>Hepatic Omentum</th>
<th>Extrahepatic Lung Serosa</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Dead</td>
<td>1487</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>degenerated calcified</td>
<td>68</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>1489</td>
<td>23</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Size of host tissue capsules (in mm)</th>
<th>Mean</th>
<th>Range</th>
<th>S.D.</th>
<th>number measured</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.30</td>
<td>1.0~ 3.0</td>
<td>0.45</td>
<td>292</td>
</tr>
<tr>
<td></td>
<td>3.46</td>
<td>2.5~ 3.5</td>
<td>0.37</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>2.88</td>
<td>2.0</td>
<td>0.48</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>1.40</td>
<td></td>
<td>0.55</td>
<td>5</td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>Intermediate hosts</th>
<th>Infected organs by metacestodes</th>
<th>No. hosts infected/No. hosts challenged</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Asian T. saginata</td>
<td>Classical T. saginata</td>
</tr>
<tr>
<td>Pigs</td>
<td>liver</td>
<td>8/16</td>
</tr>
<tr>
<td></td>
<td>visceral</td>
<td>2/16</td>
</tr>
<tr>
<td></td>
<td>muscle</td>
<td>0/16</td>
</tr>
<tr>
<td>Calves</td>
<td>liver</td>
<td>2/2</td>
</tr>
<tr>
<td></td>
<td>visceral</td>
<td>0/2</td>
</tr>
<tr>
<td></td>
<td>muscle</td>
<td>0/2</td>
</tr>
</tbody>
</table>

* 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 intestine 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-
nition 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 feature observed in this study was that the organotropism and the host animal tropism of the metacestodes were different between Asian *T. sainata* 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 cellulosae’ 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* Goze, 1782; *Taenia visceralis* treutleri 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.

**ACKNOWLEDGEMENT**

We thank Prof. Du-Hwan Jang and Prof. Hong-Ryul Han, College of Veterinary Medicine, Seoul National University; Prof. Seung-Ho Kim, Department of Veterinary Medicine, Cheju University; and Dr. Yung-Bai Kang, Veterinary Research Institute for valuable discussions. Thanks are also due to Prof. Seung-Yull Cho, College of Medicine, Chung-Ang University for reviewing drafts of this manuscript and for introducing the authors the term ‘semna’ and Mr. Won-Kil Park, a Mongologist in Chung-Ang University, who provided its etymology. The help of Dr. Young-Chul Rim in using the experimental animals is gratefully acknowledged.
REFERENCES


한국산 돼지 장에서 기원한 Asian Taenia saginata의 증례를 태지(Landrace-Duroc-Hampshire)에 감염시키고 4일~6개월 후 부검하여 간염 장기로 조사한 결과 섬유화되지 않은 남미충의 71%가 간장(肝臟)에서 회수되었으나 대장(19.2%), 폐장(8.1%), 장막(2.8%) 등의 간의 장기(extrahepatic organ)에서도 발견되어 이 조종이 증간속주에서 내장염과 육증(viscerotropic cysticercosis)을 유발한다는 사실을 관찰하였다. 동자지(Holstein-Frisian)에서는 실험적 감염 후 섬유화된 남미충이 간에서만 발견되었다. 반면에 무구조종의 남미충은 증은 돼지의 간에 제외한 동자지 뼈육 및 내부장기에 감염되었고 돼지는 감염되지 않았다. 돼지의 간내장기에서 얻은 남미충은 사망에 저작시킨 결과 인체 감염이 심심을 확인하였다. 돼지의 간이 장기로 남미충에 감염되어 인체감염의 전염이 발동한 경우의 임상적 및 실험적으로 새로운 밝혀졌다.

[기생충학잡지, 30(4):269-275, 1992년 12월]