Mapping protocol for *Taenia solium*: identification of endemic and high-risk areas

The mapping tool for *Taenia solium* has three companion elements:

- this document, the Mapping Protocol;
- an Excel document, the Risk Classification Tool; and
- a video with stepwise guidance on the Mapping Protocol and the Risk Classification Tool.

1. **Background and purpose**

Taeniasis and cysticercosis are neglected tropical diseases caused by infection with the parasite *Taenia solium* and are included in WHO’s new road map, with targets set for their intensified control by 2030 (1). Taeniasis and cysticercosis are zoonotic diseases, and the life cycle of the parasite involves humans and pigs.

In humans, cysticercosis in the central nervous system (neurocysticercosis) is the main cause of acquired epilepsy in many low-income countries. Taeniasis and cysticercosis are recognized as the leading cause of death among all foodborne parasitic diseases; the global burden of disease was estimated to be approximately 2.8 million DALYs (disability-adjusted life-years) in 2015 (2). However, these estimates may be low due to limited data. The impact of taeniasis and cysticercosis also includes social costs, as people with epilepsy suffer discrimination and stigma, as well as economic costs associated with the treatment of infected people and their ability to work. In some circumstances, economic costs are associated with the loss of an infected pig’s value (3–8).

Despite the burden that *T. solium* imposes on affected communities, there are very few active programmes to control the diseases the parasite causes. The first step in any neglected disease control programme is usually to identify affected areas and local prevalence in order to prioritize resources. Many countries or control programmes have difficulties with this first step. The aim of this protocol is to assist affected countries and interested stakeholders in mapping *T. solium* and identifying endemic and high-risk areas.

WHO recognizes *T. solium* taeniasis and cysticercosis as a neglected tropical disease. This means data and information are likely to be scarce and there are information gaps. This protocol is designed with these factors in mind while providing a pragmatic approach.

2. **Mapping process**

The objective of mapping is to identify areas endemic for *T. solium*, that is areas with the presence (or likely presence) of the full life cycle of *T. solium*. If the endemic areas are not known, the mapping process begins by identifying (i) areas with the presence of the disease and (ii) high-risk areas based on the presence of key risk factors.

Mapping involves actively searching for and gathering information which indicates or suggests that the infection is being actively transmitted by the parasite in a particular area. The information available for *T. solium* endemicity will often be incomplete. Mapping is like putting together the different pieces of a jigsaw puzzle to build a complete picture. The more pieces of information that are available and can be put together, the better the picture will be.

The mapping of *T. solium* involves four steps as shown in Fig. 1.
Steps 1–3 can be conducted as a desk review and can conclude with a preliminary map. *T. solium* is highly focal, so it might be necessary to begin the exercise at a certain administrative level, for example district, and then repeat it within that administrative level, for example at subdistrict or municipality level. Irrespective of the target administrative unit (province, district, subdistrict, municipality, etc.), the mapping process and steps are the same.

**STEP 1: Collect the information**

Two types of information can be gathered: (i) disease data and (ii) key risk factors.

(i) **Disease data**

This is information about the diseases caused by *T. solium*: taeniasis and cysticercosis in humans (a and c); and cysticercosis in pigs (b).

a) **Taeniasis** results from infection with the adult tapeworm in humans. It is acquired when people eat raw or undercooked infected pork containing viable *T. solium* cysticerci (larvae), which develop within the intestine into an adult tapeworm. Taeniasis due to *T. solium* is usually asymptomatic or characterized by mild, non-specific symptoms such as abdominal pain, nausea, diarrhoea or constipation.

Human taeniasis can be diagnosed by microscopy techniques (such as Kato–Katz), copro-antigen, serology or molecular tests. Importantly, many tests are not species-specific and do not differentiate *T. solium* from the related parasites *T. saginata* (beef tapeworm) or *T. asiatica* (Asian tapeworm). When mapping, it is therefore imperative to note whether the test used was species-specific or not. Neither *T. saginata* nor *T. asiatica* produces neurocysticercosis and, while relevant for the individual, they are not important public health problems.

b) **Porcine cysticercosis**, or cysticercosis in pigs, results from infection with the larval cysts of *T. solium*. Pigs become infected by ingesting tapeworm eggs or proglottids released in the faeces of a human infected with a *T. solium* tapeworm (Fig. 2). It is transmitted in places where pigs...
roam freely and have access to human faeces. The ingested tapeworm eggs develop into larvae, which encyst mainly in the muscles. When people eat these cysticerci in raw or undercooked pork, they develop a tapeworm. Transmission of the parasite through pigs is necessary for it to complete its life cycle.

