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Trichinellosis: a worldwide zoonosis

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Abstract

Trichinella spp. are some of the most widespread parasites infecting people and other mammals all over the world, regardless of climate. This paper attempts to describe the present status of trichinellosis worldwide and to determine if and why trichinellosis is emerging or re-emerging. The global prevalence of the disease is difficult to evaluate but as many as 11 million people may be infected. More than 10 000 cases of human trichinellosis were reported by the International Commission on Trichinellosis from 1995 to June 1997 and about 10 000 porcine infections were reported by the Office International des Epizooties in 1998. The disease is particularly worrisome in the Balkans, Russia, the Baltic republics, in some parts of China and Argentina. Horsemeat-related outbreaks have been reported in France and Italy and have involved about 3000 patients in the past 25 years. The emergence of trichinellosis in some countries is explained by a better knowledge of the disease (formerly often misdiagnosed as influenza), modifications of consumer habits, re-forestation in Europe and increase of wild game, importation of meats from countries where trichinellosis is endemic and failure of veterinary control due to human error or to social upheavals. This disease linked to meat-consumption which is theoretically easy to prevent by adequate cooking, freezing and veterinary controls, should deserve the attention of all persons involved in public health and it could be eradicated at least from domestic pigs.

Keywords: Trichinellosis; Epidemiology; Zoonosis

1. Introduction

Raskolnikov in Dostoievski's novel 'Crime and Punishment' written in 1866, dreams 'that the whole world was condemned to a terrible new strange plague that had come to Europe from the depths of Asia. Some new sort of trichinae were attacking the bodies of men but these trichinae were endowed with intelligence and will. Men attacked by them became at once mad and furious. Whole villages, whole towns and peoples went mad from the infection...'. The use of the word 'trichina' in the original text illustrates how

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this parasite, first discovered in 1835 but only linked to disease and pork-consumption in 1860 (Campbell, 1983), was then a dreaded, worldwide threat, comparable to prion disease nowadays. Outbreaks of trichinellosis have been regularly reported during the past two centuries and there is evidence suggesting that this parasitic disease may be emerging or re-emerging in some parts of the world. Trichinellosis is common in some rural areas of South America and Asia but quite infrequent in urban regions. However, over 6000 patients in the European Union (EU) acquired the disease in the past 25 years (Pozio, 1998) and a survey conducted throughout the EU in 1998 identified at least 791 cases in France, Germany, Spain and Italy (Dupouy-Camet, 1999).

Trichinella is one of the most widespread parasites infecting people and other mammals all over the world in most climates, except for deserts. It is a tissue-dwelling nematode acquired by the ingestion of raw or inadequately cooked meat-products containing encapsulated larvae. These larvae are released after gastric digestion and mature into adult worms that penetrate the mucosa of the intestine. After fertilization, the female sheds new larvae which disseminate throughout the host to find their definitive location, the striated muscle where they encyst. This larval migration may result in severe lesions, particularly when larvae migrate in the heart or in the brain. Our knowledge of *Trichinella* has greatly increased during the past 25 years and so far, 10 species of *Trichinella* have been identified by molecular studies (Pozio et al., 1992; La Rosa et al., 1992; Pozio et al., 1999; Pozio and La Rosa, 2000). They are described elsewhere in this issue of 'Veterinary Parasitology'. All these species can be pathogenic for humans and except for *T. pseudospiralis* and *T. paupae,* they have the ability to become encapsulated in muscles. The wide range of mammalian hosts and the fact that primitive mammals (marsupials) and birds can be infected, suggest that the genus *Trichinella* could have been associated with carnivorous dinosaurs and ancient mammals. Humanoids could have acquired *Trichinella* when they left their tree-dwelling mode of life to occupy the African Savannah and become carnivores. Domestication of pigs some 10 000 years ago in Asia created a permanent reservoir of parasites for humans, limited by the use of fire and Mosaic laws. Nowadays, trichinellosis is still a concern for public health workers all over the world. Trichinellosis has been reported in Iñuits from arctic Canada, Thai and Laotian villagers, urban inhabitants of France or Italy, travelers from Africa, Turkey, Egypt, Asia, former Yugoslavia, Mexico and Greenland, and farmers from Argentina, Poland, Croatia, Russia, Romania and China. This paper describes the present global status of trichinellosis and attempts to determine if and why trichinellosis is emerging or re-emerging as a worldwide zoonosis.

