Science & Society

Trichinellosis in China: epidemiology and control

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The first outbreak of human trichinellosis in China, according to official national publication, was registered in Tibet in 1964. Since then, more than 500 outbreaks, numbering 25 161 cases with 240 deaths, have been recorded. However, this reported quantity is probably highly underestimated because adequate diagnostic techniques might not have been available in the whole area. Moreover, infection in animals is widespread over China, with the prevalence of pig trichinellosis being as high as 4% in some provinces. The estimated situation of trichinellosis in China highlights the necessity not only for its control, but also for the government to elaborate new regulations and guidelines for animal inspection.

Trichinellosis, a disease caused by the nematode *Trichinella*, occurs in >100 animal species in areas with different geographical and ecological characteristics [1]. The global prevalence of the disease is difficult to evaluate, but as many as 11 million people could be infected with this parasite, and >10 000 cases of human trichinellosis were reported by the International Commission on Trichinellosis from 1995 to June 1997 [2]. Ten species/genotypes have been described within the genus *Trichinella* according to their geographical distribution and biological, morphological and biochemical characteristics: *Trichinella spiralis*; *Trichinella nativa*; *Trichinella britovi*; *Trichinella pseudospiralis*; *Trichinella murrelli*; *Trichinella nelsoni*; *Trichinella papuae*; T6; T8; and T9 [3]. The geographical distribution of the different species is related both to temperature and to host behavior. The prevalence of human and animal trichinellosis has not been well documented in all the Chinese provinces [4]; however, in the past 50 years, numerous human outbreaks and abundant epidemiological and epizootiological data have been recorded. The status of the disease and the genotypes of Chinese *Trichinella* isolates are reviewed in this article.

On the basis of literature reviews, together with data from two Chinese national surveys on human parasitic diseases, two prominent epidemiological features have emerged in China in the past 20 years: (1) there is a decrease in the prevalence of *Entamoeba histolytica*, *Fasciolopsis buski* and soil-transmitted helminthiases; and (2) there is an increase in the prevalence of food-borne helminthes, including *Trichinella*, *Clonorchis*, *Paragonimus*, *Taenia* and *Echinococcus*; among these, trichinellosis is the most widespread zoonosis in China [5].

History of human trichinellosis in China

The earliest known human case of trichinellosis in China can be traced to 1918, as assessed by official publication. In 1921, Faust listed one case out of 631 patients studied at the Peking Union Medical College (PUMC) (Hospital Report 1919–1920). However, in 1922, at the 4th Congress of the Far Eastern Association of Tropical Medicine, Faust [6] reported a *Trichinella* infection rate in Beijing, China, of 0.3% in 1918 and 0.16% in 1919.

Trichinellosis has become the most important food-borne parasitic zoonosis in China, having a high prevalence in domestic animals and, more recently, in humans. The first outbreak of human trichinellosis was documented in Tibet in 1964 [7]. Since then, >500 major outbreaks have been recorded in 12 of the 34 Chinese provinces, affecting