Pigs with porcine cysticercosis usually do not show clinical signs. Porcine cysticercosis can be diagnosed by tongue inspection (but only heavily infected animals will show cysts in their tongues), serology (which has proven to be not very specific), and necropsy with carcass dissection for the identification of cysts.

c) **Human cysticercosis (including neurocysticercosis)** results when humans ingest *T. solium* eggs via the fecal-oral route, or by ingesting food or water contaminated with eggs evacuated in human faeces infected with *T. solium* tapeworms (Fig. 3). The ingested eggs develop into larvae, which can encyst mainly in the central nervous system (known as neurocysticercosis), but also in the muscles, skin or eyes. Neurocysticercosis is the most important human disease caused by *T. solium* and is the main cause of acquired epilepsy in endemic countries. Human cysticercosis can be diagnosed by serology, imaging or a combination of both techniques.

Typically, there is a period of years (months to decades) between infection and onset of signs, so neurocysticercosis is not an indication of recent infection and an active transmission cycle because infected patients may have acquired the infection some years ago or in a different place. Approximately 80% of infected people present clinical signs within 7 years (9). However, neurocysticercosis can be indicative of the presence of the disease in the area, so this should be considered.

When humans get infected with the larval stage and develop cysticercosis, that is the end of the cycle as their tissues would not be consumed by other people to cause taeniasis.

Many cases of neurocysticercosis are diagnosed in referral hospitals or specialized centres, so reports might not necessarily reflect where people acquired the disease.

It may be difficult to obtain data on neurocysticercosis, but proxy indicators such as epilepsy can be used.

**Fig. 3. T. solium life cycle**
(development of neurocysticercosis)

The presence of *T. solium* taeniasis and porcine cysticercosis are indicative of active transmission, especially if these occur in the same area.

(ii) **Key risk factors**

The key risk factors for *T. solium* are the presence of backyard pigs roaming free in conjunction with poor sanitation. Without pigs there can be no active cycle. Where pigs are present but have no access to human faeces or items contaminated by human faeces, there can be no active cycle.
The presence of free-roaming backyard pigs is a high risk factor for acquiring *T. solium* infection. For example, in some areas, pigs may be confined when they reach a certain value, but they might roam free as piglets and may become infected at that stage in their life. In some areas, pigs might be confined during harvest, but not at other times of the year. All pigs that at some point have been allowed to roam free and might have had contact with human faeces are a risk.

Deficient sanitation includes areas in which open defecation is practiced, but also areas in which latrines are not used by the entire family, or at all times (for example, latrines distant from the house might not be used at night; if they are near the house, they might not be used during the day when people work in the fields). Latrines which allow waste to be accessed by pigs are also a risk for *T. solium*.

**Sources of information**

Information relating to taeniasis and cysticercosis and associated risk factors can be obtained from reports of the Ministry of Health and the Ministry of Livestock (or equivalent), scientific publications (peer reviewed and grey literature), PhD and MSc theses, and nongovernmental organizations, among others. Additional sources are shown in Table 1.

**Table 1. Useful information for the identification of areas of high-risk for *T. solium* endemcity**

<table>
<thead>
<tr>
<th>Type of information</th>
<th>Source of information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Disease data</td>
<td></td>
</tr>
<tr>
<td>Disease in humans</td>
<td>1. Taeniasis</td>
</tr>
<tr>
<td></td>
<td>2. Neurocysticercosis/epilepsy</td>
</tr>
<tr>
<td>Disease in pigs</td>
<td>3. Porcine cysticercosis</td>
</tr>
<tr>
<td>2. Risk factors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Backyard pigs* – areas where pigs roam free (at least during certain periods of the year)</td>
</tr>
<tr>
<td></td>
<td>2. Open defecation* – areas with absent or insufficient basic sanitation infrastructure</td>
</tr>
</tbody>
</table>

* These risk factors must be present simultaneously: the presence of backyard pigs is relevant only if pigs have access to human faeces; open defecation is relevant only if pigs have access to human faeces.