2. What is the present status of trichinellosis worldwide?

Evaluating the worldwide prevalence of the disease is difficult because the definitive localization of the larvae in the muscles precludes simple parasitological surveys (parasite identification requires muscle biopsy). Extensive surveys have been based on the examination of diaphragms from cadavers but there are no recent data from such studies. In the 1940s, 12 000 necropsies carried out in USA showed that about one in six Americans were infected (Stoll, 1947). Serological surveys are possible but have several drawbacks: they are expensive, antibody titers fall quite rapidly though patients still harbor the parasite

and cross-reaction can occur, requiring the use of expensive western blots (Robert et al., 1996; De-la-Rosa et al., 1995). In rural Chile (Contreras et al., 1994), a correlation was observed between the serologic prevalence of trichinellosis (1.5%) and necropsy positives (2%). In rural Mexico (De-la-Rosa et al., 1998), a higher prevalence of antibodies was found in females (2.36%) than in males (0.35%). In the Chinese province of Henan, serological surveys carried out some 10 years ago yielded prevalence rates ranging from 2.6 to 8.9% (Xu et al., 1995). Liu and Boireau (personal communication) reported seropositivity rates from 0.66 to 12.16% in nine Provinces of China. Such surveys have also been conducted in domestic animals but prevalence rates are different according to the geographical area: from 0.013% in pigs in 1995 in USA (Gamble and Bush, 1999) to 9% in pigs in endemic zones of Argentina (Venturiello et al., 1998). Crompton (1999), in his paper entitled 'How much human helminthiasis is there in the world?', curiously considers trichinellosis as a 'localized infection, similarly to capilliariasis and anisakiasis'. This observation contrasts with Stoll's famous 1947 paper, 'This wormy world' in which he states that at least 21 million North Americans, 1 million South Americans and 5 million Europeans were infected by *Trichinella*. The article did not mention the possible occurrence of the disease in Asia. What is the present situation? Although, the repartition of the disease has been extensively reviewed in excellent papers (Kim, 1983; Soule, 1991), not a single author has dared to evaluate the global prevalence of the disease. Data from the Gideon software reported by Berger in 1998 (http://www.medscape.com/other/ProMED/1998/05.98/ProMed.v98.n120.html) estimated that 11 million people could be infected worldwide and that trichinellosis accounted for 1.5% of all food-related outbreaks in Europe in 1991–1992. Another approach to estimate the prevalence of trichinellosis is to assume, as most cases of trichinellosis are acquired through pork-consumption, that the number of people infected by *Trichinella* would be similar to that affected by *Taenia solium*. In Chile where both parasites coexist, the prevalence of antibodies in a rural population was 1.1% for *Taenia solium* and 0.6% for trichinellosis (Aliaga et al., 1994). The current estimated number of worldwide infections by *Taenia solium* is 10 million (Crompton, 1999) but the global repartition of *Taenia solium* does not exactly overlap with that of trichinellosis. In some parts of the world, such as Africa or Madagascar, *Taenia solium* infections are present whereas trichinellosis has not been reported.

