Sexual development of *Taenia solium* in hamsters from rodent-derived cysticerci

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Abstract

In order to determine whether *Taenia solium* can be maintained in the laboratory using rodents as definitive hosts, six nude rats, 20 immunosuppressed Mongolian gerbils and 20 immunosuppressed Syrian hamsters were each inoculated through a stomach tube with three cysticerci recovered from SCID mice. No adult worms of *T. solium* were found in the intestinal tract of any of these 46 rodents. In addition, five immunosuppressed Syrian hamsters were fed with the same number of cysticerci enclosed in rodent muscles from SCID mice. Two of these hamsters were found to be infected 40 days post-infection, each harbouring a sexually developed worm in the intestinal tract. Although no eggs were produced, prepatent infections may be possible if a longer time was allowed for worm development. Moreover, the maintenance of the life cycle of *T. solium* in the laboratory using the rodent model can be established.

Introduction

Taenia solium is an important human taeniid cestode, that requires pigs as the intermediate host. The metacestode stage of this parasite can also infect humans, causing cysticercosis which may have a fatal outcome. Moreover, it is possible for humans to acquire cysticercosis by internal autoinfection (Chao, 1994). Therefore, investigations on the adult worm of this parasite are necessary. Several attempts have been made to find a suitable animal model for the adult *T. solium*. Previous results suggest that cysticerci may develop into sexually mature adult worms in immunosuppressed golden hamsters, but the worms in this rodent host do not produce mature eggs (Gnezdilov, 1957; Verster, 1971, 1974; Allan *et al*., 1991).

Recently, oncospheres of *T. solium* and *T. saginata asiatica* were shown to develop into cysticerci in severe combined immunodeficient (SCID) mice (Ito *et al*., 1997a,b), the cysticerci in the subcutaneous tissues of these mice remaining viable five months after infection. Moreover, oncospheres of these parasites can also develop into mature cysticerci in normal and immunosuppressed mice (Wang *et al*., in press). Although cysticerci of *T. solium* recovered from pigs develop into sexually mature adult worms in immunosuppressed golden hamsters (Gnezdilov, 1957; Verster, 1971, 1974; Allan *et al*., 1991), no attempts have been made to test whether the cysticerci from SCID mice can infect and then subsequently develop in rodents. In the present study, we infected nude rats, immunosuppressed Mongolian gerbils and Syrian hamsters with cysticerci obtained from SCID mice to determine the possibility of maintaining the life cycle of *T. solium* in rodents.

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Materials and methods

Collection of adult worms and cysticerci

Following chemotherapy with a mixture of areca and pumpkin seeds, adult worms of *T. solium* were collected

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Table 1. Susceptibility of immunosuppressed rodents to *Taenia solium*.

Rodent	Dosage of triamcinolone acetonide[a]	No. of rodents inoculated	No. of cysticerci per rodent	Age of infection (days)	No. of worms established
Nude rat	0	6*	3	30–90	0
Mongolian gerbil	10 mg every 10th day	20*	3	130–133	0
Syrian hamster	10 mg every 10th day	20*	3	118–128	0
Syrian hamster	10 mg every 10th day	5**	3	40	2[b]

*Cysticerci inoculated through a stomach tube. **Cysticerci enclosed in rodent muscles and eaten. [a]Subcutaneous injection.
[b]Each of two hamsters were found with one tapeworm in intestine; prevalence 40%.

from patients with cysticercosis and taeniasis solium in the King-Shui Hospital, Zhengzhou City, Henan Province, mainland China. These worms were intact but without scolices and were delivered as soon as possible to our laboratory in Taipei by air mail.

Mongolian gerbils and Syrian hamsters were obtained from the National Laboratory Animal Breeding and Research Center, BALB/c SCID mice from the Animal Centre, National Taiwan University, and nude rats from the Animal Center, National Defense Medical Center, Taipei, Taiwan. With the exception of the SCID mice and nude rats, triamcinolone acetonide (Sinicort) (Lin Inc.) was administered subcutaneously to each rodent at a dosage of 10 mg every 10th day.

Eggs were collected from the last ten gravid proglottids of adult *T. solium* and kept in a refrigerator at 4°C. The eggs were hatched by the enzyme method of Stevenson (1983) with our modifications and their viability was determined by colour changes in a 4% trypan blue solution (Wang *et al*., 1997). Each SCID mouse was injected subcutaneously with oncospheres.

The SCID mice and nude rats were kept in autoclaved (100°C for 1 h) cages with autoclaved woody bedding and covered with a filter cap. Food and drinking water were also autoclaved and provided *ad libitum*. These mice were killed by lethal ether administration. Following removal of the rodent skin, cysticerci were recovered from the subcutaneous tissues for use in the experimental infections.

Infection procedures

Each of six nude rats, 20 immunosuppressed Mongolian gerbils and 20 immunosuppressed Syrian hamsters were inoculated through a stomach tube with three cysticerci recovered from the SCID mice. In another group of five immunosuppressed Syrian hamsters, each animal was fed with three cysticerci enclosed in rodent muscles. They were killed by lethal ether administration 30-133 days after infection and adult worms of *T. solium* were collected from the intestinal tract and measured.

Following relaxation in the refrigerator (4°C) overnight, the length and number of proglottids and armed hooks on the scolex were measured and counted. The number of testes in mature proglottids was also recorded.

