Taeniases and cysticercosis in Indonesia: past and present situations

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(*Received 20 March 2013; revised 8 May 2013; accepted 10 May 2013; first published online 21 August 2013*)

SUMMARY

The main aim of this study is to overview the past and present situations of human taeniases and cysticercosis in Indonesia and including future perspectives. Through joint projects from 1996, we have confirmed the occurrence of *Taenia saginata* (beef tapeworm) in Bali, of *Taenia solium* (pork tapeworm) mainly in Papua and sporadically in Bali, and of *Taenia asiatica* in North Sumatra. These taeniases were caused through eating uncooked pork and pig viscera for *T. solium* and *T. asiatica*, respectively, and beef for *T. saginata*. The distribution of these tapeworms in Indonesia is basically highly restricted by the traditional cultural and religious backgrounds in each island. *T. saginata* is relatively common in Bali although people consume pork '*lawar*' more than beef '*lawar*'. Taeniases due to *T. saginata* or *T. asiatica* and *T. solium* and cysticercosis due to *T. solium* have also been sporadically reported in some other islands. Among these species, *T. solium* is exceptional since humans can be infected not only by larval stages (cysticerci) in pork but also by eggs released from human tapeworm carriers. Cysticercosis has been confirmed in Indonesia in humans, pigs and even dogs.

Key words: *Taenia solium*, *Taenia saginata*, *Taenia asiatica*, taeniases, cysticercosis due to *T. solium*, Bali, North Sumatra, Papua.

INTRODUCTION

Indonesia is an archipelago consisting of 17 504 islands. The five largest islands are Sumatra, Java, Kalimantan, Sulawesi and Papua. Administratively, the country is divided into 33 provinces (under the new constitution of Indonesia in 2012 is divided into 34 provinces) with a total population of 237 641 326. The majority of the population of Indonesia is Muslim (87·18%), whereas the remaining 12·82% consists of Christians, Buddhists, Hindus and others. Christian populations are the majority in certain districts in several provinces of Indonesia such as East Nusa Tenggara, North Sulawesi, Papua and North Sumatra. By contrast, in Bali Provinces, the majority of the 3 890 757 inhabitants are Hindus (83·5%) (Statistics Indonesia, 2011). Different religious and socio-cultural backgrounds in these provinces may affect the number of cases or prevalence of the major human cestode parasites in Indonesia. Usually, taeniases due to the ingestion of uncooked meat are in general rare in Indonesia, since Muslims usually do not eat uncooked meat.

Historically, *Taenia saginata* taeniasis in Indonesia was first reported in the 19th century, where Luchtmans found this disease among the Dutch in East Java in 1867 (Oemijati, 1977). By contrast, taeniasis due to *Taenia solium* was identified from a Chinese living in East Kalimantan in 1940 (Bonne, 2006).

Through joint projects starting in 1996, we have confirmed the occurrence of taeniases due to *T. saginata* from Bali, *T. solium* from Papua and Bali, and *T. asiatica* from Samosir Island in Lake Toba, North Sumatra. *T. saginata* taeniasis is rather common in Bali where local people consume uncooked beef dish (beef *lawar*) as a traditional local food (Simanjuntak *et al*. 1997; Wandra *et al*. 2007).

Taeniases due to *T. saginata* and/or *T. asiatica* and *T. solium* and cysticercosis due to *T. solium* have also been sporadically reported from other provinces: Lampung, Jakarta, West Kalimantan, North Sulawesi, South Sulawesi, South-East Sulawesi and East Nusa Tenggara (Fig. 1) (Simanjuntak *et al*. 1997; Margono *et al*. 2001*a*, 2002; Ito *et al*. 2004; Suroso *et al*. 2006; Wandra *et al*. 2007).

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Parasitology (2013), **140**, 1608–1616.
doi:10.1017/S0031182013000863

Fig. 1. Geographic maps of Indonesia (upper) and Bali (lower). 01–09: nine districts in Bali: Jembrana (01), Tabanan (02), Badung (03), Denpasar (04), Gianyar (05), Bangli (06), Klungkung (07), Karangasem (08), and Buleleng (09). Denpasar is the capital city of Bali.

DISTRIBUTION OF TAENIASIS AND CYSTICERCOSIS

T. solium *cysticercosis in Papua (formerly Irian Jaya)*

In Papua, taeniasis/cysticercosis (T/C) cases due to *T. solium* were first reported from Paniai district in early 1970s (Tumada and Margono, 1973*a*, *b*; Desowitz *et al*. 1977). In this district, increased number of cases of seizures and burns were reported from people sleeping around fire-places in local houses (Tumada and Margono, 1973*b*). During 1973–1976, the number of cases of burns increased up to 257, resulting from accidents due to epileptic seizures (Subianto *et al*. 1978). In Enarotali hospital, Paniai, a total of 15/170 hospitalized patients were positive for *Taenia* eggs (9%). Within 6 months (1972–1973), 13 cysticercosis cases were reported, and a total of 77·3% of suspected cysticercosis patients were serologically positive (Desowitz *et al*. 1977).

Movement of people from the endemic district (Paniai) to other districts, sometimes with pigs as the traditional and socio-cultural life style, appears to have spread the parasite to other 5 districts in Papua (Jayawijaya, Manokwari, Nabire, Pegunungan Bintang and Puncak Jaya) (Table 1, Fig. 2) (Simanjuntak *et al*. 1997; Wandra *et al*. 2007; Salim *et al*. 2009) and even into Papua New Guinea (PNG) (Fritzsche *et al*. 1990: Flew, 1998; Ito *et al*. 2004; Owen, 2006).

In Jayawijaya district, neurocysticercosis (NCC) appears to remain highly endemic, since people suffering from epileptic seizures and subsequently drowned in rivers were reported from District Health Office Services (Handali *et al*. 1997; Simanjuntak *et al*. 1997). During 1991–1995, the number of cases of epileptic seizures increased each year at a local health centre with a total 293 new cases of epileptic seizures and 1120 cases of burns. Serology, using highly specific native or recombinant antigens (Ito *et al*. 1998, 1999, 2004; Sako *et al*. 2000, 2013; Sato *et al*. 2003 – see this Special Issue of Parasitology, volume 140) and mitochondrial DNA (mtDNA) analysis (Yamasaki *et al*. 2004), revealed that the majority of cases of epileptic seizures and burns were due to the presence of cysticerci of *T. solium*, and approximately 25–30% of healthy people were asymptomatic but positive for cysticercosis as well (Wandra *et al*. 2000, 2003; Ito *et al*. 2004; Yamasaki *et al*. 2004).

