

## Trichinellosis in developing countries: is it neglected?

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### Abstract

Trichinellosis is a foodborne zoonosis caused by the parasitic nematode *Trichinella*, which is characterized by an extremely wide host range and geographical distribution. The aim of the present review is to provide epidemiological information on animal and human trichinellosis occurring in developing countries in the different continents, where cooking habits along with poverty and poor sanitary conditions and lack of veterinary controls may facilitate the occurrence of human trichinellosis outbreaks. Countries have been considered according to the six regions designated by the World Health Organization (WHO): 1) WHO African Region, 2) WHO Region of the Americas, 3) WHO South-East Asia Region, 4) WHO European Region, 5) WHO Eastern Mediterranean Region, and 6) WHO Western Pacific Region. For the purposes of this article, developing countries are defined as those not industrialised according to the World Economic Outlook Report of the International Monetary Fund (<http://www.imf.org>); however, with regard to the European Region of WHO, only those countries that are not member states of the European Union will be considered.

**Key words:** trichinellosis; developing countries; socio-economic impact

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### Introduction

Trichinellosis is a food-borne zoonosis caused by the parasitic nematode *Trichinella*, which is characterized by an extremely wide host range and geographical distribution [1]. At present, eight different species have been described: *T. spiralis*, *T. nativa*, *T. nelsoni*, *T. britovi*, *T. murrelli* (the so-called encapsulating species), and *T. pseudospiralis*, *T. papuae* and *T. zimbabwensis* (which, conversely do not induce the capsule formation) plus different genotypes [1]. Trichinellosis is well controlled in the European Union, where inspection of pork is mandatory with an estimated annual cost for meat inspection of pigs ranging from 25 million € to 400 million € [2]. Even though the United States government does not employ the same inspection practices for *Trichinella* that the European Union uses (except for pork that is exported to the EU), the United States Food and Drug Administration does have in place control measures that monitor the raising of pork and meat processing for infection and exposure [2]. In both the developed (i.e., China) and developing countries (DCs) trichinellosis is now emerging [1].

The aim of this review is to consider the impact of trichinellosis in developing countries where, due to modest health controls, this parasite remains a serious health threat whose control is still remote. Countries have been considered according to the six global regions designated by the World Health Organization (WHO): 1) WHO African Region, 2) WHO Region of the Americas, 3) WHO South-East Asia Region, 4) WHO European Region, 5) WHO Eastern Mediterranean Region, and 6) WHO Western Pacific Region.

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### *Life cycle of Trichinella*

Among helminths, the parasite has a unique life cycle since *Trichinella* establishes intracellular infections in enterocytes and skeletal striated muscle cells [1]. All stages in the *Trichinella* life cycle (larval and adult) occur in the same host. Any mammal can be infected, as well as birds and reptiles

[1]. Humans, swine and horses represent the most important hosts from a medical and veterinary point of view [1]. When a host ingests infected meat, the larvae, released by the action of gastric juice, pass into the small intestine. There, the parasites invade the epithelial wall, and after four moults, become sexually mature (in about 30 hours). After about one week post infection, copulation occurs; then the adult females begin to release the so-called newborn larvae (NBL). This process lasts for the rest of the life of the female. It is generally believed that the adult worms persist in the intestine for only few weeks, but they actually may survive for much longer periods, mainly in immune compromised hosts. A high variability of this process is due to host and *Trichinella* species, and the genetic background of the host within a given species, but the infection dose is crucial [1]. After the NBL have penetrated into the sub-mucosa, they are distributed through the circulatory system to various organs, causing mechanical tissue damage; however, only the larvae invading the skeletal muscle fibres can survive and grow. In most parasite species, such as those inducing the formation of a collagen capsule (encapsulating), they gradually encyst and develop into the infective stage about 21 to 30 days after infection.