Results

Susceptibilities of three species of rodents each inoculated with three cysticerci of *T. solium* through a stomach tube from SCID mice are shown in table 1. No adult worms of *T. solium* were found in the intestinal tract of six nude rats, 20 Mongolian gerbils and 20 Syrian hamsters each treated with triamcinolone acetonide (10 mg every 10th day) between 30 and 133 days post-infection (p.i.). However, in another group of five immunosuppressed Syrian hamsters infected through eating cysticerci enclosed in rodent muscles, each of two hamsters were found to harbour one tapeworm in the intestine. The infection rate was 40% (table 1).

Table 2. Measurements of adult worms of *Taenia solium* from Syrian hamsters on day 40 post infection.

	Category	Worm no. 1	Worm no. 2
Proglottids			
Length (cm)	Immature	23.5	14.7
	Mature	21.5	0
Number	Immature	487	157
	Mature	157	0
Scolex (μm)		1100×1440	1225×1350
Sucker	Diameter (μm)	325	330
Hooklet	No. of rows	2	2
	No. of inner hooklets	6	4
	Length (μm)	149 (145–150)*	155 (155–155)
	No. of outer hooklets	15	14
	Length (μm)	97 (85–110)	99 (85–105)

*Mean (range).

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Table 3. Measurements of proglottids and the number of testes in 20 mature proglottids from 40-day-old *Taenia solium* from the Syrian hamster.

	Size of proglottids (mm)		No. of testes	
	Length	Width	Poral side	Aporal side
Mean	1.4	2.2	179	212
Range	0.9–1.8	1.5–2.5	115–214	145–273

The adult worm of *T. solium* (no. 1), collected from the normal intestinal tract of a healthy hamster (body weight 145 g), measured 45 cm with an immature region of 23.5 cm and 487 proglottids and a mature region of 21.5 cm and 157 proglottids. On the scolex, there were four suckers and two rows of hooklets. The six hooklets in the inner row had a mean length of 149 μm. The outer row had 15 hooklets with a mean length of 97 μm (table 2).

A second adult worm (no. 2), collected from the inflamed intestinal tract of an unhealthy hamster (body weight 98 g), contained only 157 immature proglottids which measured 14.7 cm. The scolex had four suckers and two rows of hooklets: an inner row of four hooklets each with a mean length of 155 μm and an outer row of 14 hooklets each with a mean length of 99 μm (table 2).

Twenty mature proglottids from worm no.1 were measured. The mean size was 1.4 mm × 2.2 mm. The mean number of testes was 391 and those on the aporal side (212) was significantly larger than that on the poral side (179) (table 3).

Discussion

Although *T. solium* shows a high specificity for its definitive host, results of the present study and those reported previously by Gnezdilov (1957) and Verster (1971, 1974) indicate that hamsters can harbour young worms. Gnezdilov (1957) first reported the golden hamster as a potential definitive host of *T. solium* after recovering adult worms from 15 of 31 golden hamsters infected with five to 100 cysticerci. However, only strobilation and development of genital primordia in the posterior proglottids of *T. solium* from the intestine of one of the hamsters was observed. Later, Verster (1971, 1974) found that susceptibility of the golden hamster to *T. solium* can be increased by treatment with antilymphocytic serum or chemical immunosuppressants. Although sexually mature proglottids were observed, no gravid proglottids were observed in the immunosuppressed hamsters.

Allan *et al*. (1991) found that worms of *T. solium* in golden hamsters reached lengths in excess of 30 cm after 30 days and several worms reached over 60 cm in length. Genital primordia were clearly apparent in three worms on day 15 p.i., with genital pores being present in worms from day 19 p.i. By day 42, fully mature testes, ovaries and unbranched uteri were apparent. On day 59, the development of branched uteri containing many fertile immature eggs in a worm was observed and by day 75, three worms showed similar stages of development.

In the present study, cysticerci recovered from SCID mice were used to infect nude rats, immunosuppressed Mongolian gerbils and immunosuppressed Syrian hamsters. This is the first experimental infection of *T. solium* from rodent to rodent. From the results of our experiments, oral inoculation of cysticerci through a plastic pipette may cause digestion of cysticerci in the stomach or intestinal lumen of the rodents and result in negative findings. In the group of hamsters infected by eating cysticerci enclosed in rodent muscles, two adult worms of *T. solium* were recovered from two Syrian hamsters 40 days p.i. One worm, which contained mature proglottids, with fully developed testes, ovaries, vagina, Mehlis gland, vitellaria, vas deferens and cirrus sac, was recovered from the intestine of a healthy hamster (body weight 145 g). A second worm, containing only immature proglottids was collected from the severely inflamed intestine of a thin hamster (body weight 98 g), suggesting that the development of *T. solium* in the hamster may relate to the condition of the intestine. Worms can acquire more nutrients from a healthy definitive host, whereas in an unhealthy host there is insufficient nutritional support for worm development. Although no eggs were produced by these worms, it is possible that prepatent infections could occur if a longer experimental period was allowed. It is of interest to note that the number of testes in the 40-day-old worm (319) was greater than that reported in human adult worms (150–200) by Wardle & Mcleod (1968), Beaver *et al*. (1984) and Schmidt & Roberts (1989). The maintenance of *T. solium* in the laboratory using the rodent model is therefore a possibility, but further experimental studies are required to confirm this.

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