An epidemiological study on T/C was carried out in 5 districts of Papua in 1996–2005. A total of 1474

https://doi.org/10.1017/S0031182013000863 Published online by Cambridge University Press

Table 1. Summarized data of prevalence of taeniases and seroprevalence of cysticercosis due to *T. solium* in Papua by District, 1996–2012 (Subahar *et al*. 2001; Ito *et al*. 2002; Wandra *et al*. 2003, 2007; Salim *et al*. 2009)

Year	District	Prevalence of *T. solium* taeniasis (%)	Seroprevalence of cysticercosis in:			References
			Humans	Pigs	Dogs	
1997–1998	Merauke	0/90	1/90 (1·1)[a]	NS	NS	Wandra *et al*. (2007)
2003–2004	Manokwari	NS	8/274 (2·9)	NS	NS	Wandra *et al*. (2007)
2004	Paniai	NS	1/61 (1·6)	NS	NS	Wandra *et al*. (2007)
2009	Paniai	(9·6)	(29·2)	NS	NS	Salim *et al*. (2009)
2004–2005	Nabire	NS	10/105 (9·5)	NS	NS	Wandra *et al*. (2007)
2009	Peg. Bintang	(10·7)	(2·6)	NS	NS	Salim *et al*. (2009)
2009	Puncak Jaya	(1·7)	(2·0)	NS	NS	Salim *et al*. (2009)
1996–2002	Jayawijaya	19/146 (13·0)	203/902 (22·5)	NS	NS	Wandra *et al*. (2003)
1998–1999	Jayawijaya	NS	NS	(8·5–70·4)	NS	Subahar *et al*. (2001)
2000–2002	Jayawijaya	NS	NS	NS	(4·9–33·3)	Ito *et al*. (2002)
2009	Jayawijaya	(7·0)	(20·8)	NS	NS	Salim *et al*. (2009)
2011	Jayawijaya	NS	28/181 (15·5)	NS	NS	Swastika *et al*. unpublished
2012	Jayawijaya	NS	9/109 (8·3)	38/200 (19·0)	NS	Swastika *et al*. unpublished

NS: no sample.
[a] Imported case.

Fig. 2. Map of Papua (former Irian Jaya) and Papua New Guinea (PNG). Numbers 1–6 are District names in Papua and PNG. 1: Paniai where the first outbreak of NCC was reported in 1970' (Tumada and Margono, 1973*a*, *b*; Desowitz *et al*. 1977), 2: Jayawijaya where it was reported in 1990', 3: Merauke where only one imported case was found; 4 and 5: Nabire and Manokwari, respectively, where it was reported in 2000', 5: Manokwari where only imported case was found, 6: OK Teddy Mine where NCC cases were confirmed in 1997 (Flew, 1998; Ito *et al*. 2004; Owen, 2006).

persons were surveyed using both questionnaires and physical examinations, detection of taeniasis by copro-ELISA and mtDNA analyses. Serology of people, pigs and dogs was conducted for the detection of antibodies against cysticerci of *T. solium*. A total prevalence of 13·0% for *T. solium* taeniasis was confirmed in Jayawijaya district. No *T. saginata* or *T. asiatica* has been found from Papua. A total seroprevalence of 15·7% cysticercosis was detected in all of five districts (Jayawijaya, Manokwari, Nabire, Paniai and Merauke) (Fig. 2). The seroprevalence of cysticercosis in humans in each district was highly variable from 1·1% in Merauke (1997–1998) to 22·5% in Jayawijaya (1996–2002). There is no evidence that *T. solium* transmission occurs in Merauke. One woman showing a high antibody titre in 2007 was a transmigrant from South Sulawesi. Seroprevalence of cysticercosis in pigs in Jayawijaya ranged from 8·5–70·4% during 1998–1999 and in dogs from 4·9–33·3% in 2000–2002 (Subahar *et al*. 2001; Ito *et al*. 2002, 2004; Margono *et al*. 2003; Wandra *et al*. 2007) (Table 1). As dog meat is available in Papua, dogs as well as pigs may play a role in the completion of the *T. solium* life cycle (Ito *et al*. 2002, 2004).

Salim *et al*. (2009) reported seroprevalence of cysticercosis and taeniasis in four districts: They are 20·8 and 7·0%, respectively in Jayawijaya, 29·2 and 9·6% in Paniai, 2·6 and 10·7% in Pegunungan Bintang and 2·0 and 1·7% in Puncak Jaya. As we have no previous data on T/C in the latter two districts, it is impossible to evaluate these data, especially the uniqueness showing high prevalence of taeniasis but very low cysticercosis in Pegunungan Bintang without direct evidence other than indirect serological data.

The recent field survey of cysticercosis in Jayawijaya revealed that 15·5% (2011) and 8·3% (2012) of humans and 19% of pigs (2012) were seropositive for cysticercosis (Swastika *et al*. unpublished). The serological tools applied in Papua were ELISA, immunoblot for both people and pigs, and for people the commercially available

https://doi.org/10.1017/S0031182013000863 Published online by Cambridge University Press

Table 2. Summarized data of taeniasis cases and seroprevalence of cysticercosis by District in Bali, 2002–2013 (Wandra *et al*. 2006*a*, *b*, 2007, 2011; Sudewi *et al*. 2008)

		No. of taeniasis cases			Seroprevalence (%) of cysticercosis in	
Year	District	*T. saginata*	*T. solium*	*T. asiatica*	Humans	Pigs
2002–2013	Gianyar	107	0	0	10/431 (2·3)	NS
2004	Badung	1	0	0	0/91 (0·0)	NS
2004–2010	Denpasar	14	0	0	0/119 (0·0)	NS
2007	Bangli	0	0	0	0/32 (0·0)	NS
2008	Tabanan	0	0	0	0/42 (0·0)	NS
2008	Jembrana	0	0	0	0/84 (0·0)	NS
2009	Klungkung	0	0	0	0/100 (0·0)	NS
2009	Buleleng	0	0	0	0/47 (0·0)	NS
2006	Karangasem (urban area)	1	0	0	1/36 (2·8)	NS
2011–2013	Karangasem (rural area)[a]	0	9	0	22/389 (5·7)	36/228 (15·8)
Total		123	9	0	33/1371 (2·4)[a]	36/228 (15·8)[a]

