Taiwan and the offshore island of Penghu came under the Japanese rule in 1895 under the Treaty of Shimonoseki, when the Ching government of China ceded the islands to the Japanese government. In 1911, the Republic of China was founded, replacing the Ching government in China. However, Japanese ruled Taiwan until the end of the Second World War in 1945. Then, the Nationalist government of China came over and took control of Taiwan until this day.

The first report of taeniasis in Taiwan was made by Oi in 1915 [1], when he found 2 positive cases in a fecal parasitological survey of 301 persons composing of prisoners, students, and patients in Taichung, central Taiwan. In 1927, Oi [2] reported that 2 Japanese immigrants were shedding taeniid eggs out of 220 people surveyed for intestinal parasites in Hualien port city. Then, in 1928, Yokogawa and his associates [3] reported that out of 812 aborigines surveyed in Hsinchu, 163 (20%) were found to be excreting taeniid eggs. The locations of the study areas are shown in Fig. 1.

It was not until 1952, when Huang and associates [4-6] reported that 20.5% (130/634) of the aborigines surveyed in Wulai, Taipei prefecture [4], 16.3% (300/1,839) in Lotung, Ilan prefecture [5], and 9.7% (49/503) in Nan-ao, Ilan prefecture [6], were positive for taeniid eggs shedding, respectively. Since then, about 20 reports on the prevalence of taeniasis in humans in Taiwan had been published in the 1960s, all under the assumption that the causative agent was *Taenia saginata*. *Taenia solium* is extremely rare in Taiwan with only 5 cases being reported from 1957 to 1970 by Hsieh in southern Taiwan (Cited in Chung & Liu [7]).

**DISCOVERY OF TAIWAN TAENIA**

It was only in 1966, when Huang and associates [8] first proposed that the *Taenia* tapeworm infecting the Taiwan aborigines in such high prevalences might not be the same as the classical *T. saginata*. They observed that the aborigines do not have access to beef, and their main animal protein source came mainly from wild boars and other hunted wildlife [8,9].

It was only in the 1970s that experimental infection of the eggs of *T. asiatica* and that of the American *T. saginata* was carried out in bovine calf and goats for comparison [10].
cysticerci of the American isolate were found in the muscles of the neck, rib, heart, and legs but not in the liver. Whereas, about half of the cysticerci of the Taiwan isolate were found in the liver of the infected calf. Moreover, no hooklets were observed in any of the American isolate cysticerci, but 88% of the Taiwan isolate cysticerci had hooklets on their rostellum. In addition, it was also observed that the various morphometric parameters, such as the body length and width, protoscolex, and sucker diameter were larger for the American isolate than the Taiwan isolate. All the cysticerci of the Taiwan isolate in the experimentally infected goat were recovered only from the liver, and all of them had hooklets. It was later observed that the cysticerci of Taiwan Taenia could not grow in the liver of the cow because they degenerate at 2 months post-infection.

In the 1980s, it was apparently becoming clear that Taiwan Taenia might be a different species than that of the classical T. saginata, based on the site of predilection being in the liver, its developmental morphology, and the pig serving as its natural intermediate host (Table 1) [11,12]. The paradox of this parasite epidemiology is that in the area where T. saginata-like infection in humans is widely prevalent, the inhabitants had little chance of eating beef, and Cysticercus bovis were not present in the bovids in that area. However, the inhabitants had the habit and chance of eating raw liver of pigs. Then, Fan and collaborators from other countries observed that taeniiads with similar characteristics to Taiwan Taenia were also found in other Asian countries such as Korea (Cheju-do Island), Indonesia (Samosir Island), the Philippines, Thailand (Chiang Mai), and Myanmar [13-15].

In the early 1990s, despite the overwhelming genetic evidence that the Taiwan Taenia might be a new species, American and Australian workers still suggested that it would be more appropriate to classify it as a subspecies of T. saginata [16]. Thus, in 1995, Fan and associates [17] proposed that the Taiwan Taenia be named as T. saginata asiatica, and the classical T. saginata found in America and Europe as T. saginata saginata. Today, that parasite, which is prevalent in many Asian countries, is now internationally recognized as a distinct species, namely, T. asiatica, mainly through the efforts and description of Eom and colleagues in Korea [18,19]. Fan and his coworkers published more than 100 papers on T. asiatica. He passed away on 2 September, 2008, due to an aortic aneurysm at the age of 86.