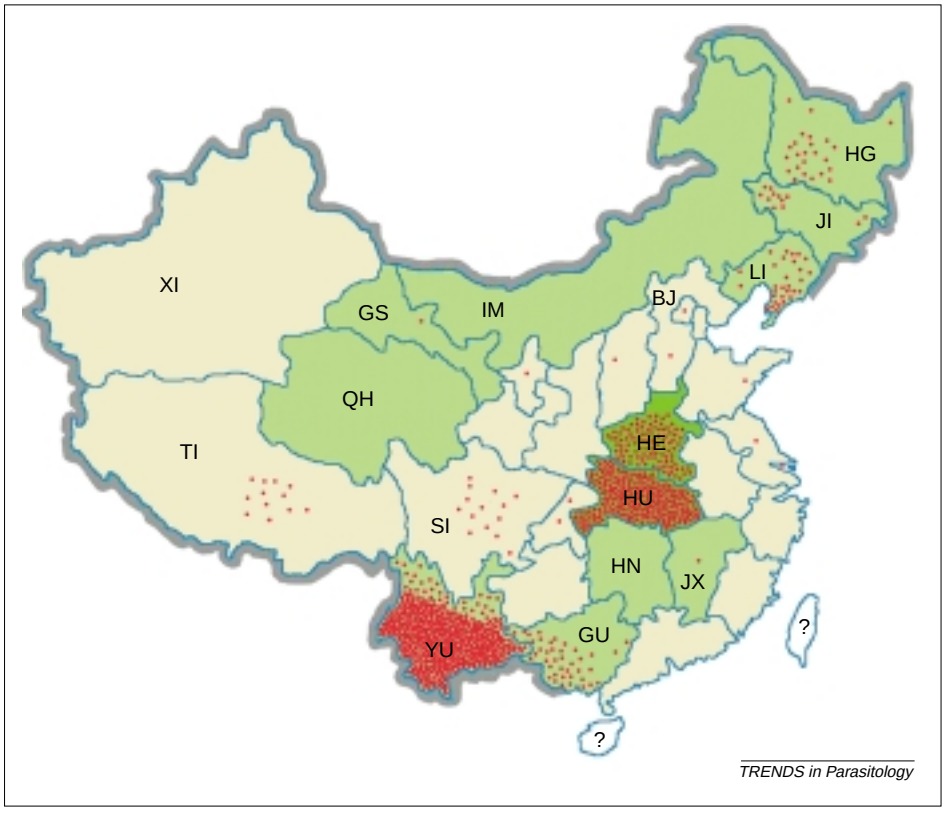

Fig. 1. The distribution and relationship of human and pig trichinellosis in China. The red points show the numbers of reported or recorded human trichinellosis cases; each red point represents ≤10 cases. Green areas represent regions where a prevalence of pig trichinellosis has been recorded. In HE and HU, the prevalence of pig trichinellosis is as high as 4%, whereas in HG, HN, GU, GS, IM, JI, JX, LI, QH and YU the prevalence is below 4%. The yellow areas indicate regions where the prevalence of pig trichinellosis has not been investigated. The question marks (?) show regions where no human and pig trichinellosis has been reported. It can be seen that the regions with severe pig trichinellosis, such as HE and HU provinces, also correspond with a higher incidence of human cases. The mass of human cases in YU and GU provinces mainly resulted from the habit of eating raw meat. The cases in north-eastern China (HG, JI and LI provinces) were mainly caused by the consumption of under-cooked dog meat. Abbreviations: BJ, Beijing; HE, Henan; HU, Hubei; GS, Gansu; GU, Guangxi; HG, Heilongjiang; HN, Hunan; IM, Inner Mongolia; JI, Jilin; JX, Jiangxi; LI, Liaoning; QH, Qinghai; SI, Sichuan; TI, Tibet; XI, Xinjiang; YU, Yunnan.

 1471-4922/02/$ – see front matter PII: S1471-4922(02)02401-7

Table 1. Periods of human trichinellosis in China

Period	No. of cases	No. of deaths	Mortality (%)	Ref.
1964–1979	4033	73	1.81	[9]
1980–1989	15 599	141	0.90	[8]
1990–2002	5529	26	0.47	[28]
Total	25 161	240	0.95	

25 161 people, with 240 deaths [8]. Most of the clinical (88.6%) and fatal (99.6%) cases occurred in regions (Yunnan, Guangxi and Tibet) where the habit of eating raw pork meat is common [9] (Fig. 1).

The distribution of reported cases can be grouped into three distinct periods (Table 1): (1) 1964–1979, which mainly occurred in regions where the local residents customarily eat raw meat; (2) 1980–1989, which could be attributed to the rapid increase in meat consumption following economic growth in 20 provinces; and (3) 1990–2002, during which the incidence of human trichinellosis decreased in the raw-meat-eating regions, but increased in the areas (e.g. Henan and Hubei) where the residents customarily eat well-cooked meat, indicating that measures of food hygiene were inadequate.

Seroepidemiological surveys using ELISA (based on the excretory–secretory antigen of *Trichinella*) in human populations of ten Chinese provinces yielded a trichinellosis prevalence of 5.5% [sample number (SN) = 36 852; 1991–2001] [10,11]. However, surveys in Henan province, based on muscle biopsy, gave a prevalence of 2.5% (SN = 1048; 1982–1996) [11]. The south-western, central and north-eastern parts of China are the main endemic areas, but the highest prevalence of trichinellosis in humans is reported in Yunnan, Hubei and Henan.