**Who can collect the information?**

Ideally, the information should be collected by someone with a basic understanding of biology and the *T. solium* life cycle. The most important attribute is someone who can search for information proactively and ask for guidance when needed. This could be done, for example, by a recent graduate or an advanced student of medicine, public health, veterinary, One Health or a related discipline. Information may also be collected as a team, for example one person focusing on the human data, and the other person on animal data.
STEP 2: Organize the information

An Excel-based tool, the Risk Classification Tool, has been created to assist with steps 2 and 3. The tool is available from WHO website:

https://apps.who.int/neglected_diseases/nttdata/forms/taenia/en/mapping_tsolium_v1.xlsm

- The first page of the Tool is the INTRO (Fig. 4). The top of the page includes the background and a summary of the mapping process. The middle of the page has a section with instructions on how to complete the Tool and summarizes what is presented here in the Mapping Protocol.

Fig. 4. INTRO page of the Risk Classification Tool

The Excel document has cells shaded in three colours:

- White - cell is not protected. Enter the value requested
- Orange - cell is not protected and includes a drop-down menu.
- Blue - cell is protected and includes formula. No data entry required.
The bottom section of the page collects basic data, which need to be entered before proceeding to the next steps:

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>How many administrative units (at the lower level) you want to map?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Name of person filling the mapping tool</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Date report</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Year** This is the year for which you are completing the Risk Classification Tool.

**How many administrative units (at the lower level) you want to map?** This question asks for the number of administrative units that you want to map (provinces, regions, districts, etc.). This figure is used to generate rows in the form where you will enter the data on disease and risk factors. Here is an example of how the number of administrative units might be determined:

- if in a country with 5 provinces it is decided to map all the provinces (at province level), the number of administrative units would be 5;
- if it was decided to map one province (or region/state) with 10 districts, and to map all the districts of that province, the number of administrative units would be 10;
- if it was decided to map the districts of 3 provinces, the number of administrative units would be the sum of the districts in those provinces, e.g.:
  - province A: 5 districts
  - province B: 2 districts
  - province C: 10 districts
  TOTAL: 17 districts

- Once the country data have been completed, you need to click on “Generate form”, on the bottom right-hand corner.
- Two more pages will appear. One is called MAPPING and the other CRITERIA_INFO. You will automatically be redirected to the MAPPING page (Fig. 5).
- In the MAPPING page, row 2 will contain the data you entered in the INTRO page. The number of rows in the table will be the number of administrative levels you entered. The columns will correspond to the names of the administrative units (columns A and B), the diseases and risk factors associated with *T. solium* as per Table 1 (columns C–H), the risk level (column I) and notes/comments (column J). Note that there are two columns for taeniasis: column D (when *T. solium* has been confirmed) and column E (when the species of *Taenia* has not been confirmed).

**Fig. 5. MAPPING page of the Risk Classification Tool**
• Entering data in the MAPPING page (Fig. 6):
  1. Enter the name of the administrative units in columns A and B.
  2. Based on the information obtained in Step 1, for each administrative level, select for each disease and risk factor (columns C–H) one of the following options from the dropdown menu (or you can leave any cell blank):
    a. YES (if the disease or risk factor has been recently confirmed*)
    b. NO (if the disease or risk factors are not present)
    c. UNKNOWN

* “Recent” can be defined as occurring within the past 5 years (or more if you think the conditions have not changed). This is a subjective definition that can be changed or adapted to local circumstances.

Fig. 6. Entering data using the dropdown menu

Considerations:
  a) It is important that porcine cysticercosis is in local pigs that have been born and reared in the area (and not simply imported from another area).
  b) Sometimes there might be evidence of epilepsy but not specifically neurocysticercosis. If the risk factors are present, you could consider entering “YES” for neurocysticercosis.
  c) Column J can be used to enter your own notes or comments (such as the source of information).

STEP 3: Classify the areas by risk

Once data on the presence of disease or risk factors have been entered, then risk can be assessed. To facilitate the assessment, a classification from 1 to 6 has been developed:

1 and 2 – High risk: evidence or high likelihood of active transmission
3 and 4 – Moderate risk: indication or potential active transmission
5 and 6 – Lower risk: active transmission may or may not be present

1. The Risk Classification Tool automatically defines the risk for the different combinations of diseases and risk factors. Click on “Define risk level” and the risk level in column I will be automatically filled (Fig. 7).
   • If you would like to clear the risk level, click on “Clear risk level” (the button below “Define risk level”). Note that all comments will be deleted.
   • It is possible to “Clear risk level” and “Define risk level” multiple times.
   • If you want to update the risk classification (for example because more information is available), there is no need to clear the risk classification first; you can simply click on “Define risk level” again, and the risk will be updated with the new information and your comments will be maintained.
2. The data can be sorted by risk level by clicking on “Sort by risk” (Fig. 8).
   • Note that there is no prioritization within each category.