NS: no sample.
[a] Swastika *et al*. unpublished.

immunochromatographic rapid kit (ADAMU-CC, ICST Co. Ltd., Saitama, Japan) using recombinant antigens and native but highly purified antigens (Sako *et al*. 2013). Subcutaneous cysticerci of *T. solium* were confirmed from several sero-positive volunteers. Compared to serological data in Jayawijaya (1996–2009), seroprevalence of cysticercosis in humans and pigs appears to be relatively lower in 2011–2012 but further follow-up studies on a larger scale are necessary to discuss the future perspectives. The data from the two groups, sero-positive and sero-negative for cysticercosis in Jayawijaya (1996–2002), showed that the most important factors associated with cysticercosis were age (18 years or older), low level of education and the habit of not washing hands before eating. Furthermore, among 506 families in Jayawijaya, surveyed during 1996–2005, it was reported that only 17% were defaecated in a latrine (Wandra *et al*. 2007).

Taeniasis/cysticercosis in Papua New Guinea

There is a possibility of introduction of T/C due to *T. solium* to the neighbouring country, PNG (Fritzsche *et al*. 1990; McManus, 1995; Flew, 1998; Ito *et al*. 2004; Dwyer, 2006; Owen, 2006). A serological survey of OK Teddy Mine in PNG (Fig. 2) was carried out in 1997 using approximately 600 human serum samples. Based on both ELISA and immunoblot examinations, approximately 3% were confirmed serologically-positive for cysticercosis (Flew, 1998; Ito *et al*. 2004). It is, therefore, urgent to conduct field surveys of T/C in PNG.

Taeniases/cysticercosis in Bali

Historically, the first report of cysticercotic pigs in Bali was published in 1928 (Le Coultre, 1928). Human subcutaneous cysticercosis (SCC) cases were reported in 1960 (Soebroto *et al*. 1960). There are several reports on *T. solium*, epileptic seizures, SCC, NCC, and seroprevalence of cysticercosis in Bali (Ngoerah, 1975; Simanjuntak *et al*. 1977; Theis *et al*. 1994; Rodriguez-Canul *et al*. 1997; Sutisna *et al*. 1999; Margono *et al*. 2001*b*, 2002; Wandra *et al*. 2006*a*, *b*, 2011; Sudewi *et al*. 2008).

Taeniasis cases have been observed in all nine districts of Bali Province (Gianyar, Badung, Denpasar, Bangli, Tabanan, Jembrana, Klungkung, Buleleng and Karangasem) during 2002–2013 (Fig. 1). A total of 1492 persons were surveyed using both questionnaires and physical examinations. *Taenia* eggs were detected by microscopic examination of faecal samples (Kato-Katz method). Identification of *Taenia* species using the expelled proglottids was carried out by mitochondrial DNA analysis (Yamasaki *et al*. 2004; Myadagsuren *et al*. 2007; Wandra *et al*. 2007). Serology of people (1369) and pigs (228) was carried out for the detection of *T. solium* cysticercosis.

Among 1492 people, a total of 123 *T. saginata* taeniasis cases were found which were distributed in four districts (Gianyar, Badung, Denpasar and an urban area in Karangasem) (107, 1, 14 and 1 cases, respectively), and 9 cases of *T. solium* taeniasis in Karangasem (rural area). *T. solium* was first observed in rural area of Karangasem in 2011 (3 cases) after one decade of surveys in Bali from 2002 onwards (Fig. 1) (Wandra *et al*. 2011; Swastika *et al*. unpublished).

So far, there is no real evidence of *T. asiatica* in Bali (Table 2). We have concluded from interviews that this is because the majority of local people prefer uncooked pork *lawar* but dislike uncooked viscera of pigs. It is crucial difference from local people in Samosir Island in Lake Toba, North Sumatra (see below). However, several persons interviewed in

https://doi.org/10.1017/S0031182013000863 Published online by Cambridge University Press

Table 3. Summarized data of cysticercosis in Bali, 2003–2010 (NCC: neurocysticercosis, OCC: ocular cysticercosis)

Hospital/Area (year)	Diagnosis	No. of cases	References
Sanglah Hospital/Denpasar (2003)	Disseminated Cysticercosis	1	Sudewi *et al*. (2008)
Sanglah Hospital/Denpasar (2004)	NCC	3 (1 with 2 nodules)	Sudewi *et al*. (2008)
Sanglah Hospital/Denpasar (2005)	NCC	1 (with 2 nodules)	Sudewi *et al*. (2008)
Gianyar District (2007)	NCC	1 (with *T. saginata* taeniasis: dual infection)	Wandra *et al*. (2011)
Sanglah Hospital/Denpasar (2009)	NCC	5	Sudewi *et al*. in prep.
Sanglah Hospital/Denpasar (2009)	NCC	3	Sudewi *et al*. in prep.
Indera Hospital/Denpasar (2010)	OCC	1	Swastika *et al*. (2012)
Gianyar District (2010)	NCC (1[a])	3 (with *T. saginata* taeniasis: dual infection)	Wandra *et al*. (2011)
	Cysticercosis (2[b])		Swastika *et al*. (2012)

[a] Serology and CT Scan (+).
[b] Serology (+) but CT Scan (−).

Karangasem in 2013 told us that they consumed undercooked liver of pigs as well as pork. Therefore, the possibility of an epidemic of *T. asiatica* taeniasis remains at least in this area, especially when carriers of *T. asiatica* taeniasis visit this area and pigs are contaminated with eggs of this parasite, and meat and viscera of pigs are served as a local dish without meat inspection.

A total of seroprevalence of 2·4% *T. solium* cysticercosis was confirmed using both glycoproteins purified from *T. solium* cyst fluid (Ito *et al*. 1998) and chimeric recombinant antigen (Sako *et al*. 2000; Sato *et al*. 2003). Among 1369 human serum samples examined after mass screening in the nine districts, serum samples from only 2 districts (Gianyar and Karangasem) were sero-positive for cysticercosis (2·3 and 2·8%, respectively). A total of sero-prevalence of 15·8% (36/228) [5 of 64 (7·8%) in 2011 (based on ELISA and immunoblot) and 18·9% (31/164) in 2013 (based on ELISA)] was detected in pigs in Karangasem (Table 2) (Swastika *et al*. unpublished). So, there can be no doubt that Karangasem is exceptionally highly endemic with T/C in Bali.

