Trichinellosis: general overview and OIE standards to prevent human infections through on-farm measures

Edoardo Pozio
Istituto Superiore di Sanità
Rome, Italy
The *Trichinella* ‘fathers’

- In 1835, *Trichinella* larvae were discovered in a cadaver by J. Paget in UK, and then described as *Trichina spiralis* by R. Owen.
- In 1859, the natural cycle was described by R. Virchow.
- In 1860, F. Zenker proved the *Trichinella* pathogenicity in humans.
- In 1895, Railliet changed the genus name from *Trichina* into *Trichinella*. 

*Trichinella* history
Trichinella history

The expedition to the North Pole of Salomon A. Andrée in 1897

The crashed balloon ‘The Eagle’ on the pack ice in 1897

A polar bear hunted by Andrée in 1897

Pictures found on the pack ice by the Norwegian expedition Bratvaag in 1930
Trichinella history

**FIGURE 3.** Trichinoscopy in the United States. Inspection of export pork at a meat-packing plant in Chicago, 1896.

**FIGURE 4.** Trichinoscopy in Sweden. Women inspecting pork for trichinosis in Stockholm in 1911. The right-hand picture on the facing wall is a photograph of a similar scene, in the same room, in 1901.
Trichinella history

**FIGURE 1.** An old Danish cartoon envisioning the arrest of a trichina by the police.

**FIGURE 2.** Early trichinoscopy in Germany. Butchers bring their pork to the inspector’s office. From a newspaper of 1881. Granger Collection, New York.
The correct terminology

- Trichinellosis the correct term to refer the disease caused by *Trichinella* worms in humans
  - trichinosis or trichiniasis are obsolete terms

- The term ‘trichinellosis’ should be used only for humans

- Animals do not show any clinical sign of the infection

- For animals, the term ‘*Trichinella* infection’ is more appropriate
Trichinella

- *Trichinella* spp. round worms (Nematodes)
- Cosmopolitan distribution
Taxonomy, phylogeny and main hosts of the genus *Trichinella*

**Encapsulated species/genotypes**
- *T. nativa* 98%
- *Trichinella T6*
- *Trichinella T9* 97%
- *T. murreli*
- *Trichinella T8* 99%
- *T. britovi* 63% 36%
- *T. patagoniesis* 99%
- *T. nelsoni* 94% 6%
- *T. spiralis* 86% 10%
- *T. papuae* 48% 35%
- *T. zimbawensis* 98%
- *T. pseudospiralis* 54% 27%

**Non-encapsulated species/genotypes**
- Mammals
- Mammals and reptiles
- Mammals and birds
World map of *Trichinella spiralis*

They infect only mammals, mainly domestic and sylvatic swine
They infect only mammals, mainly wild carnivores
Geographical distribution of encapsulated species of *Trichinella* transmitted by a sylvatic cycle - 2

They infect only mammals, mainly wild carnivores, seldom swine.
Geographical distribution of non-encapsulated species of *Trichinella*

*T. pseudospiralis* infects mammals and birds
*T. papuae* and *T. zimbabwensis* infect mammals and reptiles
Distribution of *T. britovi* and *T. spiralis* in EU
### Relationship between *T. spiralis* and *T. britovi* and their hosts in Europe

<table>
<thead>
<tr>
<th>Host species</th>
<th><em>Trichinella</em> isolates</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>T. britovi</em> (%)</td>
<td><em>T. spiralis</em> (%)</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Carnivores</td>
<td>559 (89)</td>
<td>70 (11)</td>
<td>629</td>
<td></td>
</tr>
<tr>
<td>Swine</td>
<td>206 (32)</td>
<td>437 (68)</td>
<td>643</td>
<td></td>
</tr>
<tr>
<td>Rats</td>
<td>6 (18)</td>
<td>28 (82)</td>
<td>34</td>
<td></td>
</tr>
</tbody>
</table>
Trichinella sp. epidemiology

Sylvatic cycle ↔ Domestic cycle
The sylvatic cycle

- *Trichinella* spp. are primarily parasites of wildlife

- A poor management of wild fauna and domestic animals can favor *Trichinella* transmission from wildlife to the domestic habitat and vice versa

- *Trichinella* infecting larvae belonging to some encapsulated species can survive in frozen muscles
The domestic cycle

- The domestic cycle occurs when the farming practices are poor and pigs, horses or other farmed animals are fed or can feed on:
  - pork scraps from slaughtered pigs
  - rubbish of food origin containing pork
  - pig carcasses
  - garbage dumps
  - game animal carcasses
The role of rats in the domestic cycle