Fig. 8. Ordering the areas by risk order

3. The data can also be sorted alphabetically by clicking on “Sort alphabetically” (the button below “Sort by risk”).
   • Once you have sorted the data by risk or alphabetically, it is not possible to sort the data as you originally entered them (unless you did it alphabetically). However, you can change between “Sort by risk” and “Sort alphabetically” multiple times.

4. Save the document in the Excel format in your preferred location using the button “Save in Excel”. The file will automatically be named using the information you entered in the INTRO page.

5. You can also print the mapping table using the usual Excel menu.

How is risk classified?

Risk is classified by using a Risk Criteria Table. This table defines an overall level of risk for different combinations of diseases and risk factors in a particular area. Table 2 presents some combinations of disease and risk factors, which illustrate how the risk level is determined, as well as some comments which explain some of the reasoning behind the levels of risk that are assigned to the combinations.

• Note that not every permutation of disease and risk factors is either likely or represented. The table includes the most likely scenarios.

• Some information may supersede other information. For example, in the first row, if porcine cysticercosis is present, the other diseases and risk factors might or might not be present or confirmed, but the single fact that porcine cysticercosis is present in local pigs indicates that there is active transmission, and that it is a high-risk area.

• The table is included in the Risk Classification Tool in the page CRITERIA_INFO, and it is provided for information only.
Because information about *T. solium* is likely to be scarce, the use of a Risk Criteria Table was preferred over other methods that may add complexity, include more assumptions and have other limitations.

**Table 2. The Risk Criteria Table for *T. solium* explains how risk is classified**

<table>
<thead>
<tr>
<th>Disease</th>
<th>Risk factors</th>
<th>Risk level</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porcine cysticercosis</td>
<td>Yes</td>
<td>1</td>
<td>T. saginata, indicates active transmission present</td>
</tr>
<tr>
<td>Taeniasis by <em>T. solium</em></td>
<td>0</td>
<td>1</td>
<td>Presence of backyard pigs not confirmed (but likely)</td>
</tr>
<tr>
<td>Neurocysticercosis</td>
<td>0</td>
<td>2</td>
<td>Maybe still open defecation in fields or latrines not used</td>
</tr>
<tr>
<td>Open defecation</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Backyard pigs common</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>?</td>
<td>3</td>
<td>Could be <em>T. saginata</em></td>
</tr>
<tr>
<td>Yes</td>
<td>?</td>
<td>4</td>
<td><em>T. solium</em> might not be necessarily present</td>
</tr>
<tr>
<td>Yes</td>
<td>?</td>
<td>5</td>
<td><em>T. solium</em> could have been acquired somewhere else</td>
</tr>
<tr>
<td>Yes</td>
<td>?</td>
<td>6</td>
<td>Could be <em>T. saginata</em></td>
</tr>
<tr>
<td>Yes</td>
<td>?</td>
<td>6</td>
<td>Presumed porcine cysticercosis in imported pigs or pork</td>
</tr>
<tr>
<td>Yes</td>
<td>0</td>
<td>6</td>
<td>Insufficient information to classify risk</td>
</tr>
<tr>
<td>Yes</td>
<td>0</td>
<td>6</td>
<td>Insufficient information to classify risk</td>
</tr>
<tr>
<td>Yes</td>
<td>?</td>
<td>6</td>
<td>Insufficient information to classify risk</td>
</tr>
</tbody>
</table>

Ø: “Might be present” means that the disease or risk factors might be present or not. Either way, it does not change the risk classification.

**Presenting the information in a map:**
Once the administrative units have been classified in the different risk levels, you may then choose to represent your classification in a map. A fictitious example is shown in Fig. 9. (Note: you would have to create your own map – it is not provided by this tool).

**Mapping at different administrative levels:**
Remember that mapping can be undertaken at different administrative levels:
- in some instances, you might want to start at country level to identify provinces, and then repeat the exercise within provinces to identify districts;
- or you might want to do it at district level, and then repeat at municipality level;
- it depends on the objectives that you set up when doing the mapping.