In those non-encapsulating species, the larvae do not induce the formation of a capsule. However, skeletal muscle fibre still undergoes the transformation in the so-called "nurse cell" [1]. Larval infectivity can be retained for various years, depending on the host species. The larvae appear to be non-pathogenic for the natural hosts (excluding humans) unless very large numbers are installed in the muscles.

### **Epidemiological information from developing countries in the different WHO Regions**

#### *African Region - North Africa*

In this part of the African continent, due to the prevalent Muslim religion, trichinellosis cases are sporadic and most often only infections in tourists reveal the presence of the parasite.

In Algeria *T. britovi* is present in wildlife and domestic pigs and wild boars are the usual meats responsible for human cases in this country (represented by infected *Sus scrofa*); however, a jackal (*Canis aureus*), was also identified as the source in one single case [1]. No epidemiological data are available on a large scale.

#### *Sub-Saharan Africa*

In Congo DR, Guinea, Mozambique, Namibia, and Zimbabwe no information on domestic cycle or human cases has ever been reported [1]. On the contrary, several wild animal species were found infected with different *Trichinella* spp.: spotted hyena (*Crocuta crocuta*) in Congo DR; Viverridae in Guinea (*Trichinella britovi*); wild Nile crocodiles (*Crocodylus niloticus*) (*T. zimbabwensis*) in Mozambique and Zimbabwe; wild Nile monitors (*Varanus niloticus*) in Zimbabwe; lions (*Panthera leo*) (*Trichinella* T8) in Namibia [1]; and jackals (*Canis aureus*) and warthogs (*Phacochoerus aethiopicus*) (*Trichinella* spp. infection, probably *T. britovi*) in Senegal.

Human cases have been described in Ethiopia related to the consumption of warthog (*Phacochoerus aethiopicus*) meat. In the period between 1986 and 1990, twenty-eight human cases were reported with an average incidence between 0.02 and 0.04%, caused by wild game meat consumption [2].

In Kenya, no more than 50 cases were reported, of which one was fatal, in almost thirty years, with pork from red river hogs (*Potamochoerus porcus*) the main source of infections. In this country, as well as in Tanzania, *T. nelsoni*, has been detected in a wide spectrum of carnivorous mammals [1]. Cases of human trichinellosis cases related to the consumption of pork from a warthog (*Phacochoerus aethiopicus*), sometimes with fatalities [1], have also occurred in Senegal and Tanzania.

In 2009, several cases of trichinellosis were reported in tourists who had travelled back to France from Senegal. The three confirmed and three suspected cases were linked to consumption of smoked warthog (*Phacochoerus africanus*) ham in a hotel in Saint-Louis (Ndar) [3].

#### **Region of the Americas**

##### *Argentine Republic*

Today in Argentina, there are endemic, non-endemic and *Trichinella*-free provinces [4]; however, infected animals have been recently discovered in some areas which were considered until now *Trichinella*-free, such as in the National Park Administration, located in the Centre-east of the Entre Rios province, along the western riverside of the Uruguay River, where 11.4% of tested wild boars were found to be infected with *T. spiralis* although with a low parasite burden [5]. In the period between 1990 and 2005, a total of 5,221 human cases were reported with an average incidence of 1.48%, caused

by domestic pig meat consumption [2]. Responsible for human outbreaks affecting up to one thousand of individuals per year, *T. spiralis* has been found in both domestic and wild animals [6]. Wild animals identified to be infected with *T. spiralis* include wild boars (*Sus scrofa*), foxes (*Pseudalopex gracilis*) opossums (*Didelphis albiventris*), armadillos (*Chaetophractus villosus*), capybaras (*Hydrocaeris hydrocaeris*), grey fox (*Lycalopex gymnocercus*) coypus (*Myocastor coypus*), skunks (*Conepatus chinga*), ferrets (*Galictis cuja*), wild cats (*Felis geoffroyi*) and pumas (*Puma concolor*) and in synanthropic brown rats (*Rattus norvegicus*) and mice (*Mus musculus*) [6, 7]. Very recently, a new encapsulated isolate of muscle larvae of *Trichinella*, probably a new genotype (T12), was found in a mountain lion (*Puma concolor*) originating from the Patagonia region [8].