• The “Rat Theory”
  – in 1860, R. Leuckart proposed that rats were the reservoir of *T. spiralis* for pigs
  – in 1871, F.A. Zenker considered:
    • Rat infection as a symptom of the infection in pigs
    • the source of infection for both animals was scraps and offal of pig carcasses
  – *T. spiralis* infection in pigs is often associated with infection in rats living in abattoirs, farms, and garbage dumps
  – no reports of *T. spiralis* infection in rats where pig populations have been found to be negative, i.e. rats are merely an accidental host
  – *T. spiralis* disappeared from rats living in garbage dumps of US after the ban to rear pigs on garbage dumps for the control of the swine fever
  – rats can be vectors of *Trichinella* from one to another farm
Rodent control programme should be in place at the farm
**Trichinella** infection in horses

- 1975-2004 - 14 human outbreaks in France (2,296 cases) and in Italy (1,038 cases) for the consumption of horse meat
  - France and Italy are the only two countries where horse meat is consumed raw
- 1988-2010 - *Trichinella* larvae have been detected in muscles of 21 horses at slaughtering (6 in France, 8 in Italy, 1 in Serbia, 2 in Poland, and 4 in Mexico)
- It has been roughly estimated less than one *Trichinella*-infected horse every 250,000 slaughtered horses
Clinically confirmed cases of trichinellosis in humans in the WHO regions 1986-2009

<table>
<thead>
<tr>
<th>WHO region</th>
<th>No. of countries with trichinellosis (%)</th>
<th>Documented human infections (%)</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>African (46)</td>
<td>1 (2.2)</td>
<td>28 (0.04)</td>
<td>1</td>
</tr>
<tr>
<td>Americas (12)</td>
<td>5 (41.7)</td>
<td>7,179 (10.90)</td>
<td>10</td>
</tr>
<tr>
<td>Eastern Mediterranean (22)</td>
<td>2 (9.0)</td>
<td>50 (0.07)</td>
<td>0</td>
</tr>
<tr>
<td>European (50)</td>
<td>29 (58.0)</td>
<td>56,911 (86.46)</td>
<td>24</td>
</tr>
<tr>
<td>South-East Asia (11)</td>
<td>1 (9.0)</td>
<td>219 (0.33)</td>
<td>1</td>
</tr>
<tr>
<td>Western Pacific (27)</td>
<td>3 (11.1)</td>
<td>1,344 (2.04)</td>
<td>6</td>
</tr>
<tr>
<td>Other*</td>
<td>-</td>
<td>86 (0.13)</td>
<td>0</td>
</tr>
<tr>
<td>Total (168)</td>
<td>41 (24.4)</td>
<td>65,817</td>
<td>42 (0.05%)</td>
</tr>
</tbody>
</table>

*Infections acquired in countries other than the one in which diagnosis occurred
### Trichinellosis in humans in the EU 1986-2009

<table>
<thead>
<tr>
<th>Country</th>
<th>Period</th>
<th>N. of cases</th>
<th>Average incidence x 100,000 inhabitants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulgaria</td>
<td>1990-06</td>
<td>4108</td>
<td>2.4 - 2.9</td>
</tr>
<tr>
<td>Czech Rep.</td>
<td>1986-09</td>
<td>31</td>
<td>0.01</td>
</tr>
<tr>
<td>Estonia</td>
<td>1986-09</td>
<td>91</td>
<td>0.0 - 2.9</td>
</tr>
<tr>
<td>France</td>
<td>1986-89</td>
<td>1261*</td>
<td>0.005 - 0.006</td>
</tr>
<tr>
<td>Germany</td>
<td>1986-09</td>
<td>185</td>
<td>0.005</td>
</tr>
<tr>
<td>Greece</td>
<td>2009</td>
<td>1</td>
<td>0.008</td>
</tr>
<tr>
<td>Hungary</td>
<td>1986-09</td>
<td>158</td>
<td>0.18 - 0.027</td>
</tr>
<tr>
<td>Ireland</td>
<td>2007</td>
<td>2**</td>
<td>0.04</td>
</tr>
<tr>
<td>Italy</td>
<td>1986-09</td>
<td>1181*</td>
<td>0.0 - 0.9</td>
</tr>
<tr>
<td>Latvia</td>
<td>1986-09</td>
<td>636</td>
<td>0.07 - 0.38</td>
</tr>
<tr>
<td>Lithuania</td>
<td>1990-04</td>
<td>3979</td>
<td>0.4 - 21.8</td>
</tr>
<tr>
<td>Poland</td>
<td>1986-07</td>
<td>3084</td>
<td>0.05 - 1.5</td>
</tr>
<tr>
<td>Romania</td>
<td>1986-07</td>
<td>28564</td>
<td>1.7 - 16.1</td>
</tr>
<tr>
<td>Slovakia</td>
<td>1986-08</td>
<td>440</td>
<td>0.0 - 6.2</td>
</tr>
<tr>
<td>Slovenia</td>
<td>1989-06</td>
<td>203</td>
<td>0.00 - 10.5</td>
</tr>
<tr>
<td>Spain</td>
<td>1986-09</td>
<td>1684</td>
<td>0.0 - 0.4</td>
</tr>
<tr>
<td>UK</td>
<td>1999</td>
<td>7**</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>45,615</strong></td>
<td></td>
</tr>
</tbody>
</table>