For this review paper, the global distribution of trichinellosis was assessed by scrutinizing the MEDLINE database (1965–1999) using the following query: (*Trichinella* or trichinosis) and name of the considered country. Titles and abstracts were analyzed to estimate the worldwide distribution of trichinellosis in humans and animals (Fig. 1). The data published in the OIE (Office International des Epizooties) report entitled World Animal Health Report (World Animal Health, 1998) were used to list countries where animal trichinellosis occurred in 1998, around 10 000 cases of porcine infection were reported to OIE in 1998, mainly from the Balkans (Table 1). Finally, a survey available at the web site (http://euliste.krenet.it/ict) of the International Commission on Trichinellosis (ICT) yielded that more than 10 000 cases (including 18 fatal) were notified to the commission between 1995 and June 1997 (Table 2).

These data confirm that *Trichinella* has a worldwide distribution. It was not reported in desert zones and data are missing for the northern parts of South America (Brazil, Venezuela, Colombia etc.). Some regions of Africa and Madagascar have not been investigated. From a public health point of view, the situation appears particularly worrisome in Argentina,

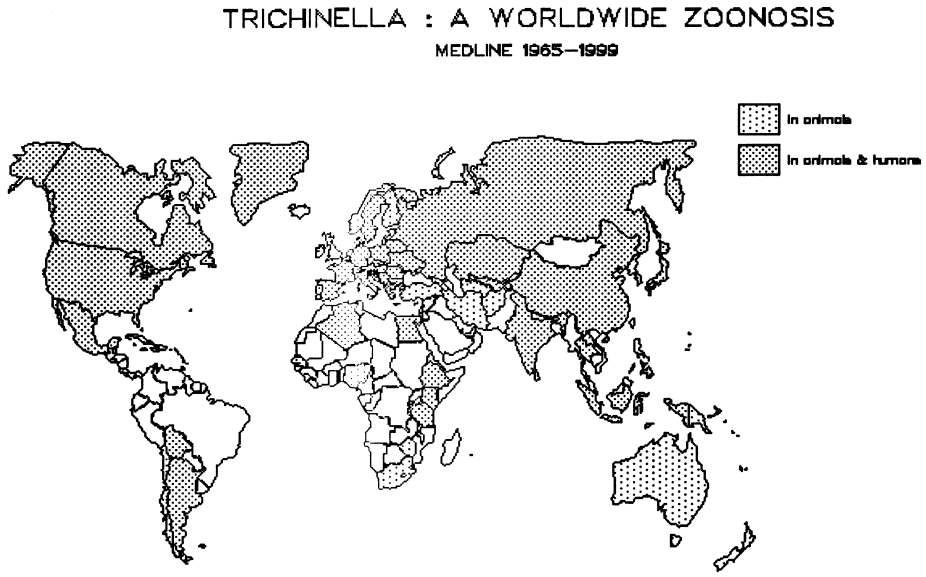

Fig. 1. *Trichinella* reports in animals and in humans by country (Medline, 1965–1999).

Croatia, Yugoslavia, Russia, Romania, Latvia, Lithuania and China. In most of those countries, outbreaks are generally linked to pork (see Tables 1 and 2). However, an unusual 'vector' — horsemeat — has emerged in the past 25 years and has been responsible for at least 3000 cases in France and Italy alone. Some outbreaks involved more than 100 cases from a single carcass: 125 cases in Chatenay-Malabry, France in 1975; 431 and 642 cases in France in August and October 1985; more than 300 cases in Salsomaggiore, Italy in 1986; more than 500 cases in Barletta, Italy in 1991; 538 cases in Paris and other places in 1993; 126 and 405 cases in the Toulouse region in 1998 (Ancelle, 1998; Dupouy-Camet, 1999). Curiously, none of those horsemeat-related outbreaks are mentioned in the annual reports of

Table 1
Countries in which *Trichinella* infected pigs were reported (OIE, 1998)

Country	No.
Argentina	661
Belarus	1
Bulgaria	30
Croatia	2500
Finland	13
Israel	7
Lebanon	5
Lithuania	120
Romania	5305
Russia	148
Ukraine	5
Yugoslavia	1062