**EXPERIMENTAL ANIMAL INFECTION WITH T. ASIATICA EGGS**

Cysticerci of T. asiatica have been recovered mainly from the liver of pig, calf, goat, and monkey after oral inoculation of the eggs. However, only calcified and degenerated cysticerci were observed in the liver of goat and monkey [13,20]. T. asiatica cysticerci were found to be able to develop to maturity in scid mice [21,22] and also Mongolian gerbil [21] after subcutane-

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**Table 1. Comparison of Cysticercus bovis from Taiwan and American Origins**

| Origin                  | Intermediate host | Cysticercus locality | Cysticercus examined | Hooklets on cyst |
|-------------------------|-------------------|----------------------|----------------------|------------------|
| Taiwan aborigine        | Calf (cow)        | Liver                | 33                   | Absent: 6 (18.2%) Present: 27 (81.8%) |
| Taiwan aborigine        | Goat              | Liver                | 16                   | Absent: 0 (0.0%) Present: 16 (100%) |
| American volunteer      | Calf (cow)        | Muscles              | 39                   | 39 (100%)       |

*a* Fan et al. [11].

*b* A total of 48 cysticerci were recovered in the heart (8), neck (4), intercostal (4), foreleg (24), and hindleg (8) muscles, but only 39 were examined.
ous injection of oncospheres. These cysticerci were able to grow to maturity in the rodents and then develop into the tapeworm stage in the rodent alternative definitive host or in humans [23].

CLINICAL MANIFESTATIONS AND CHEMOTHERAPY OF TAENIASIS PATIENTS IN TAIWAN

Humans infected with taeniasis infection experience many types of clinical symptoms but not all of them are the same. Table 2 shows the clinical manifestation of taeniasis among Aborigines in Taiwan and these patients were most probably infected with the Taiwan Taenia. To study the various symptoms of Taiwan taeniasis and to obtain the adult worm, many brave researchers had volunteered to orally infect themselves with cysticerci of *T. asiatica* by eating the raw pig liver (Fig. 2).

Since there were many taeniasis patients in Taiwan through the 6 decades, many types of drugs had been used in the chemotherapy deworming trials. These drugs include atabrine (quinacrine), dichlorophen (arecoline), bithionol (bithin), yomesan (niclosamide), acanil (mebendazole), albendazole, and praziquantel (Table 3). It was observed that niclosamide (Table 4) [24], albendazole (Table 5) [25,26], and mebendazole [27] were not very efficacious against human *T. asiatica* infections. However, Rim et al. [28,29] stated that albendazole was effective for treatment of *T. saginata* and *T. solium*. Nevertheless, it must be noted that the efficacy of anthelmintic drugs can be influenced by the patient’s physiological status such as being in a fasting or non-fasting condition [30].

Table 2. Clinical manifestation of taeniasis among aborigines in Taiwan

| Clinical signs                        | No. of cases (Total 1,258) | %  |
|--------------------------------------|----------------------------|----|
| Proglottids shed in feces            | 1,200                      | 95 |
| Pruritis at perianal area            | 963                        | 77 |
| Nausea                               | 584                        | 46 |
| Abdominal pain                       | 564                        | 45 |
| Dizziness                            | 523                        | 42 |
| Increased appetite                    | 374                        | 30 |
| Headache                             | 321                        | 26 |
| Diarrhea                             | 222                        | 18 |
| Weakness/Lethargy                    | 210                        | 17 |
| Feeling of hunger                    | 200                        | 16 |
| Constipation                         | 135                        | 11 |
| Weight loss                          | 71                         | 6  |
| Abdominal discomfort                 | 66                         | 5  |
| Tiredness                            | 53                         | 4  |
| Loss of appetite                     | 52                         | 4  |
| Vomiting                             | 50                         | 4  |
| No appetite despite fasting          | 14                         | 1  |
| Muscular pain                        | 13                         | 1  |
| Stomach discomfort                   | 9                          | <1 |
| Gastric pain                         | 8                          | <1 |
| Feeling sleepy                       | 4                          | <1 |
| Convulsion                           | 2                          | <1 |
| Anxiety                              | 2                          | <1 |
| Skin pruritis                        | 1                          | <1 |
| Respiratory irregularity             | 1                          | <1 |
| Hunger pain                          | 1                          | <1 |