Animal trichinellosis

To date, *Trichinella* has been found in 14 species of animals, including pig, dog, cat, rat, cow, fox, bear, tiger, marten, raccoon, muntjac, yellow weasel, wolf and wild boar, and is distributed in all Chinese provinces except the Hainan and Taiwan islands [12] (Fig. 1).

Swine trichinellosis is a very serious problem in China because the prevalence is very high in some provinces. To date, twelve provinces have partially or completely carried out their epidemiology survey. Among them, Hubei is the most affected province, with a prevalence of 6.76% (SN = 302 667; 1997) by direct diagnostic methods (microscopy or artificial digestion) in the slaughterhouses [13]. In Henan, the average prevalence was up to 4.27% (SN = 75 821; 1997) by direct detection methods in 43 counties and, in some counties, the level remained extremely high (e.g. reaching 18.5% and 34.2% in Xinye and Deng counties, respectively) [14]. Except for Hubei and Henan, the prevalence of pig trichinellosis was between 0.001% and 0.897% (SN = 81 713 989; 1993–1999) in nine provinces, as detected by microscopy or artificial digestion [15].

Dogs are also highly infected in north-eastern China. The trichinellosis prevalence in dogs revealed: 9.82% (SN = 1469; 1995) in Jilin [16], 39.5–44.8% (SN = 13 864; 1995–1997) in Heilongjiang [17], 23.52% (SN = 1079; 1996) in Inner Mongolia [18] and 35.6% (SN = 59; 1997) in Liaoning [19]. Rats, the main host thought to transmit *Trichinella* to pigs, were also highly infected in six provinces where surveys were conducted by microscopy: the prevalence of rat trichinellosis was 1.98–15.06% (SN = 4038; 1939–1998) [15].

Distribution of *Trichinella* spp.

As early as 1985, Lee [20] observed that two isolates from different regions of China were of different size. Before 1996, little was known about the *Trichinella* spp. isolated from various parts of China. However, 19 isolates have been recently obtained from north-eastern, south-western, central and eastern regions of China [21]. Out of the 19 isolates, 14 were identified as *T. spiralis*, which was distributed almost all over the country, mainly in pig (13 of the 14), whereas the remaining five isolates from dogs were identified as *T. nativa* essentially in the north-eastern area of China [22]. There are no more isolates from wild animals, no detailed comparative information from the west of China, especially in Tibet, Xinjiang, Gansu and Sichuan, and no isolates from human outbreaks; therefore, there is no evidence of other *Trichinella* spp. such as *T. britovi* and *T. pseudospiralis* (the most probable species of temperate areas in Europe, Russia and middle Asia).

Table 2. Change in prevalence of human and animal trichinellosis in regions of China

Region	Year	Prevalence (%)	Year	Prevalence (%)	Host	Method	Ref.
Nanyang	1975	0.92	1997	32.2	Pig	Microscopy	[14]
Henan	1980	3.7	1996	4.01	Human	ELISA	[11]
Beijing	1989	5.5	1997	7.3	Pig	Microscopy	[34]
Jilin	1991	9.82	1995	13.97	Dog	Microscopy	[16]
Jiangxi	1980	0.0026	1989	0.021	Pig	Microscopy	[35]

Epidemiological and epizootiological factors

Epidemiological surveys have shown that 94.3% of human trichinellosis outbreaks nationwide were caused by the consumption of raw or under-cooked pork. Despite the establishment of many industrialized farms in China, most pigs slaughtered in abattoirs today come from villages in the countryside, where farmers usually feed fewer than ten animals in small pigsties. The pigs frequently roam free and could come into contact with infected rodent carcasses, pork scraps, garbage containers, garbage dumps, and so on. Most farmers also feed pigs with pigswill and uncooked animal organs. All these factors were suspected to favor the high prevalence of swine trichinellosis, and lead to the high incidence of human trichinellosis.

Dog trichinellosis is another source of human infection. Eight outbreaks were reported to correlate with the consumption of dog meat [23], especially in the north of China, where the high prevalence of *T. nativa* infection in dogs is a result of the free roaming practice used by farmers who breed dogs for human consumption. A few outbreaks that resulted from the tasting of game meat were mainly associated with the practice of eating bear, which caused three outbreaks in China [9].