Table 2
Countries in which cases of human trichinellosis were reported (International Commission on Trichinellosis, January 1995–June 1997)

Country	Human cases	Fatalities	Source
Argentina	1274	3	Pork
Canada (1995)	9	2	Wild game
Chile	169	1	Pork
China	776	4	Pork
France	24	–	Wild boar, horsemeat
Germany	14	–	Pork
Italy	36	–	Wild boar, pork
Latvia	142	2	Wild boar, pork
Lithuania	593	1	Wild boar, pork
Mexico (1993–1995)	282	–	Pork
Poland	148	–	Wild boar, pork
Romania	3092	2	Pork
Russia	1432	2	Pork, dogmeat
Thailand	104	1	Pork
Slovak Republic	7	–	Pork wild game
Spain (1995–1996)	86	–	Wild boar
Yugoslavia	1806	2	Pork
USA	36	–	Wild game
Totals	10030	18	

World Animal Health. Other unusual meats have also been involved in human cases (Soule, 1991): bears (in Greenland, Canada, USA, Japan, Eastern Europe and China), walrus in Canada and Alaska (Margolis et al., 1979), cougar in USA (Dworkin et al., 1996), foxes in Italy (Pozio, personal communication), mutton in China (Wang et al., 1998), warthog in Africa (Kefenie and Bero, 1992) and dog in China and Slovakia. A recent outbreak, involving some 340 patients in central Slovakia, was related to the consumption of home-made dogmeat sausages (Dubinsky et al., 1999). Although, bovines could be exceptionally infected (Murrell, 1994), they have never been involved in outbreaks.

3. Is trichinellosis an emerging or re-emerging disease worldwide?

All the data obtained from the different sources mentioned above, could merely be the tip of a huge iceberg. While, in most countries of the developed world, trichinellosis or food-borne diseases are reportable, this is not the case in a lot of other countries and the evolution of the prevalence of the disease is difficult to estimate. Therefore, this second query was submitted to MEDLINE: trichinellosis and human and (outbreak or focus or epidemic). This query yielded 252 answers but the analysis of the titles or summaries (when available) identified 156 reports of outbreaks from 1965 to the present. Interestingly, the number of reports increased regularly: 96 outbreaks were reported from 1965 to 1989 (3.84 outbreaks per year) whereas 60 were reported in the past 10 years (six outbreaks per year). However, this MEDLINE report has limited value, as in the last decade, physicians in some countries may have been more prone to publish their results in MEDLINE-indexed

papers. Conversely, in some other countries, reports may have been published in national journals not indexed in MEDLINE or not published at all. For example in France, only nine outbreaks are reported in MEDLINE, despite 21 outbreaks that were identified since 1975 in this author's records. The disease is emerging in some parts of the world: Russia (10 reports from 1965 to 1989, 9 from 1990 to 1999), China (2 reports from 1965 to 1989, 13 from 1990 to 1999), EU (17 reports from 1965 to 1989, 16 from 1990 to 1999), Yugoslavia (2 reports from 1965 to 1989, 71 from 1990 to 1999). In China, one or two human cases were reported before 1951 (Chin and Tu, 1951–1952) and no outbreaks had been described in Henan before 1984. In Henan, seven outbreaks and many sporadic cases were reported between 1992 and 1996, involving at least 467 patients. In that region, the mean prevalence in pigs was between 4.3 and 8.25% in 1997, contrasting with 0.4% in 1982 and 1.3% in 1987 (Wang et al., 1998). Moreover, by reviewing the English and Chinese literature, Liu and Boireau (personal communication) identified in 559 outbreaks in China from 1964 to 1999 which involved about 25 000 patients. Most of these outbreaks were due to pork consumption but 23 were related to mutton, 8 to dogmeat and 3 to bearmeat. In a recent paper from Yugoslavia, the occurrence of 70 outbreaks was reported between 1984 and 1993 (Seguljev et al., 1995). Nevertheless, in other countries, the number of reports is declining: USA (18 reports from 1965 to 1989, 3 from 1990 to 1999), Canada (11 reports from 1965 to 1989, 1 from 1990 to 1999), Slovak republic (6 reports from 1965 to 1989, 0 from 1990 to 1999).