During 2003–2010, a total of 13 cases of *T. solium* cysticercosis from Sanglah Hospital, University of Udayana and 1 case from Indera Hospital, Denpasar, were reported sporadically. These cases were mostly from people living in Gianyar and Karangasem and the remaining cases lived in other districts. A total of 4 cases were detected in the field during epidemiological an survey in Gianyar (Table 3) (Sudewi *et al*. 2008; Wandra *et al*. 2011). It is assumed that the source of infection of *T. solium* in Bali, especially in Gianyar, is due to *T. solium* carriers from Karangasem who periodically migrated to other districts of Bali for looking for jobs during the dry season from April to October.

There is a crucial difference in the socio-economic data of local people between Gianyar (2002–2004) and other districts (2004–2010) including Karangasem (2011). Almost all families in Gianyar have good sanitary facilities and do not defaecate in the backyard, and all pigs are kept indoors (Wandra *et al*. 2006*a*, *b*). People in Gianyar like to eat uncooked beef '*lawar*', whereas most people in other districts eat cooked beef (Wandra *et al*. 2011). *Lawar* is a traditional local dish of raw pork or raw beef and it suggests a reason why we can detect taeniasis due to *T. saginata* every year in Gianyar. By contrast, in rural Karangasem, 29% (18/62) of families have no sanitary facilities and people defaecate in the garden, 83·9% (40/46), 10·9% (5/46) of pig owners keep their pigs in a fenced field, and 2·2% (1/46) in open common pasture and roaming free. Interviews of 62 respondents of 62 families in Karangasem in 2011 showed that all were Hindus, of whom 83·9% (52/62) consumed pork *lawar* and 9·7% (6/62) consumed beef *lawar* (Swastika *et al*. unpublished). Such crucial differences may be in part due to the crucial difference in geographic situation between the two districts. Gianyar is located between Karangasem and the capital city, Denpasar and is basically a flat region whereas the rural area in Karangasem is the slope of Mount. Agung (3142 m) (Fig. 1). Also, local beef contaminated with cysticerci of *T. saginata* may be widely consumed in Bali, but only people who eat uncooked beef become infected with *T. saginata,* as shown in Gianyar. It cannot explain the reason why *T. saginata* infections are not rare in people living in Badung, Denpasar and the urban area of Karangasem. Uncooked beef *lawar* is prepared and sold exclusively in Gianyar. So, people in other districts may acquire infection by consumption of beef *lawar* prepared in Gianyar by (1) attending religious ceremonies in Gianyar, or (2) people from Gianyar bringing beef *lawar* as a gift mainly for the religious ceremonies for their relatives or friends living in other districts.

However, the source of infection for *T. saginata* taeniasis is still not clear, since cattle in Bali are also

https://doi.org/10.1017/S0031182013000863 Published online by Cambridge University Press

slaughtered in unlicensed slaughterhouses. Quality control of beef, even in the markets, is rather difficult because of the limited number of meat inspectors (Wandra *et al*. 2006*a*, 2007). During 2002–2004, three of 56 *T. saginata* carriers in Gianyar were beef *lawar* sellers and several other taeniasis carriers bought *lawar* from these sellers (Wandra *et al*. 2006*b*). In addition, screening of 15 *lawar* sellers in 2004 revealed that 40% (6/15) of them were *T. saginata* carriers (Wandra *et al*. 2011).

Taeniasis/cysticercosis in Samosir Island, Lake Toba, North Sumatra

Although *T. asiatica* was described as an independent species by Eom and Rim (1993), this parasite has been recognized for long time as common in Asia and known as 'Asian *Taenia*' which is common in people who eat meat and viscera of pigs but not cattle in Taiwan, the Philippines and Indonesia (Yokogawa, 1935; Huang *et al*. 1966; Kosin *et al*. 1972; Chao and Fan, 1986; Fan *et al*. 1987, 1990*a*, *b*; Fan, 1988; Kosman *et al*. 1988; Simanjuntak *et al*. 1997; Ito *et al*. 2003, 2005; de Leon, 2005). One example of this unique 'Asian *Taenia*' was reported as common tapeworms from Samosir Island (Kosin *et al*. 1972). Epidemiological surveys in 1986 and 1987 revealed that 21% (97/465) of 76 families in Samosir Island were infected with 'Asian *Taenia*' (Kosman *et al*. 1988). The Indonesian parasitologists joined with Fan in Taiwan and confirmed the unique life cycle of this 'Asian *Taenia*' (Fan *et al*. 1990*a*, *b*). It is interesting to note that eggs of 'Asian *Taenia*' develop into mature metacestodes in the liver of pigs and cattle but not in muscle. Nonetheless, it has been stressed that *T. asiatica* inhabits the liver of pigs and differs from *T. saginata* in its organotropism for liver rather than muscle.

These Taiwan, Indonesian and Korean researchers regarded 'Asian *Taenia*' as an independent species (Chao and Fan, 1986; Fan *et al*. 1987, 1990*a*). However, several researchers working on molecular differences between 'Asian *Taenia*' and *T. saginata* recommended that it should not be described as an independent species (Zarlenga *et al*. 1991; Bowles and McManus, 1994; Simanjuntak *et al*. 1997). The most recent molecular studies on *T. asiatica* and *T. saginata* carried out in several areas where both species are occur sympatrically have revealed hybrids of these two species (Okamoto *et al*. 2010; Yamane *et al*. 2012, also see this Special Issue of Parasitology, volume 140, 2013). So, the species status is still under debate.