Sheep and cow are not established as sources of human trichinellosis, although many outbreaks were reported to be associated with them. Because many restaurants often prepared mutton or beef with other meats, such as pork, or sometimes dog meat, it was more difficult to investigate the real sources for the

outbreaks. Although two reports recorded the prevalence of trichinellosis in sheep and cow [24], until now there was no evidence that samples of mutton and beef from human outbreaks carried *Trichinella*. Xu [25] reported the discovery of rat carcasses in the first stomach of sheep when necropsies were performed in Inner Mongolia, which suggested the possibility that *Trichinella* could be transmitted from rats to sheep. However, a survey of 3590 goats in Henan province [15] did not find a single positive case of trichinellosis; hence, the precise epidemiological role of mutton and beef in human trichinellosis in China remains to be elucidated.

Modes of animal slaughter and special eating habits

According to Chinese regulation, animals must be killed in slaughterhouses or small local abattoirs, and carcasses can only be sold after veterinary inspection. Inevitably, some farmers slaughter animals privately without any inspection, especially during festivals, weddings and parties. Moreover, meat is sometimes sold in the local free markets without any inspection. Therefore, such uninspected meat has become the main source of human trichinellosis, because epidemiological data underlined the fact that most national outbreaks arose from pigs slaughtered in small villages and not from national slaughterhouses [9].

The special eating habits of the local people are also a major factor associated with severe human trichinellosis. The first example is the habit of eating raw meat, which caused mass cases from 1964 to 1980 in the provinces of Yunnan, Tibet and Guangxi. The second example is the consumption of typical under-cooked foods (e.g. Jiao Zi, or scalded dog meat), which could have served as a source of infection in most parts of the country after 1980. The prevalence of human trichinellosis increased in parallel with the fast economic development in Chinese society, and the facilities for more Chinese to obtain a wide variety (in terms of origin and nature) of meat. The development of national slaughterhouses and intensive breeding could explain in part the drop of human trichinellosis outbreaks during the past ten years.

Awareness of trichinellosis

In the villages, farmers usually pay little attention to trichinellosis because of its comparatively low virulence (the mortality is below 1% for 25 000 human cases) [4]. City inhabitants also pay little attention to trichinellosis because of a general lack of knowledge of the clinical symptoms and sequellae. In addition, most clinicians lack experience in diagnosing trichinellosis; it can easily be confused with other febrile infections, such as rheumatism, influenza, acute nephritis, typhoid, leptospirosis and acute pneumonia. Indeed, among the outbreaks, as many as 13.8% (SN = 347; 1994) of the cases were misdiagnosed [26].

General unawareness of the disease in the country could facilitate the spread of the disease in both human and animal populations. This is substantiated by the increasing prevalence of disease and by the extending epidemic area of animal and human trichinellosis in some regions (Table 2).

Trichinellosis control in China

Before 1980, the severe prevalence of pig trichinellosis was thought to be a consequence of feeding pigs with pigswill and, in 1980, the Government forbade this practice. However, because pigs can also be infected by other means, this regulation was not very effective. Despite much effort towards vaccine preparation, there is an urgent need to develop alternative methods of control at low cost [27]. Recently, some Chinese veterinarians attempted to prevent pig trichinellosis by adding an anthelmintic such as albendazole to animal feed [28]. Experimental results [11,28] in restricted areas indicate that this is an effective method to reduce the prevalence of swine trichinellosis. For example, in the Nanyang area, the prevalence rate was reduced from 32.2% to 0.12% [11] and, in the Dali area, from 12.2% to 0% [28]. However, at present, because nothing is known about the side effects of the drug residues in pork, this method is not approved by law and is not widely used in the epidemic areas.

Since 1956, the direct detection method for trichinellosis (by microscopy) has become mandatory in the slaughterhouses in China. However, this method is not only time-consuming for bulk production, but it also lacks diagnostic sensitivity [29]. Before 1996, Chinese food hygiene regulation tolerated that carcasses with light infection (below five larvae per sample) could be consumed after high-temperature treatment. After 1996, a new food hygiene regulation was implemented and the infected carcass must now be destroyed, even if there is only one larva. To increase the accuracy of inspection, the pooled-sample digestion method is also commonly used in many slaughterhouses throughout the country. Nevertheless, there is no standard detecting method for other animals such as dogs (usually, the inspectors in dog slaughterhouses check tongues for dog trichinellosis).