*most from imported horse meat

** from imported pork
Epidemiology of trichinellosis

- *Trichinella* infection in humans is strongly associated with food habits
  - in France and Italy, most trichinellosis cases have been due to the consumption of raw horse meat (a peculiarity related to the French culture)
  - in China, Russia and the Slovak Republic, dog meat was the source of infection for several foci
  - in Romania, the highest prevalence of trichinellosis occurs in the Transylvanian region where the local ethnic group of German origin maintains the food habit of raw meat consumption
  - in Israel, Lebanon and Syria, where the Judaic and Muslim religions forbid the consumption of pork, human outbreaks of trichinellosis have been documented for the consumption of pork from wild boars among the Christian Arab population and immigrants from Thailand
Epidemiology of trichinellosis

- in Algeria and Senegal, since the majority of the human population is Muslim, trichinellosis has been documented only in expatriates from Europe.
- Muslim population is not exempt from acquiring trichinellosis, as shown by the occurrence of large outbreaks of trichinellosis for the consumption of minced beef illegally mixed with pork of unknown origin or from wild boar in Turkey.
- Hunters, their relatives, and their friends are at risk of trichinellosis infection when raw meat from game animals (e.g., bears, cougars, foxes, walruses, and wild pigs) is not tested for *Trichinella* before consumption.
Epidemiology of trichinellosis

- The migratory flow of humans with their own food practices including:
  - the consumption of raw meat
  - the illegal importation of not-controlled meat from endemic to non-endemic countries

  resulted in outbreaks in Austria, Denmark, Germany, Ireland, Italy, Netherlands, Spain, Sweden, Switzerland, United Kingdom, and USA
Global pig production

• Pork is the world’s most consumed meat from terrestrial animals
• It is forecast that the global yearly pig production will reach one billion by 2015 (double compared to 1970s)
• About a half of pigs are raised in China
• The pig production is:
  – global (except for some regions with cultural and religious reservations regarding the consumption of pork)
  – characterized by an increasing dichotomy of production systems:
    • the traditional subsistence-driven small-scale production
    • the specialized industrial farming
• Indoor farms are now responsible for more than half of the global pig production
Pig production and herd size

- **Europe**
  - 1.5% of pig farms have at least 400 fattening pigs and manage 75.7% of pig population (about 120 million animals)
  - there are national differences
    - e.g. in Poland, only 21.6% of fattening pigs are kept in large farms as compared to 90% or more in other nine EU countries
    - pigs kept in units of less than 10 animals represent a consistent part of the pig population in Bulgaria (34.8%), Lithuania (31.9%), and Romania (66.2%)
    - these small units manage 5.3% of fattening pigs (about 8.5 million animals), but account for 85.8% of the pig farms

- **USA**
  - 21.4% of pig farms have at least 500 fattening pigs, and manage 97.3% of the pig population (about 115 million animals)
  - 78.6% of pig farms are small units (<500 pigs), and manage 2.7% of fattening pigs (about 3.2 million animals)

- **Australia**
  - 4.3% of pig farms have at least 500 fattening pigs, and manage 57% of the pig population (about 1.3 million pigs)
  - 56.2% of pig farms are small units (<100 pigs), and manage 4.6% of pigs
Relationship between socioeconomic emergences and *Trichinella* in pigs