Recent epidemiological surveys of T/C and soil-transmitted helminthiases carried out in 2003, 2005 and 2006 revealed that six of 371 people (1·6%) from 285 families [2 of 58 (3·4%) in 2003 and 4 of 182 (2·2%) in 2005] were confirmed as infected with *T. asiatica* by multiplex PCR (Yamasaki *et al*. 2004; Wandra *et al*. 2007). We could not detect any case of *T. asiatica* in 2006 and there was no evidence of the occurrence of *T. solium* or *T. saginata* in this island, since all tapeworms were identified to be *T. asiatica* by multiplex PCR (Wandra *et al*. 2007). The residents of Samosir Island eat a traditional dish made with minced pork (Kosman *et al*. 1988; Fan *et al*. 1992). When they cut pork into small pieces, they eat uncooked viscera (liver) which contains the cysticerci of *T. asiatica*, which is a clear risk factor for taeniasis. It is more common for the butcher to taste the small pieces of viscera of pigs through preparation of these foods in North Sumatra (Wandra *et al*. 2006*b*, 2007).

Throughout our field surveys in Samosir Island in 2003, 2005 and 2006, microscopic stool examination of a total of 371 samples revealed that 45 (12·1%), 44 (11·9%) and 28 (7·5%) were positive for *Ascaris lumbricoides*, *Trichuris trichiura* and hookworm eggs, respectively. However, 30 (8·1%), 11 (3·0%) and 19 (5·1%) were mixed infections of both *A. lumbricoides* and *T. trichiura*, both *A. lumbricoides* and hookworms and both *T. trichiura* and hookworms. Furthermore, 15 (4·1%) were mixed infections of all three nematode species (Wandra *et al*. unpublished). By contrast, we could not detect any *Taenia* eggs. It indicates that taeniasis is a neglected NTD. We could confirm *T. asiatica* in Samosir Island based on the questionnaire and whether individuals had any experience of expulsion of proglottids. This approch was much more sensitive than the microscopic detection of eggs in faeces. All of the 285 respondents were Christians, 173 (60·7%) had no formal primary or secondary school education, 242 (84·9%) were farmers or merchants, and 146 (51·2%) of families had no sanitary facilities. Available data from 96 respondents from 96 families on behaviour and personal hygiene showed that the most of families (82·3%) obtained water from springs, 6·3% consumed water without boiling, 57·3% did not wash their hands before eating, 56·3% did not wash their hands after defaecating, and 39·6% ate raw vegetables and fruits. The drastic decrease in the number of taeniasis cases due to *T. asiatica* in Samosir Island is considered to be due to the change in eating boiled but not uncooked pork through sustainable education (Wandra *et al*. 2007, 2011).

CONTROL STRATEGIES

Considering the differences in cultures, religions, levels of education, socio-economics, control strategies should be adapted to the local epidemiological situations. The following criteria are expected to take the priority (Suroso *et al*. 2006; Wandra *et al*. 2006*b*): (1) Active case finding and treatment of tapeworm carriers; (2) Periodic hygiene checks of the traditional dishes concerned in transmission of

https://doi.org/10.1017/S0031182013000863 Published online by Cambridge University Press

infection; (3) Periodic check of the health of *lawar* sellers (in Bali) and including their family members; (4) Establishment of an inspection system to check the quality of beef/pork/viscera and determine the distribution of infected animals; (5) Investigation of the family members and the neighbourhoods of cysticercosis patients who were diagnosed at the hospital; (6) Sustainable public health education in personal hygiene, environmental sanitation, including improved practices related to pig and cattle raising, to all communities, and (7) Encouragement of political commitment and inter-sectoral collaboration at local, national and international levels. Improvement of simple diagnostic laboratory tools, strengthening surveillance system and establishment of reference laboratories are also essential.

FUTURE PERSPECTIVES

Recent advances in molecular and immunodiagnostic tools, especially for the real-time detection of infections in people and pigs and even dogs have revealed that cysticercosis due to *T. solium* is a re-emerging disease in Bali and still an emerging disease in Papua. In Bali, most of the people live in the cities and towns and keep pigs indoors through sustainable education. Through our joint international projects over the last one decade, it has recently been revealed that from 2011 onwards there are still some villages where people keep pigs outdoors, and taeniasis and cysticercosis in local people and cysticercosis in pigs due to *T. solium* infection have been confirmed using the real-time detection tools (Ito, 2013 – see this Special Issue of Parasitology, volume 140). In 2011, we found three taeniasis carriers in the villages but in 2013 we found more carriers in people in the neighbouring village and the beach-side urban area of the same District. It is urgent task to prevent re-emergence of cysticercosis in Bali, Indonesia. Thus it is very important that we commence the eradication of *T. solium* from this area in Bali. Bali is a small island and basically rich with a good education system, and we would expect to eradicate this disease from Bali. Cysticercosis was rather common in Bali 2–3 decades ago (Sutisna *et al.* 1999) but we were unable to detect any *T. solium* tapeworm carriers in surveys conducted between 1996–2011 (Wandra *et al.* 2011), which we assume to be due to the sustainable education here. However, we are now facing re-emergence of this disease in several villages in Karangasem. If this disease is distributed exclusively in this area, we have a great chance to eradicate it. Therefore, we have just started international joint project for transmission ecological studies of T/C in Karangasem with the third tool, GPS in order to obtain more concrete evidence (Giraudoux *et al.* 2013). In North Sumatra, people have changed their eating habitats from uncooked to cooked meat and viscera, even though they do not wash hands. Due to such drastic change in the life style, it is now very difficult to detect *T. asiatica* cases. It has taken approximately 30 years. If we can cut off the life cycle of *T. asiatica* or *T. solium* between pigs and humans, the pig is the ideal and economic animal which can scavenge human faeces without any *Taenia* after eradication. However, STHs are still common in North Sumatra. So, sustainable education regarding hand washing before eating and general improvements for the better standards of living are important. At this time, we have no clear ideas for control of taeniasis/cysticercosis in Papua. It will take much longer for control of this disease in Papua than in Bali. The local Government in Papua and the central Government in Jakarta are budgeting for the training public health personnel for control of this disease in Papua, but not yet in Bali. Also, such strategies are affected by the improvement in economy. Another difficulty in general is that we have the weakness to be tempted to eat uncooked foods.

In this review, we have discussed taeniases and cysticercosis in the three islands where we have worked over many years. Indonesia consists of more than 17 500 islands and the peoples of each island will have their own traditional life styles. Taeniasis due to *T. saginata, T. asiatica* or *T. solium* has not yet been identified by molecular tools in other islands.

ACKNOWLEDGEMENTS

We acknowledge many colleagues who have joined us in Samosir Island, Bali and Papua.