However, the use of data from MEDLINE introduces an obvious bias: in some countries such as USA and Canada, most outbreaks (even those with a limited number of cases) are published whereas in other countries only huge outbreaks are reported. In the USA, the trichinellosis surveillance program implemented since 1947 may have led to over-reporting of outbreaks before 1989 (Moorhead et al., 1999).

Reports of human infections due to the non-encapsulated species *Trichinella pseudospiralis* have also emerged in the past decade. Sixteen years after the suggestion of Pawlowski and Ruitenberg (1978) that this species was likely to be a human pathogen, Andrews et al. (1994) described the first human case due to *Trichinella pseudospiralis*. An outbreak due to this same species was described in Thailand after consumption of meat from a wild pig involving 59 individuals, one of whom died (Jongwutiwes et al., 1998). Other cases related to pork consumption were also reported in 1996 from Kamtchaka (Britov, 1997). The first European human outbreak of *Trichinella pseudospiralis* was encountered in France by Faugeres (personal communication) and involved four consumers of a wild boar shot in the Rhône delta, a place known for its numerous birds.

4. Factors regulating the emergence or re-emergence of trichinellosis

Is trichinellosis emerging or re-emerging, or is it the diagnosis of this disease which is emerging? The first obvious cause of this apparent emergence of trichinellosis could be better reporting to an improved public health system of a disease formerly misdiagnosed as influenza. The clinical signs of trichinellosis (fever, fatigue and myalgia) are not very characteristic and facial edema can be due to allergic reactions to medications prescribed for flu. Only eosinophilia and increased muscular enzyme-levels in blood are pathognomonic for the disease (Capo and Despommier, 1996; Dupouy-Camet et al., 1998). Antibody-assays

are very sensitive but are frequently negative during the first week of the disease, only becoming positive when the patient is beginning to recover. During the 1993 horsemeat-related outbreaks, the trichinellosis foci coincided with the usual winter flu foci and only a better knowledge of the disease led to correct identification of the zoonosis. For example, misdiagnosis of the disease no doubt explains why no outbreaks were reported in France between 1876 and 1952 (Dupouy-Camet, 1999) and the failure to report trichinellosis in Henan before 1984.

The usual factors of emergence of infectious diseases, described by Morse (1995) may also apply to trichinellosis. The critical situations observed in the former Yugoslavia, Romania and Russia have led to a public health breakdown and a disorganization of veterinary controls. The development of international travel explains the acquisition of the disease (from warthogs in Africa, polar bears in Greenland or polar, black or brown bears in Alaska) by individual travelers or small groups (Singal et al., 1976; Mc Auley et al., 1991; Nozais et al., 1996). Though, both traditional and unusual culinary habits (eating raw meat) may explain these imported cases, they cannot explain the emergence of the disease in countries where these culinary habits are ancestral. In contrast, it appears that high-class restaurants are increasingly serving barely cooked dishes while boasting the freshness of their ingredients. As well, new fashionable culinary habits such as 'nouvelle cuisine' are leading consumers to eat under-cooked wild boar. Conversely, trichinellosis is practically never reported in Muslim countries or in Jewish communities, due to the proscription of domestic and wild pork. However, in Lebanon, outbreaks were reported in Christian communities consuming undercooked pork as an ingredient of 'kubeniye' (Haim et al., 1997).