Table 3. Chemotherapeutic agents for cestode infections

| Chinese herbs (plant name, effective compound) | Drug name          |
|-----------------------------------------------|--------------------|
| Pumpkin seed (*Cucurbita pepo, Cucurbitine*)  | Atabrine (Quinacrine) |
| Betel nut (*Areca catechu, Arecoline*)        | Dichlorophen       |
| Somegranate root (*Punca granatum, Pelletierine*) | Bithionol (Bithin) |
| Flix mas (*Okraea aspidium*)                  | Yomesan (Niclosamide) |
| Kamala (*Mollotus philippinensis*)            | Acanil (Mebendazole) |

Table 4. Efficacy of niclosamide in the treatment of human taeniasis

| No. of worms expelled | No. of cases | Deworming results | Questionnaire |
|-----------------------|--------------|-------------------|---------------|
|                       |              | Worm | With scolex | No. cases | Worm expelled |
| 1                     | 13           | 13   | 4          | 3         | 3*             |
| 2                     | 3            | 6    | 2          | 0         |                |
| 3                     | 2            | 6    | 0          | 0         |                |
| 8                     | 1            | 8    | 5          | 0         |                |
| Total                 | 19           | 33   | 11         | 3         | 3              |

*Chung et al. [16], Fan et al. [12,15,31].

*Fan et al. [24].

*Cure rate, 84.2% (16/19); dose of niclosamide, 2 g/case.

*Worms were expelled with atabrine 4 months later.

Fig. 2. A volunteer, Dr. Chung WC, trying to infect himself with *Taenia asiatica* by eating raw wild boar liver that contained cysticerci.
Praziquantel, at a single dose of 150 mg, was found to be the most effective against *T. asiatica* infection in humans, without causing any side reaction [27]. This efficacy is followed by atabrine and then by niclosamide [31]. However, sometimes no complete worms could be recovered from the feces of the patient after treatment, probably due to dissolution of the worm by the drug.

Atabrine, despite producing some side effects, can still be used, in properly controlled dosages, as the drug of choice for human *T. asiatica* infection if we need to recover the expelled worms for morphological examinations. It can be taken orally at a total of 1 gm divided into 2 equal doses given at 30 min interval, after the patient is fasted and given 4 gm of sodium bicarbonate to prevent vomiting. The patient should then be given a purgative of magnesium salt (25 g in 1 liter of water) at 1.5 hr after taking the second dose. The expelled worm can then be collected from the feces within a few hours. To date, the most number of worms collected from a single patient in Taiwan was 24 specimens, after medication with atabrine (Fig. 3).

**Lesions in the pig liver**

The pig serves as the natural intermediate host of *T. asiatica* and the site of predilection is in the liver (Fig. 4). However, other parasitic pathogens might also cause apparently similar hepatic lesions. A differential comparison of the hepatic lesions caused by other parasites is presented in Table 6 [32-36].

**Present status of *Taenia asiatica* in Taiwan**

*T. asiatica* is still present in Taiwan today but in only some aborigines who live in the mountainous areas. However, the
cases are getting rarer with the improvement of rural medical health services. *Taenia asiatica* has always been there and has come a long way for its recognition. We just need to train our eyes to see in different dimension.

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Table 6. Parasites that produce lesions in the liver of pigs

| Parasite                     | Location | Principal lesions in the liver |
|------------------------------|----------|--------------------------------|
| Clonorchis sinensis          | Bile duct| Dilation of the bile duct, periductal fibrosis |
| Opisthorchis teruicollis     | Bile duct| Dilation of the bile duct, periductal fibrosis |
| Dicrocoelium dendriticum     | Bile duct| Dilation of the bile duct, periductal fibrosis |
| Fasciola hepatica            | Bile duct| Dilation of the bile duct, periductal fibrosis |
| Fasciola gigantica           | Bile duct| Dilation of the bile duct, periductal fibrosis |
| Schistosoma japonicum        | Liver    | Pinpoint white spot, granuloma  |
| Taenia hydatigena            | Liver    | White cyst                      |
| Echinococcus granulosus      | Liver    | White cyst                      |
| E. multilocularis            | Liver    | White cyst                      |
| Taenia asiatica (Taiwan taenia) | Liver  | White cyst                      |
| Ascaris suum                 | Liver    | Pinpoint white spot             |
| Toxocara canis               | Liver    | Pinpoint white spot             |
| Stepnosurus dentatus         | Liver    | Pinpoint white spot             |

*Ooi et al. [32], Kamiya et al. [33], Schilhorn van Veen [34], Soulsby [35], Taira et al. [36].*
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