FINANCIAL SUPPORT

The studies were supported by Grant-in-Aid for scientific research (1994–2015) and Asia-Africa Scientific Platform Funds (2006–2008, 2009–2011) from the Japan Society for the Promotion of Science, and the Special Coordination Fund for Promoting Science and Technology (2003–2005, 2010–2012) from the Ministry of Education, Culture, Sports and Science & Technology in Japan (MEXT). The content is solely the authors' responsibility and does not necessarily represent the official views of the funders.

REFERENCES

Bonne, C. (2006). De lintwormen van den mensch in Indie (Human cestodes in Indie). Samenvattend overzicht (A summary). *Geneeskunde Tijdschrift voor Nederlandsche-India* **80**, 2376–2384 (in Dutch).

Bowles, J. and McManus, D. P. (1994). Genetic characterization of the Asian *Taenia*, a newly described Taeniid cestode of humans. *American Journal of Tropical Medicine and Hygiene* **50**, 33–44.

Chao, D. and Fan, P. C. (1986). Larval stage of a possible new species of tapeworm from Taiwan aborigines. *Chinese Bioscience* **27**, 1–6.

de Leon, W. U. (2005). Taeniasis and cysticercosis in the Philippines. In *Taeniasisi/Cysticercosis and Echinococcosis in Asia* (ed. Ito, A., Wen, H. and Yamasaki, H.), pp. 85–88. Asian Parasitology Vol. 2. AAA Committee/ Federation of Asian Parasitologists, Chiba, Japan.

Desowitz, R. S., Margono, S. S. and Simanjuntak, G. (1977). Observation on the application of counterimmunoelectrophoresis for the seroepidemiology of human cysticercosis. *Southeast Asian Journal of Tropical Medicine and Public Health* **8**, 303–307.

https://doi.org/10.1017/S0031182013000863 Published online by Cambridge University Press

Dwyer, P. D. (2006). People, pigs and parasites in New Guinea: relational contexts and epidemiological possibilities. *Parasitology International* **55**, S167–S173.

Eom, K. S. and Rim, H. J. (1993). Morphologic descriptions of *Taenia asiatica* spn. *Korean Journal of Parasitology* **31**, 1–6.

Fan, P. C. (1988). Taiwan *Taenia* and taeniasis. *Parasitology Today* **4**, 86–88.

Fan, P. C., Chung, W. C., Chan, C. H., Wong, M. M., Wu, C. C., Hsu, M. C., Huang, S. H. and Chen, Y. A. (1987). Studies on taeniasis in Taiwan III. Preliminary report on experimental infection of Taiwan *Taenia* in domestic animals. *Proceedings of the First Sino-American Symposium* **1**, 119–125.

Fan, P. C., Chung, W. C., Soh, C. T. and Kosman, M. L. (1992). Eating habits of East Asian people and transmission of taeniasis. *Acta Tropica* **50**, 305–315.

Fan, P. C., Kosman, M. L., Kosin, E., Depary, A. A. and Napitupulu, T. (1990*b*). Indonesia *Taenia* and taeniasis. *Yonsei Report in Tropical Medicine* **21**, 33–37.

Fan, P. C., Soh, C. T. and Kosin, E. (1990*a*). Pig as a favorable intermediate host of a possible new species of *Taenia* in Asia. *Yonsei Report in Tropical Medicine* **21**, 39–58.

Flew, S. (1998). Human health, nutrition and heavy metals: report of a survey from the Fly River, Western Province, Papua New Guinea June 1998. [Online]. www.oktedi.com/reports/reports/31/MWMP_Fly-River_Health_Report.pdf.

Fritzsche, M., Gottstein, B., Wigglesworth, M. C. and Eckert, J. (1990). Serological survey of human cysticercosis in Irianese refugee camps in Papua New Guinea. *Acta Tropica* **47**, 69–77.

Giraudoux, P., Raoul, F., Pleydell, D., Li, T., Han, X., Qiu, J., Xie, Y., Wang, H., Ito, A. and Craig, P. S. (2013). Drivers of *Echinococcus multilocularis* transmission in China: small mammal diversity, landscape or climate? *PLoS Neglected Tropical Diseases* **7**, e2045.

Handali, S., Liying, H., Lusikoy, C., Senis, K. and Sihombing, D. (1997). A survey report – July 1993: cysticercosis in the Grand Dani valley, Jayawijaya district, Irian Jaya province, Indonesia. *Southeast Asian Journal of Tropical Medicine and Public Health* **28**(Suppl. 1), 22–25.

Huang, S. W., Lin, C. Y. and Khaw, O. K. (1966). Studies on *Taenia* species prevalence among the aborigines in Wulai District, Taiwan. *Bulletin of the Institute of Zoology, Academia Sinica, Republic of China* **5**, 87–91.

Ito, A. (2013). Nothing is perfect! Trouble shooting in immunological and molecular studies on cestode infections. *Parasitology* **140**, in press.

Ito, A., Nakao, M. and Wandra, T. (2003). Human taeniasis and cysticercosis. *Lancet* **362**, 1918–1920.

Ito, A., Plancarte, A., Ma, L., Kong, Y., Flisser, A., Cho, S., Liu, Y., Kamhawi, S., Lightowlers, M. W. and Schantz, P. M. (1998). Novel antigens for neurocysticercosis: simple method for preparation and evaluation for serodiagnosis. *American Journal of Tropical Medicine and Hygiene* **59**, 291–294.

Ito, A., Plancarte, A., Nakao, M., Nakaya, K., Ikejima, T., Piao, Z. X., Kanazawa, T. and Margono, S. S. (1999). ELISA and immunoblot using purified glycoproteins for serodiagnosis of cysticercosis in pigs naturally infected with *Taenia solium*. *Journal of Helminthology* **73**, 363–365.

Ito, A., Putra, M. I., Subahar, R., Sato, M. O., Okamoto, M., Sako, Y., Nakao, M., Yamasaki, H., Nakaya, K., Craig, P. S. and Margono, S. S. (2002). Dogs as alternative intermediate hosts of *Taenia solium* in Papua (Irian Jaya), Indonesia confirmed by highly specific ELISA and immunoblot using native and recombinant antigens and mitochondrial DNA analysis. *Journal of Helminthology* **76**, 311–314.