#### Plurinational State of Bolivia

*Trichinella* spp. larvae were never found previously in either animals or humans, but sera from domestic pigs originating from different country regions were found positive for anti-*Trichinella* antibodies [9,10]. In a recent serological survey of 255 pigs in the eastern part of the country, a positivity rate of 2.3% was found, probably due to cross-reactivity (Macchioni, personal communication).

#### Republic of Chile

In the period between 1991 and 2004, a total of 698 human cases were reported with an average incidence of 0.36%, caused by domestic pig meat consumption [2]. As in Argentina, *Trichinella spiralis* has been found in both domestic and wild animals [11]. No information is available at present from Colombia, Costa Rica, Paraguay, Peru, Uruguay, Venezuela, etc.

### Southeast Asia Region

#### Republic of the Union of Myanmar (Burma)

*Trichinella* infection has been found in domestic pigs in this region. An outbreak in a village in Chiangrai Province, Northern Thailand, was reportedly due to two pigs illegally imported from Burma [12]. Unfortunately, no information is available regarding the prevalence of infection.

### European Region

Among the food-borne helminthic infections, trichinellosis is the most common nematode infection

in Eastern Europe and it is considered a *neglected infection of poverty* [13]. The emergence or re-emergence of trichinellosis in the former Soviet bloc countries and the Balkans has been linked to widespread breakdowns in veterinary public health services that resulted from the economic collapse associated with the fall of Communism or regional conflicts [14,15].

#### Republic of Azerbaijan

*Trichinella* infection occurs in wildlife [16].

#### Republic of Belarus

Both domestic and sylvatic cycles occur. A prevalence of 0.0005% in pigs was previously reported. In addition, *Trichinella* spp. larvae have been detected in many wild animals such as red foxes, wolves, raccoon dogs, black polecats, martens, and also in wild boars. In humans, a prevalence of 0.55 per 100,000 inhabitants has been reported in the past [1].

#### Bosnia-Herzegovina

Sylvatic and domestic cycles are present also in this country. Human trichinellosis is usually caused by the consumption of pork from wild boars as well as from pigs. In the last 14 years more than 51 outbreaks (775 infected people) occurred, with some fatal cases [17].

#### Republic of Croatia

There is a high prevalence of both *T. spiralis* and *T. britovi* in wildlife. Recently, a control programme has strongly reduced prevalence in swine from 3.6% to 0.0001%. Between 30 and 50 human cases are reported every year [18]. Muscle samples were collected from 67 wolves in Dalmatia between 1996 and 2007 and analyzed by artificial digestion. About 31% of examined animals were found to be infected by either *Trichinella britovi* (19 out of 21) or *Trichinella spiralis*. The presence of the so-called "domestic" cycle was an unexpected finding since only *T. britovi* was previously reported in that region [19].

#### Republic of Georgia

*Trichinella* spp. infection was documented in 1970 in stone martens (*Martes foina*), jackals (*Canis aureus*), red foxes (*Vulpes vulpes*), corsac foxes (*Vulpes corsac*), and domestic cats, as well as in humans [20]. Recently, trichinellosis in humans is

increasing with hundreds of infections reported per year [2].

#### Republic of Kazakhstan

*T. nativa* and *T. britovi* were found in several wild animals such as red and corsac foxes (*Vulpes vulpes* and *Vulpes corsac*), wolves (*Canis lupus*), jackals (*Canis aureus*), martens (*Martes martes*), wild cats (*Felis silvestris*), lynxes (*Lynx lynx*) and wild boars (*Sus scrofa*). *T. pseudospiralis* has been observed in a smaller number of wild animals: only one corsac fox (*Vulpes corsac*), crows (*Corvus frugilegus*), and an eagle (*Aquila rapax*) were found infected [16]. Wild boar (*Sus scrofa*) meat consumption was responsible for different outbreaks [16]. In the Republic of Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan, *Trichinella* spp. infection has been documented in wildlife [14]. In this last country, a large outbreak of trichinellosis was caused by the consumption of pork from a wild boar (*Sus scrofa*) [20].

