

Human trichinellosis in Southeast Asia, 2001–2021

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ABSTRACT

To present the situation of human trichinellosis in Southeast Asia in the last 20th years we analyzed outbreak data and seroprevalence studies from 2001 to 2021 for this region. We queried PubMed (<https://pubmed.ncbi.nlm.nih.gov>) using keywords “Trichinella”, “human” and “Southeast Asia”. In addition, we described *Trichinella* species circulating in this region.

In Southeast Asia, in communities eating pork, several cultural factors play important roles in the transmission of *Trichinella* to humans. The seroprevalences of *Trichinella* infection in humans are known for Laos and Vietnam to be 0–10.5% in some villages. Also, in Cambodia, Laos, Malaysia, Thailand and Vietnam relatively few human outbreaks (13) and cases (1604) have been recorded during the last 21st years. Their associated mortality rates were low (0.75%). *Trichinella spiralis* and *T. papuae* were transmitted after consumption of raw or undercooked pork from domesticated and wild pigs. *T. papuae* transmission was related to consumption of wild boar. In this region, trichinellosis was frequently subclinical and clinical or severe cases were sporadic and occurred more in male patients. Nevertheless, it is likely that trichinellosis is widely underdiagnosed and is an endemic disease.

1. Introduction

Trichinellosis is a parasitic disease caused by nematodes of the genus *Trichinella* that is contracted by ingestion of raw or undercooked meat from infected animals (non-ruminant mammals, birds, and reptiles). Numerous animals species (about 100), including humans, can be infected but the most common source of human trichinellosis at a worldwide level is meat from domesticated pigs (*Sus scrofa domesticus*) or wild boar (*Sus scrofa*) (Gottstein et al., 2009). As a consequence, this disease is not only a public health hazard, but also an economic problem in pig production and food safety.

Southeast Asia is at the crossroads of India and China and stretches from West to East from Myanmar (Burma) to the Philippines, passing through Thailand, Laos, Cambodia, Vietnam, Malaysia, Singapore, Brunei, and Indonesia.

In the 20th century, trichinellosis has been documented in Southeast Asia, especially in Thailand (Limsuwan and Siriprasert, 1994; (Khamboonruang, 1991; (Jongwutiwes et al., 1998). Since 1962, at least 120 outbreaks of this disease involving 5511 patients have been reported. Outbreaks occurred mostly in rural areas associated with villagers celebrating local and traditional festivals. The source of infection had been traced to either hill-tribe pigs that were raised like wild animals, or to boars. Infection was usually acquired

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through the consumption of a local dish called “lahb,” traditionally served during these celebrations. This popular dish consists of raw finely chopped meat mixed with spices and chilies (Khamboonruang, 1991). In Bali, evidence of trichinellosis in humans was revealed by a seroprevalence rate of 19.5% in children and teenagers (Chomel et al., 1993) and documented infections in European travelers returning from the island (De Carneri and Di Matteo, 1989).

Since the beginning of the 21st century, relatively few human outbreaks have been recorded (Bruschi, 2012). Most of the outbreaks reported for Thailand, Laos, and Vietnam occurred in northern mountainous regions among indigenous people who practice free-roaming pig husbandry (Murrell and Pozio, 2011; Barennes et al., 2008; Kusolsuk et al., 2010; Khumjui et al., 2008). In these regions cultural factors such as consumption of traditional dishes based on raw or undercooked meat play an important role in the transmission of *Trichinella* spp. to humans. As this region lacks veterinary controls (no *Trichinella* monitoring and no *Trichinella*-free pig production programs) it seems likely that disease incidence is underestimated. In other regions such as Malaysia and the Philippines, the majority of people are Muslim and consequently do not eat pork, so limiting the occurrence of trichinellosis.

Here, we present the situation of human trichinellosis in Southeast Asia (i.e. the species of *Trichinella* described to date, human outbreaks described in the last 21 years, and reported seroprevalences). To do this we selected reports in PubMed (<https://pubmed.ncbi.nlm.nih.gov>) using the keywords “*Trichinella*”, “human”, and “Southeast Asia” and then we discuss the epidemiologic situation of trichinellosis in Southeast Asia.