- economic and demographic changes (wars, revolutions, etc.) can result in:
  - a strong reduction in the number of experienced veterinary control officers
  - a change in the swine industry with:
    - a reduction in the number of large slaughterhouses and replacement with small abattoirs, that are too small to afford full-time in-house inspection
    - an increase in smallholder pig farming with reduced government oversight to ensure high standards in pig-rearing practices
Cost estimate for *Trichinella* inspection

- cost estimates range from 0.12 to 2.5 $ (0.09-1.9 €) per pig
- the cost can increase up to 10-15 $ (7.7-11.6 €) per pig in small slaughterhouses where few pigs are slaughtered per week
- in large slaughterhouses, where thousand pigs are slaughtered per day, the real cost is the time of diagnosis, because the carcasses cannot be cut before the test is completed, when they are still worm, or costly procedures should be put in place to trace each carcass piece
- the execution of the digestion test in small field laboratories in poor regions is difficult and extremely expensive considering the low number of slaughtered pigs per week or month
- the slaughtering of most free-ranging and backyard pigs is:
  - concentrated in a short period of time (end of autumn and beginning of winter)
  - dispersed over a large territory making the control of individual pig carcass extremely difficult
# Trichinella infections in pigs

<table>
<thead>
<tr>
<th>Country</th>
<th>Prevalence or number of infected pigs in controlled system per year</th>
<th>Prevalence or number of infected pigs in non-controlled systems</th>
<th>Ref period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belarus</td>
<td>no data</td>
<td>0.0005%</td>
<td>1980-89</td>
</tr>
<tr>
<td>Bosnia-Herzegovina</td>
<td>no data</td>
<td>about 300 per year</td>
<td>1997-2000</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>0.0/0.35 million</td>
<td>about 40 per year</td>
<td>2006-2012</td>
</tr>
<tr>
<td>Croatia</td>
<td>2,288/7,068,532 (0.03%)</td>
<td>13,866/6,294,308 (0.22%)</td>
<td>1998-2006</td>
</tr>
<tr>
<td>Estonia</td>
<td>0.0/0.48 million</td>
<td>2</td>
<td>1994; 1999</td>
</tr>
<tr>
<td>Finland</td>
<td>0.0/4.8 million</td>
<td>343</td>
<td>1995-2004</td>
</tr>
<tr>
<td>France</td>
<td>0.0/16 million</td>
<td>19 in the Corsica island</td>
<td>2004-2012</td>
</tr>
<tr>
<td>Germany</td>
<td>0.0/49 million</td>
<td>7</td>
<td>2003-2011</td>
</tr>
<tr>
<td>Greece</td>
<td>0.0/4.5 million</td>
<td>36/13,434</td>
<td>2009-2012</td>
</tr>
<tr>
<td>Hungary</td>
<td>0.0/4.0 million</td>
<td>2 in 2000, 6 in 2003, 4 in 2009</td>
<td>2000-2012</td>
</tr>
<tr>
<td>Italy</td>
<td>0.0/9.0 million</td>
<td>17</td>
<td>2005-2012</td>
</tr>
<tr>
<td>Latvia</td>
<td>0.0/0.3 million</td>
<td>2</td>
<td>2011</td>
</tr>
<tr>
<td>Lithuania</td>
<td>0.0/0.8 million</td>
<td>84</td>
<td>2006-2011</td>
</tr>
<tr>
<td>Country</td>
<td>Prevalence or number of infected pigs in controlled system per year</td>
<td>Prevalence or number of infected pigs in non-controlled systems</td>
<td>Ref period</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Poland</td>
<td>0.0/20 million</td>
<td>342</td>
<td>2001-2011</td>
</tr>
<tr>
<td>Macedonia</td>
<td>0.0/0.1 million</td>
<td>0.0</td>
<td>2000-2003</td>
</tr>
<tr>
<td>Montenegro</td>
<td>0.0/0.05 million</td>
<td>26-42/year</td>
<td>2000-2003</td>
</tr>
<tr>
<td>Romania</td>
<td>0.0/3.0 million</td>
<td>416/year</td>
<td>2007-2011</td>
</tr>
<tr>
<td>Serbia</td>
<td>0.0/1.7 million</td>
<td>461-2554/year</td>
<td>2003-2011</td>
</tr>
<tr>
<td>Slovakia</td>
<td>0.0/0.8 million</td>
<td>sporadic reports</td>
<td>2000-2011</td>
</tr>
<tr>
<td>Spain</td>
<td>0.0/38 million</td>
<td>160/9,000/year</td>
<td>2004-2008</td>
</tr>
<tr>
<td>Argentina</td>
<td>0.0/1.5 million</td>
<td>100/1 million</td>
<td>last 4 years</td>
</tr>
<tr>
<td>Canada</td>
<td>0.0/30,000 tested</td>
<td></td>
<td>last 5 years</td>
</tr>
<tr>
<td>Chile</td>
<td>287/56 million tested in 12 years</td>
<td></td>
<td>last 12 years</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.0/10 million</td>
<td>0.0-0.002/5 million</td>
<td>last 20 years</td>
</tr>
<tr>
<td>US</td>
<td>0.0/85 million</td>
<td>10-20/15 million</td>
<td>last 10 years</td>
</tr>
</tbody>
</table>
Rearing practices involved in transmission of *Trichinella* to pigs