#### Republic of Macedonia

Wildlife and free-roaming pigs have been found infected by *Trichinella britovi*. Human infections are rare and are usually caused by the consumption of pork from wild boars (*Sus scrofa*) as well as free-roaming and backyard pigs [1].

### Eastern Mediterranean Region

#### Islamic Republic of Afghanistan

*Trichinella* spp. larvae have been found in many wild animals such as lynx (*Lynx lynx*), wolf (*Canis lupus*), jackals (*Canis aureus*), red foxes (*Vulpes vulpes*), mongoose (*Herpestes ichneumon*). No human case or infection in domestic animals has ever been reported [1].

#### Arab Republic of Egypt

*T. spiralis* has been found in stray dogs and pigs and probably *T. britovi* in wild animals. An important decrease in the prevalence of infected pigs from 1975 (4.5%) to 2000 (1.7%) was observed at the Cairo abattoir; furthermore, a prevalence of up to 13.3% has been detected among synanthropic rats of Alexandria abattoirs. These suggest the existence of both a domestic and sylvatic cycles [1].

In Tunisia, *Trichinella* spp. larvae (probably *T. britovi*) have been detected in sylvatic carnivores, but no human case or domestic infection has yet been reported [1].

#### Iran Islamic Republic

In 2007 six cases were reported with an average incidence of 0.008 % [2]. *Trichinella* spp. infection was shown in several wild animals: jackals (*Canis aureus*), red foxes (*Vulpes vulpes*), stray dogs, brown bears (*Ursus arctos*), wildcats (*Felis silvestris*) and wild boars (*Sus scrofa*) of the Caspian region. Two species were found: *T. spiralis* and *T. britovi* [16]. No case from domestic pig has ever been reported in the last twenty years [20].

#### Republic of Lebanon and Syrian Arab Republic

Large outbreaks have occurred in Christian villages caused by the consumption of meat derived from wild boars (*Sus scrofa*) in Lebanon [21]. In this country, 44 cases were reported in 1995 with an average incidence of 1.25%. No case from domestic pig has ever been reported in the last twenty years [2]. In Christian villages in Syria AR, small trichinellosis outbreaks have occurred due to the consumption of wild boar (*Sus scrofa*) meat [20].

### Western Pacific Region

#### Cambodia and Republic of Indonesia

The epidemiological situation of these two countries is quite similar. Anti-*Trichinella* antibodies have been detected in the rural population (in the Bali island, 19.5% of young people) but no human case has ever been reported [22], suggesting the existence of false positivites due to cross-reactivity.

#### Lao People's Democratic Republic

In the period between 2004 and 2006, a total of 123 cases were reported with an average incidence rate of 2.09% [2]. *Trichinella spiralis* should be the most probable species responsible since outbreaks have been documented in humans due to the consumption of pork from domestic pigs [23]. Furthermore, *T. spiralis* has been isolated from both a human biopsy as well as from a domestic pig.

A large outbreak of at least 650 estimated patients in Udomxay (Northern Laos) occurred in June 2005. No deaths were recorded. Consumption of uncooked or fermented pork at funeral and wedding ceremonies was the main source of infection. *T. spiralis* larvae were found in one of 11 local pigs which, however, were not involved in this outbreak [24].

An outbreak of imported trichinellosis (the first in China) involving 49 cases in Yunnan (P.R. China) during December 2006 originated from Laos. The affected individuals, all government officials who

had visited Laos, consumed raw and poorly cooked meat but the exact source of the infection could not be identified [25].