2. *Trichinella* species circulating in Southeast Asia

2.1. *Trichinella spiralis* (Owen, 1835)


T. spiralis is the main etiological agent of trichinellosis in humans both in Southeast Asia and worldwide (Murrell and Pozio, 2011). *T. spiralis* was the first species discovered and has been the best characterized due to its importance as a causative agent of human disease. This species shows the highest infectivity and the longest survival time (more than three years) (Pozio, 2019) of larvae in muscles of domestic and wild pigs, compared to the other species of the genus *Trichinella* (Pozio and Darwin, 2006).

T. spiralis originated in East Asia and was introduced into Southeast Asia by trade probably at the beginning of the second



Fig. 1. Source of human trichinellosis in Southeast Asia, 2001-2021

T. spiralis in wild boar  or pig 

T. papuae in wild boar 

millennium; then it spread to the American continent, New Zealand, and Hawaii during European colonization (Pozio and Zarlenga, 2013). Today, the distribution of *T. spiralis* is mainly linked to regions with backyard and free-ranging pigs that generally correspond to less developed regions (Pozio, 2019).

In Southeast Asia, *T. spiralis* has been isolated in synanthropic rats and wild boars and was detected in 14.5% of domesticated pigs from northwestern Vietnam (Vu Thi et al., 2010; Thi et al., 2014), and 2.1% of domesticated pigs from northern Laos (Conlan et al., 2014). Several outbreaks have been reported in humans involving *T. spiralis* in Vietnam (5 between 1970 and 2012) (Vu Thi et al., 2013), Laos (Barennes et al., 2008), and Thailand (Pozio and Khamboonruang, 1989) (Fig. 1). Between 1970 and 2012 mortality related to *T. spiralis* in this region was 6.3% (Van De et al., 2015).

2.2. *Trichinella pseudospiralis* Garkavi, 1972

T. pseudospiralis belongs to the non-encapsulating clade of the genus *Trichinella* and is the only *Trichinella* species infecting both mammals and birds (Pozio and Darwin, 2006). In Southeast Asia, a human outbreak involving *T. pseudospiralis* has been reported in Thailand (Jongwutiwes et al., 1998). *T. pseudospiralis* was identified from patients' muscle biopsies using random amplified polymorphic DNA (RAPD) analysis, rather than the reference method (multiplex PCR). Therefore, it's possible that the etiological agent could have been *T. papuae* that had not been described at that time (Pozio, 2016).

2.3. *Trichinella papuae* Pozio et al., 1999

T. papuae was first detected using molecular techniques in sylvatic swine of Papua New Guinea in 1999 (Pozio et al., 1999). Like *T. pseudospiralis*, *T. papuae* is a non-encapsulated species. Experimental infections show that *T. papuae* develops in caimans and lizards and to a lesser degree in turtles (Pozio, 2005). It could be acquired by the consumption of raw meat from domestic and wild pigs, saltwater crocodiles, and turtles (Pozio and Zarlenga, 2013).

T. papuae was reported in outbreaks in Thailand in 2006 (Khumjui et al., 2008) and 2007 (Kusolsuk et al., 2010), in Cambodia in 2017 (Caron et al., 2020), and in one patient returning from Malaysia in 2011 (Intapan et al., 2011) (Fig. 1). The sources of infection were raw hunted wild boar meat.

3. *Trichinella* infection in humans

In Southeast Asia, the seroprevalence of *Trichinella* has been studied in some countries (Table 1) and relatively few human outbreaks have been recorded in the last 21 years (Table 2).

3.1. Cambodia

Little data exist on the seroprevalence of *Trichinella* infection in humans and animals in Cambodia. However, the presence of anti-*Trichinella* antibodies in asymptomatic persons in a rural population (location unavailable) has been described (Pozio, 2001).

In September 2017, a trichinellosis outbreak with severe clinical forms occurred in Cambodia following the consumption of raw wild boar meat: 33 people were infected and 8 died (Caron et al., 2020). Histopathological preparation on muscle biopsy revealed non-encapsulated *Trichinella* larvae. Multiplex PCR and 5S rDNA intergenic spacer region PCR followed by sequencing identified the parasite as *T. papuae*. A high number of ingested larvae, a late diagnosis in a rural setting, and/or the choice of some patients to use traditional medicine instead of modern medicine could explain the unusually high mortality rate (24%). Access to medical care in Cambodia is limited and at the same time the national health care system, enables, encourages, and sanctions unregulated practices (Gryseels et al., 2019).