Economic loss in China

The high prevalence of trichinellosis in both humans and animals invariably leads to significant economic losses especially in endemic areas. For example, from 1981 to 1993, the slaughterhouse in the Xiangfan county (Hubei province) found 45 666 infected pigs, and destroyed 27 400 heavily infected animals [30]. From 1975 to 1985, the Nanyang county slaughterhouse in Henan lost US$ 550 000 because of trichinellosis [31]. According to the China Statistic Yearbook of 1996, there were more than 500 million pigs slaughtered in China during that year. China spends huge amounts of money in carrying out swine inspection, although the average cost is far less (about US$ 0.3 per pig) [8] compared with the European union (US$ 3 per pig) [1]. There is also a high cost in destroying infected carcasses and treating human cases [32].

Concluding remarks

Two main epidemiological cycles are described in China, one involving *T. spiralis* in domestic pigs and the other involving *T. nativa* in dogs. The limited studies reported to date stress the existence of other cycles and particularly the involvement of other *Trichinella* spp. in the western part of China. The number of human clinical cases reported in China is the highest figure in the world for human trichinellosis; it gives the precise rate of mortality as 0.95% (SN = 25 161) and an incidence of two cases per 10 0000; although, this figure remains far from the actual total as revealed by serological studies [4]. The greatest spreading of infection appears to be in Hubei, Henan, Yunnan, Guangxi and north-eastern China.

This article stresses the need to enforce effective measures for controlling trichinellosis in China. The easiest measure would be to educate and inform the public, insisting on the need to cook pork or dog meat thoroughly. The second

objective would be to organize a network of laboratories specifically responsible for *Trichinella* monitoring and control in animals in slaughterhouses, and to use a standard method as recently indicated by the International Commission on Trichinellosis [33] (i.e. the digestion test, which is ten times more sensitive than microscopy). It would also be useful to collect samples from wild animals, to evaluate more precisely the areas where intense control should be applied.

Acknowledgements

We thank Jean Fransois Fabien for his hard work in figure preparation; Edoardo Pozio, Ronald Ko, Isabella Vallee and Jean Dupouy-Camet for their helpful comments; Young Chen for revising the manuscript; and Yan Qun Pan, Bao Quan Fu, Qiang Lu and Xiu Ping Wu and Chun Yu Yao for epidemiological data. The authors also apologize to authors of relevant material that was not included in the reference list because of space constraints. This paper was supported by the PRA 9612 and AQS 1999 A 2659 grants of France and the NSFC-30170709 grants of the National Nature Science Foundation of China.

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ParaSite

Swan-song – 'after many a summer dies the swan'

Or as Coleridge put it:

> 'Swans sing before they die - 'twere no bad thing
> Did certain persons die before they sing.'

However, for this, the last ParaSite, it is to be hoped that the title of 'Epilogue' (a speech or short poem addressed to the spectators by one of the actors after the play is over) is more appropriate.

ParaSite began in June 1996 in *Parasitology Today* as comment on Internet parasite discussion groups, rudely and wrongly referred to by one person as 'chat groups'. Although, on occasion, there are trivial or disagreeable exchanges on subjects such as the FDA or the attitude of the developed world towards the poor, generally participants are true to the purpose of the groups and ask and answer specific questions and debate serious scientific matters seriously. A little irritation has sometimes been shown in response to recurring claims for, or questions about, 'natural' remedies, such as tincture of Wormwood, Cloves and Black Walnut Hull or Cascabel 'made from the bone of a very special species of tropical rattle snake', or for other magic cures or mysterious insect repellents. When a claim was made for a potion used for malaria prophylaxis by the Maya 'during the 4500 plus years of their civilized existence', one sharp questioner asked how could the tribes have made the discovery because malaria only entered the Americas after Columbus? 'Or did they retain the knowledge in their long journey from Asia

  PII: S1471-4922(02)02377-2