The emergence of horsemeat-related outbreaks of trichinellosis in the past 25 years in France and Italy is particularly difficult to explain and illustrates the difficulties of prevention, even in industrialized countries. In both countries, horsemeat has been consumed for years without any apparent cases of trichinellosis but since 1975, 13 outbreaks have been reported, despite veterinary controls implemented in 1985 (five outbreaks from 1975 to 1985, 8 since 1986). An insufficient amount of meat examined, professional mistakes and fraud and the absence of quality controls (Forbes and Gajadhar, 1999) would explain the failure of veterinary control. The fact that herbivorous animals such as horses are carriers of *Trichinella* spp. implies that these animals are fed intentionally with meat or accidentally with hay containing pieces of rodents, as we have personally observed (Dupouy-Camet et al., 1994).

Globalization of international trade is also a risk factor: many countries where trichinellosis is endemic among wildlife (e.g. in North America) or domestic animals (e.g. in eastern Europe) are exporting animals for consumption. In December 1998, a small outbreak of four cases in Normandy was due to the consumption of vacuum-packed meat sold as wild boar imported from the USA. It is believed that all horses responsible for the French and Italian outbreaks were imported either from North America (USA, Canada, Mexico) or eastern Europe (former Yugoslavia, Poland). In China, the foci of human and swine trichinellosis were located along railway lines, suggesting that transportation of live pigs and pork increased the risk of transmission (Wang et al., 1998).

Ecological modifications can result in an increase of wild game. Re-forestation (a 44% increase in forests in France from 1912 to 1990, a 0.13% increase between 1980 and 1990 in Europe), the increase in fallow land and the reduction in the number of farms have led to an increase in wild boar populations in Europe and has contributed to the maintenance of

sylvatic trichinellosis (Pozio et al., 1996). In France, a nine-fold increase in populations of wild boars has been observed in the past 25 years: 36 429 wild boars were killed in 1973–1974, compared to 322 767 in 1997–1998 (Office National de la Chasse). Modern pig farming (indoor housing with rodent barriers and commercial diets) has made pork-related trichinellosis rare in the European Union. Nevertheless, the recent development of traditional extensive outdoor breeding could facilitate the transmission of *Trichinella* from wildlife to pigs.

In some countries, there is no apparent emergence of trichinellosis. This is the case of the USA where a trichinellosis surveillance program was implemented 50 years ago and the annual number of cases of human trichinellosis has declined from 400 (10–15 deaths) in 1947 to 13 cases in 1996 (Moorhead et al., 1999). Therefore, surveillance and control programs should be implemented in all countries where trichinellosis is still a public health problem and should include: slaughter testing, processing methods to inactivate *Trichinella* and on-farm control. These methods are detailed in a document prepared by the ICT entitled 'Recommendations on methods for the control of *Trichinella* in domestic and wild animals intended for human consumption' (see Appendix in this issue of Veterinary Parasitology).

5. Conclusions

Trichinellosis is a notifiable disease in some countries but the precise evaluation of the number of human cases remains particularly difficult. The annual reports by the OIE focus on porcine trichinellosis and the data are given on a voluntarily basis by government agencies. MEDLINE introduces too much bias to draw general conclusions. The ICT network is useful to inform the scientific community on the development of outbreaks but not all countries have representatives. In a recent EU survey, this network yielded an estimation, within a few days of the epidemiological situation (Dupouy-Camet, 1999). Therefore, the ICT could disclose an annual report of all human cases reported by the ICT network which would allow regular worldwide surveillance of the zoonosis. This disease linked to meat-consumption which is theoretically easy to prevent by adequate cooking and veterinary controls, deserves the attention of all persons involved in public health and it could be eradicated at least from domestic pigs. Freezing of meat is a good preventive measure in most regions of the world where *Trichinella nativa*, highly freeze-resistant, is not found. The cost of the disease (some 1.5 million dollars for the 1073 French cases of 1985) are far higher than the cost of prevention (Ancelle et al., 1990; Pozio, 1998). Finally, I agree with Kim's statement (1991): 'the emergence of new foci for human trichinellosis emphasizes the importance of direct communication and interaction on a worldwide basis regarding the parasite and the infection'.

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