#### *Independent State of Papua New Guinea*

*Trichinella papuae* has been documented among wild (11.5% prevalence rate in a remote region) and domestic pigs and farmed saltwater crocodiles (*Crocodylus porosus*) [26]. A high serological prevalence (10%) for anti-*Trichinella* antibodies has been detected among humans living in this area (Western region) of Papua New Guinea, where the main meat source is the wild pig, according to interview results [27]. Seroprevalence significantly increased with age. Furthermore, it was higher in villages close to the hunting area where wild pigs infected with *Trichinella papuae* were found [27].

#### *Socialist Republic of Vietnam*

Between 2004 and 2007 in the Socialist Republic of Vietnam, 43 cases were reported with an average incidence of 0.058%. All cases were related to the consumption of pork from domestic pigs, suggesting the occurrence of the domestic cycle [2].

### **Concluding remarks**

Trichinellosis has declined significantly as a zoonosis, particularly in developed countries where a reduction of the domestic cycle was observed in the last decades [1]. It remains, however, a potential risk because of the still existing presence of most species of *Trichinella* in wild animals. In fact, a large biomass of the parasite continues to exist in developing countries of Central and South America, Europe, and Asia, where the human population movement from the country is increasing. This important demographic factor is responsible for trichinellosis emergence in some urban areas in China where affluence has increased the demand for pork, particularly in dishes such as meat dumplings, which by tradition may not be well cooked [28]. On the contrary, in sub-Saharan Africa, despite the presence of the parasite in many wild animal species, human outbreaks are rare. One reason may be adherence to ethnic habits. In fact, the populations living in this region belong mainly to the Bantu ethnic group, who does not consume meat at all. Religion may also affect the occurrence of human outbreaks, as seen in Muslim or Jewish countries where consuming pork is banned and the risk of infection is drastically reduced. However, different factors such as increasing secularism, demographic

changes, and the presence of other populations with different religions in these countries, along with the increasing tourism, has brought an increase in pig production as well as the consumption of game meat which does not undergo veterinary controls [20]. Furthermore, food adulteration should not be ruled out as exemplified by the Izmir (Turkey) trichinellosis outbreak in 2004. The population living in that country is predominantly Muslim; however, 474 people were infected after consumption of raw meatballs, usually prepared with beef, which were mixed deceptively with pork infected with *T. britovi* [29].

However, although if pork represents the main cause of infection all over the worldwide, infection may also derive from the consumption of meat from several different animals (armadillo, badger, black and brown bears, cougar, dog, fox, horse, jackal, monitor lizard, squirrel, turtle, walrus, warthog), according to the various different habits of populations living in the different countries [2].

Human behaviour remains the most important factor responsible for the persistence of trichinellosis in many geographical areas [2] where it – along with adequate regulations aimed to guarantee meat safety – are neglected. Trichinellosis must be considered not only neglected in Europe but also among the “other diseases” of the Millennium Development Goal [30]. According to Molyneux *et al.* [31], *zoonotic diseases have been even more neglected than other neglected tropical diseases*. The reasons for this neglect are several: a lack of data on disease burden in endemic countries; the fact that both clinicians and policy makers often have little knowledge of zoonotic causes of human disease; the lack of referral hospitals and reference laboratories in developing countries with the capacity to diagnose many endemic zoonoses; and the need of data collection systems for zoonotic diseases at multidisciplinary levels (public health, veterinary or wildlife services). Such negligence is inexcusable. It is time to recognize the severity of food-borne parasitic diseases and provide the funds, capacity, and human resources to find a solution to a controllable situation.

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## Dedication

This review is dedicated to Gianfranco Del Prete. I remember him not only as a scientist very well known from the literature for many years, but also as a colleague whom I only very recently had the opportunity to meet personally when I started a collaboration with him, in the field of immunology of trichinellosis. I will always remember his passion in experimental work and his great enthusiasm in approaching an experimental model, such as that of trichinellosis. I miss not only an outstanding scientist but also a very good friend. In this review I have combined our Dr Del Prete's recent interest in trichinellosis with his long-time pursued theme of research benefitting developing countries.

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