3.2. Indonesia

In Indonesia, the communities are Muslim except on the island of Bali. No human cases or outbreaks have been reported.

3.3. Laos

In the Lao People's Democratic Republic pigs are kept in close contact with families. The risk of human infection with pig zoonoses

Table 1
Seroprevalences of *Trichinella* infection in humans in Southeast Asia.

Country	Date	Seroprevalence (method)	No. Individuals	Authors
Laos	2011	40.5-59.0% (ELISA)	822	Holt et al., 2016
	2014	7.5% (ELISA, WB)	1,419	Conlan et al., 2014
Vietnam	2014	1.6-3.5% (ELISA, WB)	645	Vu Thi et al., 2014
	2015-2016	0.0-10.5% (ELISA, WB)	4,362	Huong et al., 2017

ELISA: enzyme-linked immunosorbent assay, WB: western blot.

Table 2
Features of human outbreaks and single cases of trichinellosis in Southeast Asia.*

Country	Date	N of cases	Male/female	Infected meat	No death (%)	Trichinella species (molecular identification method)	Authors
Cambodia	2017	33	32/1	Boar	8 (24)	<i>T. papuae</i> (multiplex PCR, 5S rDNA intergenic spacer)	Caron et al., 2020
Laos	2004	22	10/12	Pig	0 (0)	–	Sayasone et al., 2006
	2005	650	–	Pig	0 (0)	<i>T. spiralis</i> (multiplex PCR, 5S rDNA intergenic spacer)	Barennes et al., 2008
Malaysia	2005	1	1/0	Boar	0 (0)	<i>T. papuae</i> (12S rDNA)	Intapan et al., 2011
Thailand	2002	289	*	–	0 (0)	–	Kaewpitoon et al., 2006
	2003	126	*	–	0 (0)	–	Kaewpitoon et al., 2006
	2004	212	*	–	0 (0)	–	Kaewpitoon et al., 2006
	2005	84	*	–	0 (0)	–	Kaewpitoon et al., 2006
	2006	28	18/10	Boar	0 (0)	<i>T. papuae</i> (<i>cox1</i>)	Khumjui et al., 2008
	2007	34	–	Boar	0 (0)	<i>T. papuae</i> (<i>cox1</i> , ES5 of 28S rDNA)	Kusolsuk et al., 2010
Vietnam	2001	22	–	Pig	0 (0)	<i>Trichinella</i> sp.	Toan et al., 2002T; Van De et al., 2015
	2004	20	–	Pig	2 (9.0)	<i>Trichinella</i> sp.	Nhan and Van De, 2004; Van De et al., 2015
	2008	47	–	Pig	2 (4.3)	<i>T. spiralis</i> (multiplex PCR)	Taylor et al., 2009; Van De et al., 2015
	2012	36	–	Boar	0 (0)	<i>T. spiralis</i> (multiplex PCR)	Vu Thi et al., 2013; Van De et al., 2015

cox1: cytochrome oxidase subunit 1, ES: expansion segment.

* : sex ratio of 1.7 from 2002 to 2005.

arises from direct contact and consumption of unsafe pork products. Seroprevalence in humans was 41 and 59% in Savannakhet and Luang Prabang Provinces, respectively (Holt et al., 2016). In northern Laos, the seroprevalence was 7.5% in humans (Conlan et al., 2014). The difference in seroprevalence between the two studies could be related to differences in serological methods. Immunoblot was used as a confirmatory test for sera positive by ELISA (Conlan et al., 2014). Cross-reactions with other nematodes could possibly occur when ELISA was used alone (Holt et al., 2016).

After 30 years with no reports, in 2004 a small outbreak of 22 patients was described in Central Lao PDR (Laos) and in 2005 a large outbreak of at least 650 estimated patients occurred in Udomxay (northern Laos) (Sayasone et al., 2006; Barennes et al., 2008). *T. spiralis* was suspected in these outbreaks characterized by a low number of ingested larvae and/or mild clinical signs and symptoms (probably related to premunition). However, diagnosis was not correctly performed and consequently, the public health services were not informed (Barennes et al., 2008). Since 2005, no outbreaks have been reported.

3.4. Malaysia

Trichinellosis occurred in Malaysia in 2005: a case was reported in a traveler from Thailand who had eaten raw hunted wild boar meat (Chotmongkol et al., 2005; Intapan et al., 2011). *T. papuae* was the incriminated species, but since this case no human outbreak has been reported.