Ito, A., Wandra, T., Yamasaki, H., Nakao, M., Sako, Y., Nakaya, K., Margono, S. S., Suroso, T., Gauci, C. and Lightowlers, M. W. (2004). Cysticercosis/taeniasis in Asia and the Pacific. *Vector-Borne and Zoonotic Diseases* **4**, 95–107.

Ito, A., Wen, H. and Yamasaki, H. (2005). *Taeniasis/Cysticercosis and Echnococcosis in Asia*. pp. 1–334. Asian Parasitology Vol. 2. AAA Committee/Federation of Asian Parasitologists, Chiba, Japan.

Kosin, E., Depary, A. and Djohansjah, A. (1972). Taeniasis di pulau Samosir. *Journal of Medical Faculty, University North Sumatra* **3**, 5 (in Indonesian).

Kosman, M. L., Depary, A. A., Napitupulu, T., Kosin, E. and Fan, P. C. (1988). Epidemiology and chemotherapy of taeniasis in Samosir Island, North Sumatra, Indonesia. *Simposium Parasitologi Kedokteran* **88**, 1–10.

Le Coultre, A. P. (1928). Cysticerci in het vleesch van rund and varken (cysticerci in beef and pork). Een hygienische studie, nar aanleiding van een bijzonder onderzoek naar deze parasieten op het eiland Bali (A study on hygiene after special investigation of these parasites in Bali Island). Thesis. University of Utrech, The Netherlands (in Dutch).

Margono, S. S., Himawan, S., Purnama, T. A., Subahar, R., Hamid, A. and Ito, A. (2002). Multiple cysticercus nodules in skin and brain in a Balinese woman: a case report. *Medical Journal of Indonesia* **11**, 169–173.

Margono, S. S., Ito, A., Sato, M. O., Okamoto, M., Subahar, R., Yamasaki, H., Hamid, A., Wandra, T., Purba, W. H., Nakaya, K., Ito, M., Craig, P. S. and Suroso, T. (2003). *Taenia solium* taeniasis/cysticercosis in Papua, Indonesia in 2001: detection of human worm carriers. *Journal of Helminthology* **77**, 39–42.

Margono, S. S., Ito, A. and Suroso, T. (2001*a*). The problem of taeniasis and cysticercosis in Irian Jaya, Indonesia. *Medical Journal of Indonesia* **10**, 110–114.

Margono, S. S., Subahar, R., Hamid, A., Wandra, T., Raka Sudewi, S. S., Sutisna, P. and Ito, A. (2001*b*). Cysticercosis in Indonesia: epidemiological aspects. *Southeast Asian Journal of Tropical Medicine and Public Health* **32**(Suppl. 2), 79–84.

McManus, D. P. (1995). Improved diagnosis as an aid to better surveillance of *Taenia solium* cysticercosis, a potential public health threat to Papua New Guinea. *Papua and New Guinea Medical Journal* **38**, 287–294.

Myadagsuren, N., Davaajav, A., Wandra, T., Sandar, T., Ichinkhorloo, P., Yamasaki, H., Sako, Y., Nakao, M., Sato, M. O., Nakaya, K. and Ito, A. (2007). Taeniasis in Mongolia, 2002–2006. *American Journal of Tropical Medicine and Hygiene* **77**, 342–346.

Ngoerah, I. G. N. G. (1975). Cysticercosis of the nervous system. *Majalah Ilmiah Universitas Udayana* **2**, 31–38 (in Indonesian).

Oemijati, S. (1977). Taeniasis and cysticercosis in Indonesia: a review. *Southeast Asian Journal of Tropical Medicine and Public Health* **8**, 494–497.

Okamoto, M., Nakao, M., Blair, D., Anantaphruti, M. T., Waikagul, J. and Ito, A. (2010). Evidence of hybridization between *Taenia saginata* and *Taenia asiatica*. *Parasitology International* **59**, 70–74.

Owen, I. L. (2006). Current status of *Taenia solium* and cysticercosis in Papua New Guinea. *Parasitology International* **55**, S149–S153.

Rodriguez-Canul, R., Allan, J. C., Fletes, C., Sutisna, I. P., Kapti, I. N. and Craig, P. S. (1997). Comparative evaluation of purified *Taenia solium* glycoproteins and crude metacestodes extracts by immunoblotting for the serodiagnosis of human *T. solium* cysticercosis. *Clinical and Diagnostic Laboratory Immunology* **4**, 579–582.

Sako, Y., Nakao, M., Ikejima, T., Piao, X. Z., Nakaya, K. and Ito, A. (2000). Molecular characterization and diagnostic value of *Taenia solium* low-molecular-weight antigen genes. *Journal of Clinical Microbiology* **38**, 4439–4444.

Salim, L., Ang, A., Handali, S., Cysticercosis Working Group in Papua and Tsang, V. C. (2009). Seroepidemiologic survey of cysticercosis-taeniasis in four central highland districts of Papua, Indonesia. *American Journal of Tropical Medicine and Hygiene* **80**, 384–388.

Sato, M. O., Yamasaki, H., Sako, Y., Nakao, M., Nakaya, K., Plancarte, A., Kassuku, A. A., Dorny, P., Geerts, S., Benitez-Ortiz, W., Hashiguchi, Y. and Ito, A. (2003). Evaluation of tongue inspection and serology for diagnosis of *Taenia solium* cysticercosis in swine: usefulness of ELISA using purified glycoproteins and recombinant antigen. *Veterinary Parasitology* **111**, 309–322.

Simanjuntak, G. M., Margono, S. S., Okamoto, M. and Ito, A. (1997). Taeniasis/cysticercosis in Indonesia as an emerging disease. *Parasitology Today* **13**, 321–323.

Simanjuntak, G. M., Margono, S. S., Schalan, R., Harjono, C., Rasidi, R. and Sutopo, B. (1977). An investigation on taeniasis and cysticercosis in Bali. *Southeast Asian Journal of Tropical Medicine and Public Health* **8**, 494–497.

Soebroto, F. X., Tjing, H. N. and Nmoeljono, D. (1960). Cysticercosis di bawah kulit pada manusia (subcutaneous cysticercosis in human). *Madjalah Kedokteran Indonesia* **10**, 460–463 (in Indonesian).

Statistics Indonesia (2011). The 2010 Indonesian Population Census. http://www.datastatistik-indonesia.com.