- Feed on wild animal carcasses
  - hunters who leave animal carcasses in the field after skinning, or remove and discard the entrails, or disposed of in dumps
  - hunters who feed pigs with animal carcasses
  - road-killed wild animals
- Introduction of new pigs on a farm without any information on the farm of origin and previous farming conditions
- Cannibalism due to a high mortality rate
- Feed on garbage containing pork or wild animal scraps
- Feed on pork scraps from pigs slaughtered at the farm
- Feed on carcasses or scraps from farmed fur animals (both mammals and reptiles)
- Feed on rats
- Feed origin and right daily feed intake not always controlled
- Lack of mechanical barriers to prevent entry of synanthropic and wild animals (both mammals and birds) into the pigsty
Measures to prevent infection in domestic pig herds kept under controlled management conditions - 1

- Prevention of infection is dependent on minimizing exposure to potential sources of *Trichinella*:
  - facilities and the surrounding environment should be managed to prevent exposure of pigs to rodents and wildlife
  - raw food waste of animal origin should not be present at the farm level
  - feed should be stored in a manner to prevent access by rodents and wildlife
- a rodent control program should be in place
- dead animals should be immediately removed and disposed of
- introduced pigs should originate from herds officially recognized as being under controlled management conditions, or from herds of a compartment with a negligible risk of *Trichinella* infection

The Veterinary Authority may officially recognize pig herds as being under controlled management conditions if:

- all management practices are complied with and recorded
- visits by approved auditors have been made periodically to verify compliance with good management practices
- the frequency of inspections should be risk-based, taking into account historical information, slaughterhouse monitoring results, knowledge of established farm management practices and the presence of susceptible wildlife
- a subsequent program of audits is conducted

Prerequisite criteria for the establishment of compartments with a negligible risk of *Trichinella* infection in domestic pigs kept under controlled management conditions

- Compartments with a negligible risk of *Trichinella* infection in domestic pigs kept under controlled management conditions can only be established in countries, in which the following criteria, as applicable, are met:
  - *Trichinella* infection is notifiable in the whole territory and communication procedures on the occurrence of the infection are established between the Veterinary Authority and the public health authority
  - the Veterinary Authority has knowledge of, and authority over, all domestic pigs
  - the Veterinary Authority has knowledge of the distribution of susceptible species of wildlife
  - an animal identification and animal traceability system for pigs is implemented
  - Veterinary Services have the capability to assess the epidemiological situation, detect the presence of *Trichinella* infection (including genotype, if relevant) in domestic pigs and identify exposure pathways

Measures to prevent infection in domestic pig herds kept under controlled management conditions

Compartment with a negligible risk of *Trichinella* infection in domestic pigs kept under controlled management conditions

• Veterinary Authority may recognize a compartment as having negligible risk of *Trichinella* infection in domestic pigs kept under controlled management conditions, if the following conditions are met:
  – all herds of the compartment are kept under controlled management conditions for at least 24 months
  – the absence of *Trichinella* infection in the compartment has been demonstrated by a surveillance program which takes into account current and historical information, and slaughterhouse monitoring results, as appropriate
  – once a compartment is established, a subsequent program of audits of all herds within the compartment is in place
  – if an audit identifies a lack of compliance and the Veterinary Authority determines this to be a significant breach of biosecurity, the herd(s) concerned should be removed from the compartment until compliance is re-established

Trichinella in pigs and wildlife
Concluding remarks

• funds and efforts for the control of *Trichinella* in pigs should be moved from controlled to non-controlled management conditions

• the control of backyard and free-ranging pigs will reach a double result
  – the consumer protection
  – the collection of epidemiological information (sentinel animals)

• public health services should promote consumers’, hunters’, and farmers’ education
Thank you for your attention