**Fig. 9. Example of how risk areas for *T. solium* can be mapped**

Mapping *T. solium* is not difficult, but it requires time, patience and proactively searching for information.
STEP 4: Confirm endemicity

If the data compiled for a specific area are recent and conclusive, there may be no need to confirm endemicity. However, if that is not the case, and active and recent transmission of the parasite is suspected but not confirmed, then the next step is to confirm the active transmission.

It is important to confirm the active transmission of *T. solium* before starting a control programme. This can be done by demonstrating the presence of local cases of *T. solium* taeniasis in humans or local cases of porcine cysticercosis, as they indicate an active transmission cycle.

Further details on the available tests and suggested thresholds are included in the report of a WHO meeting of experts [10]. The main conclusions of the meeting were:

1. Currently available diagnostic tests are not well-suited for use in public health programmes. Most tests are not commercially available (or are available only for research use) or are not affordable to programmes in low- and middle-income countries. Many tests are not adequate in terms of sensitivity and/or species specificity.

2. Currently, there are limited diagnostic options for mapping and monitoring *T. solium* programmes, namely:
   - In humans
     - Microscopy: microscopy techniques are not sensitive and not species-specific, so should be followed by *Taenia* species confirmation by purging (treating *Taenia*-positive persons to recover worms) and parasite identification or molecular methods. If these methods are not available, demonstrating the presence of *T. solium* cysticercosis in pigs can serve as a confirmatory method of the presence of the transmission cycle.
   - In pigs (always in local born and reared pigs)
     - Tongue palpation (in pigs over 4 months of age). This technique has a low sensitivity, especially in animals with light infections.
     - Enhanced meat inspection: incision of the *T. solium* preferred locations (i.e., the masseter muscles, triceps brachii muscles, tongue, heart and diaphragm). This technique has a low sensitivity (though substantially higher than tongue palpation), especially in animals with light infections.

3. All of the available options have important limitations regarding sensitivity, so it is essential that an adequate sample size be used in the context of a programmatic survey.

4. Given the low sensitivity of available tests, even a weak signal should warrant a public health response, either in terms of treatment or further investigation. Therefore, the suggested prevalence threshold to start a programme is ≥ 0.5% in humans or ≥ 2% in pigs.

Fig. 10 summarizes the suggested flow for confirmation of endemicity in an area that would trigger a public health programme or response. The starting point should be suspicion of disease caused by *T. solium* or the presence of both key risk factors: roaming pigs and deficient sanitation. A survey using either option should be sufficiently powered to detect a low prevalence of infection and should use purposive sampling among high-risk populations. For more details, please refer to the source document (10).
3. Next steps

It is very likely that the information collected is limited and therefore some areas might not have been classified properly. It is important to continue to gather information and update the risk level accordingly. For example:

- if the species of *Taenia* has not been confirmed, efforts should be made to define the species present in the area;
- try to confirm the presence of the risk factors; and
- set up surveys if necessary.

Prioritize the areas in which information should be gathered, for example areas with risk level 2, or areas surrounded by areas of high risk.

The most important next step is to start control programmes in the areas where there is active transmission of *T. solium*.

Feedback and suggestions

Please send your feedback and suggestions to the WHO Department of Control of Neglected Tropical Diseases (neglected.diseases@who.int) and Dr Bernadette Abela-Ridder (abelab@who.int). Your feedback is very important to ensure that we continue to develop and improve this protocol.
References


Acknowledgements

Bernadette Abela (WHO Department of Control of Neglected Tropical Diseases [WHO/NTD]), Ana Lucianez (Pan American Health Organization/WHO Regional Office for the Americas [PAHO/WHO]), Alexei Mikhailov (WHO/NTD), Pauline Mwinzi (WHO Regional Office for Africa), Santiago Nicholls (PAHO/WHO), Aya Yajima (WHO Regional Office for the Western Pacific), Meritxell Donadeu (Consultant).

Department of Control of Neglected Tropical Diseases
World Health Organization
Avenue Appia 20, 1211 Geneva 27 Switzerland

Mapping protocol for *Taenia solium*: identification of endemic and high-risk areas
ISBN 978-92-4-007634-1 (print version)

© World Health Organization 2023. Some rights reserved. This work is available under the CC BY-NC-SA 3.0 IGO licence.