3.5. Myanmar (Burma)

Trichinellosis is supposed to be present in domestic pigs from Myanmar because an outbreak occurred in Northern Thailand after people had consumed pork illegally imported from Myanmar (Watt et al., 2000). However, no other studies have been performed.

3.6. Singapore

Since 1998, when a large outbreak occurred in travelers from a neighboring island (Kurup et al., 2000), there have been no reports of human cases in Singapore. The pork supply comes from >20 countries and two local farms that have been fully accredited by the Agri-Food and Veterinary Authority of Singapore (2020).

3.7. The Philippines

There have been no reports of human trichinellosis in the Philippines and this is reflected in the recent observation of a very low seroprevalence (0.54%) of *Trichinella* infection in pigs from slaughterhouses in the Bulacan province (Lagrimas et al., 2021).

3.8. Thailand

In Thailand, several human outbreaks caused by *T. spiralis* and *T. papuae* have been reported (Kusolsuk et al., 2010; Khumjui et al.,

2008; Kaewpitoon et al., 2006). From 2002 to 2007, an outbreak was described each year. The last outbreaks were due to *T. papuae*: in 2006 in the North and in 2007 in the Uthai Thani Province after consumption of raw wild boar (Khumjui et al., 2008; Kusolsuk et al., 2010). >80 larvae were isolated from a muscle biopsy (approximately 10 mm × 10 mm × 5 mm) of a single patient with a severe clinical picture (Kusolsuk et al., 2010). After implementation of a health education program, trichinellosis has not been documented in BanRai in the last 10 years (Kusolsuk, 2019).

3.9. Vietnam

In northern Vietnam, the seroprevalence in humans was reported to be 1.6–3.5% in some villages (Vu Thi et al., 2014). Seroprevalence was low in wild and synanthropic animals (wild boar, rat) (2.8–3.2%), as well as in domestic animals (pig, dog) (4–5.6%) (Vu Thi et al., 2010; Thi et al., 2013; Thi et al., 2014). In the majority of back-yard and free-range pigs, a low worm burden (<1 larva per gr) was reported suggesting that in a community where uncooked pork is consumed most infections are subclinical (Vu Thi et al., 2014; Vu Thi et al., 2010). In a larger survey (20 rural districts), seroprevalence was estimated to be in the range of 0.0–10.5% (Huong et al., 2017). Increasing age, being male and consuming pork as well as a larger proportion of roaming pigs increased risk of infection. Furthermore, consuming pork at another village market with a higher prevalence was also a risk factor.

Four outbreaks occurred from 2001 to 2012 in northern Vietnam with 125 cases of which 4 patients (3.2%) died. Infected people had consumed raw or undercooked pork (Taylor et al., 2009; Toan et al., 2002; Nhan and Van De, 2004) or wild boar (Vu Thi et al., 2013). The short incubation period (average of 9 days), the severity of symptoms, and high mortality suggest that patients had ingested a large number of larvae. Larvae collected from pigs during the 2008 outbreak and from a patient's muscle biopsy during the 2012 outbreak, were both identified as *T. spiralis* (Van De et al., 2015).

4. Discussion and conclusions

Trichinellosis due to the consumption of raw and undercooked pork of domesticated pigs and wild boar meat continues to occur throughout Southeast Asia (Diaz et al., 2020), in contrast to Europe and the United States, where trichinellosis surveillance systems and laws regulating the marketing of pork have limited trichinellosis outbreaks.

From 2001 to 2021, 1604 cases of trichinellosis have been described in Southeast Asia, including Cambodia, Laos, Malaysia, Thailand, and Vietnam. Most of the cases were from northern regions of Laos (672) and Thailand (773). During this period no cases were reported for Myanmar and the Philippines. When compared to the period 1993–2009 the incidence of trichinellosis had increased (76.4 cases per year in this study versus 22.7 cases per year as reported in Murrell and Pozio, 2011), and an outbreak was described in Cambodia. This tendency could be related to an improvement of case notification in some countries.