Subahar, R., Hamid, A., Purba, W., Wandra, T., Karma, C., Sako, Y., Margono, S. S., Craig, P. S. and Ito, A. (2001). *Taeniasis solium* infection in Irian Jaya (West Papua), Indonesia: a pilot serological survey of human and porcine cysticercosis in Jayawijaya District. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **95**, 388–390.

Subianto, D. B., Tumada, L. R. and Margono, S. S. (1978). Burns and epileptic fits associated with cysticercosis in mountain people of Irian Jaya. *Tropical and Geographical Medicine* **30**, 275–278.

Sudewi, A. A. R., Wandra, T., Artha, A., Nkouawa, A. and Ito, A. (2008). *Taenia solium* cysticercosis in Bali, Indonesia: serology and mtDNA analysis. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **102**, 96–98.

Suroso, T., Margono, S. S., Wandra, T. and Ito, A. (2006). Challenges for control of taeniasis/cysticercosis in Indonesia. *Parasitology International* **55**, S161–S165.

Sutisna, P., Flaser, A., Kapti, I. N., Rodriguez-Canul, R., Puta Widjana, D., Craig, P. S. and Allan, J. C. (1999). Community prevalence

study of taeniasis and cysticercosis in Bali, Indonesia. *Tropical Medicine and International Health* **4**, 288–294.

Swastika, K., Dewiyani, C. I., Yanagida, T., Sako, Y., Sudamaja, M., Sutisna, P., Wandra, T., Dharmawan, N. S., Nakaya, K., Okamoto, M. and Ito, A. (2002). An ocular cysticercosis in Bali, Indonesia caused by *Taenia Solium* Asian genotype. *Parasitology International* **61**, 378–380.

Theis, J. H., Goldsmith, R. S., Flisser, A., Koss, J., Chioino, C., Plancarte, A., Sugura, A., Widjana, D. and Sutisna, P. (1994). Detection by immunoblot assay of antibodies to *Taenia solium* cysticerci in sera from residents of rural communities and from epileptic patients in Bali, Indonesia. *Southeast Asian Journal of Tropical Medicine and Public Health* **25**, 464–468.

Tumada, L. R. and Margono, S. S. (1973*a*). Cysticercosis in the area of the Wissel Lakes, West Irian. *Southeast Asian Journal of Tropical Medicine and Public Health* **4**, 371–376.

Tumada, L. R. and Margono, S. S. (1973*b*). Intestinal helminthic infection in the Paniai Highlands, with special reference to *Taenia* and *Hymenolepis nana*. *Majalah Kesehatan Indonesia* **7/8**, 103–107.

Wandra, T., Depary, A. A., Sutisna, P., Margono, S. S., Suroso, T., Okamoto, M., Craig, P. S. and Ito, A. (2006*a*). Taeniasis and cysticercosis in Bali and North Sumatra, Indonesia. *Parasitology International* **55**, S155–S160.

Wandra, T., Ito, A., Yamasaki, H., Suroso, T. and Margono, S. S. (2003). *Taenia solium* cysticercosis, Irian Jaya, Indonesia. *Emerging Infectious Diseases* **9**, 884–885.

Wandra, T., Margono, S. S., Gafar, M. S., Saragih, J. M., Sutisna, P., Sudewi, R., Depary, A. A., Yulfi, H., Darlan, D. D., Okamoto, M., Sato, M. O., Sako, Y., Nakao, M., Nakaya, K., Craig, P. S. and Ito, A. (2007). Current situation of taeniasis and cysticercosis in Indonesia. *Tropical Medicine and Health* **35**, 323–328.

Wandra, T., Subahar, R., Simanjuntak, G. M., Margono, S. S., Suroso, T., Okamoto, M., Nakao, Y., Nakaya, K., Schantz, P. M. and Ito, A. (2000). Resurgence of cases of epileptic seizures and burns associated with cysticercosis in Assologaima, Jayawijaya, Irian Jaya, Indonesia, 1990–1995. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **94**, 46–50.

Wandra, T., Sudewi, A. A., Swastika, I. K., Sutisna, P., Dharmawan, N. S., Yulfi, H., Darlan, D. M., Kapti, I. N., Samaan, G., Sato, M. O., Okamoto, M. and Ito, A. (2011). Taeniasis/cysticercosis in Bali, Indonesia. *Southeast Asian Journal of Tropical Medicine and Public Health* **42**, 793–802.

Wandra, T., Sutisna, P., Dharmawan, N. S., Margono, S. S., Sudewi, R., Suroso, T., Craig, P. S. and Ito, A. (2006*b*). High prevalence of *Taenia saginata* taeniasis and status of *Taenia solium* cysticercosis in Bali, Indonesia, 2002–2004. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **100**, 346–353.

Yamane, K., Suzuki, Y., Tachi, E., Li, T., Chen, X., Nakao, N., Nkouawa, A., Yanagida, T., Sako, Y., Ito, A., Sato, H. and Okamoto, M. (2012). Recent hybridization between *Taenia asiatica* and *Taenia saginata*. *Parasitology International* **61**, 351–355.

Yamane, K., Yanagida, T., Li, T., Chen, X., Dekumyoy, P., Waikagul, J., Nkouawa, A., Nakao, M., Sako, Y., Ito, A., Sato, H. and Okamoto, M. (2013). Genotypic Relationships between *Taenia Saginata, Taenia asiatica* and their hybrids. *Parasitology* **140**, in press.

Yamasaki, H., Allan, J. C., Sato, M. O., Nakao, M., Sako, Y., Nakaya, K., Qiu, D. C., Mamuti, W., Craig, P. S. and Ito, A. (2004). DNA differential diagnosis of taeniasis/cysticercosis by multiplex PCR. *Journal of Clinical Microbiology* **42**, 548–553.

Yokogawa, S. (1935). On the taeniasis saginata among the aborigines in Taiwan. *Nippon Gakujutsu Kyokai Hokoku* **10**, 497–500.

Zarlenga, D. S., McManus, D. P., Fan, P. C. and Cross, J. H. (1991). Characterization and detection of a newly described Asian taeniid using cloned ribosormal DNA fragments and sequence amplification by the polymerase chain reaction. *Experimental Parasitology* **72**, 174–183.

https://doi.org/10.1017/S0031182013000863 Published online by Cambridge University Press