Trichinellosis is a predominantly adult disease occurring equally among both sexes (2631 [51%] of 5154 infections occurred in male patients (Murrell and Pozio, 2011)). However, in Southeast Asia men were more frequently infected: 64% in Thailand, 91% in Vietnam, and 97% in Cambodia (Murrell and Pozio, 2011; Caron et al., 2020; Khumjui et al., 2008). An explanation of this unbalanced sex ratio could be a common popular belief associated with a “strength transfer” when men eat raw wild boar meat, while this kind of food is widely rejected by women due to its very pronounced taste (Caron et al., 2020). Another explanation could be that while hunting men tend to eat undercooked pork.

In Southeast Asia several cultural factors play an important role in the transmission of *Trichinella* to humans in communities eating pork: i) people consume traditional dishes based on raw or undercooked meat (Khieu et al., 2017); and, ii) in some areas popular beliefs encourage the consumption of raw pork (Caron et al., 2020). Moreover, hygiene and sanitation influence the transmission of *Trichinella* infection and pig farming is mostly traditional free-range (Holt et al., 2016; Burniston et al., 2015).

The seroprevalence of *Trichinella* infection in humans was 0–10.5% in Laos and Vietnam. Previous data from Bali in Indonesia showed a seroprevalence (19.5%) in 190 children and teenagers (Chomel et al., 1993). However, this result is questionable since a non-validated test was used at that time. Seroprevalences are unknown in other countries (i.e. Cambodia, Malaysia, Philippines, and Thailand).

In Southeast Asia the relatively low worm burden of *Trichinella* in domestic pigs could lead to low infectious doses when eating undercooked pork (Vu Thi et al., 2010; Vu Thi et al., 2014). The existence of a premunition in populations that are accustomed to eating undercooked meat might also result in a milder clinical form (Holt et al., 2016; Chomel et al., 1993; Conlan et al., 2014; Owen et al., 2005). Severe clinical cases predominantly occur as sporadic point source outbreaks, or sporadic isolated cases (Caron et al., 2020; Conlan et al., 2011; Odermatt et al., 2010).

During the period under study the mortality rate was low (0.7%, 12 of 1604). In comparison, the observed lethality during the French epidemics of 1985 was 0.5% (Dupouy-Camet et al., 2010). Epidemiological investigations following the diagnosis of confirmed cases revealed that only a proportion of cases had sought health care during the outbreaks (Conlan et al., 2011; Caron et al., 2020). Moreover, people living in rural or forest areas need to have better access to health care and diagnosis for trichinellosis (Vu Thi et al., 2013; Caron et al., 2020; Conlan et al., 2011). Therefore, trichinellosis is probably a widely under-diagnosed and an endemic disease in Southeast Asia (Conlan et al., 2011; Barennes et al., 2008; Caron et al., 2020).

During the study period, two out of three *Trichinella* species described for this region were involved in human cases: *T. spiralis* in three outbreaks due to the consumption of pig and wild boar and *T. papuae* in three outbreaks, and one case due to the consumption of wild boar indicating that *T. spiralis* is circulating in both domestic and sylvatic life cycles. It is clear that *T. papuae* has a sylvatic life cycle, but it could not be excluded that it is present in a domestic life cycle, particularly in rural areas. So, it's important to highlight the spectrum of domestic hosts through epidemiological studies (Caron et al., 2020). Unfortunately, identification of *Trichinella* species has

not been achieved in all outbreaks (Kaewpitoon et al., 2006; Nhan and Van De, 2004; Sayasone et al., 2006; Toan et al., 2002).

To avoid important and/or fatal outbreaks in Southeast Asia there's a need to implement veterinary surveillance and educational programs to prevent infection (Barennes et al., 2008; Caron et al., 2020; Vu Thi et al., 2013). The consumption of raw (hunted or domestic) meat must be avoided. When applied in Thailand in 2009, such a recommendation was effective (Kusolsuk, 2019). The authorities of Southeast Asia countries should set up measures in a “One Health” concept to limit the impact of this major zoonotic parasite and its spread to pig farms. However, the cost of some control measures could limit implementation. In the European Union the estimated annual cost incurred from meat inspection of 167 million pigs ranges from €25 million to €400 million. Even in countries without mandatory meat inspection (e.g., United States), the economic cost of selling pork in international and national markets is substantial (Murrell and Pozio, 2011).

As a consequence, in the absence of veterinary controls in Southeast Asia, educational programs in rural or urban populations explaining the risks of consuming undercooked meat are essential in the prevention of trichinellosis.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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