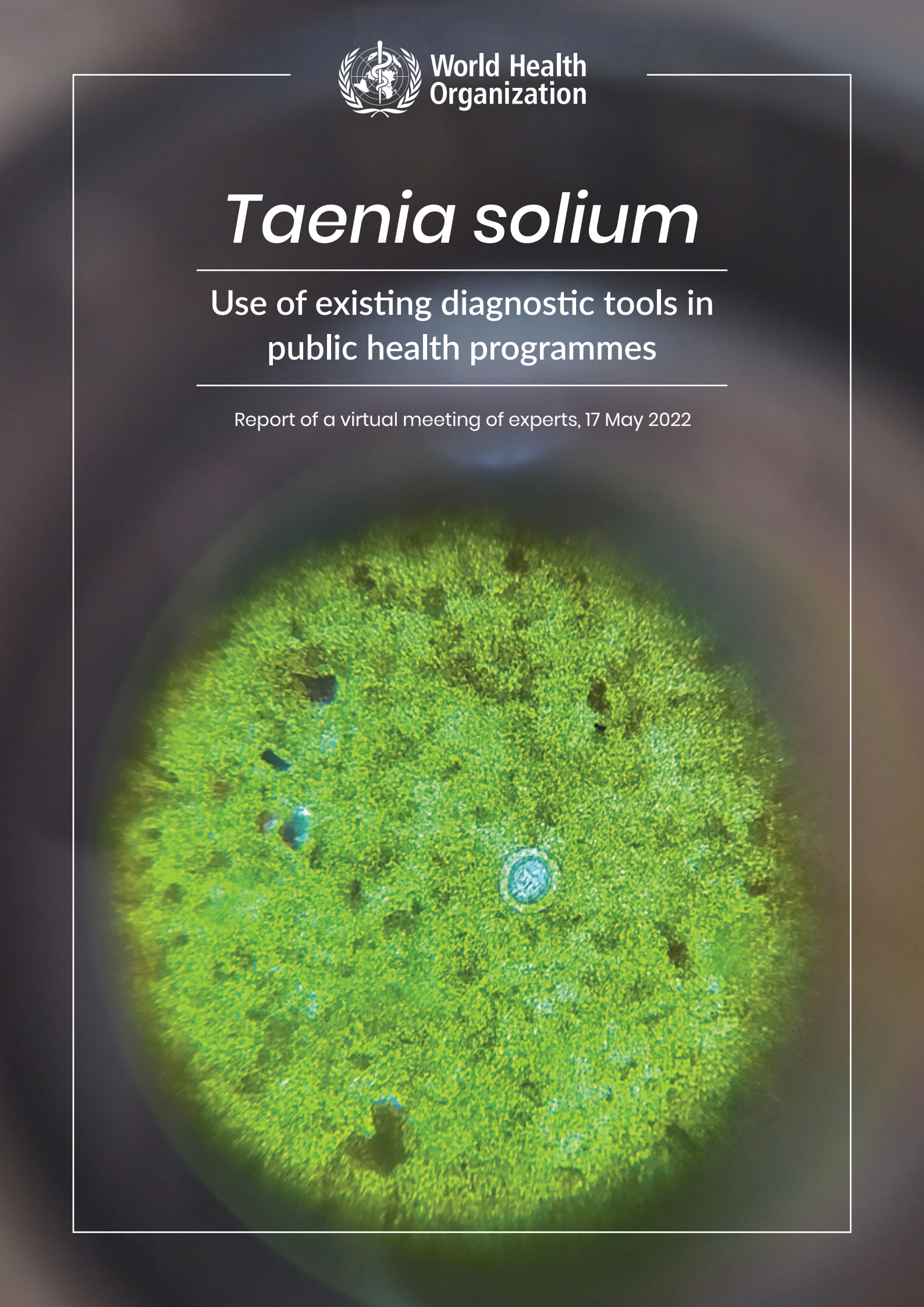
World Health Organization

Taenia solium

Use of existing diagnostic tools in public health programmes

Report of a virtual meeting of experts, 17 May 2022



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1. Meeting objectives

The World Health Organization (WHO) convened a virtual meeting of experts on 17 May 2022 to review existing diagnostic tools for *Taenia solium*, which can be used to provide evidence to support the decision to implement public health programmes to control diseases caused by *T. solium*. The participants are listed in the Annex. All invited experts and observers completed the WHO conflict of interest and confidentiality forms. No conflicts were identified. The outcome of this review will inform the development of a *T. solium* monitoring and evaluation framework.

The specific meeting objectives were:

1. To evaluate the key characteristics (sensitivity, specificity, commercial availability and affordability) of the existing diagnostic tools for *T. solium* in both humans and pigs that could be used to determine whether infection prevalence exceeds a defined threshold in population-based surveys;

2. To describe the usefulness of the tools for mapping and monitoring, with consideration for survey setting, age group and sample size; and

3. To identify immediate priorities for *T. solium* test development for public health programmes.

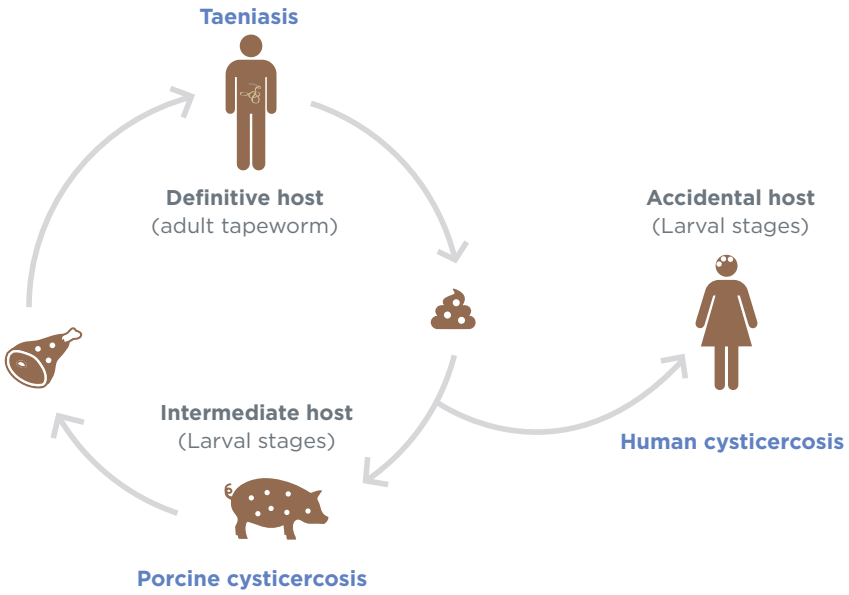
2. Background

Taeniasis and cysticercosis caused by the parasite *T. solium* affect vulnerable populations, mainly in Latin America, sub-Saharan Africa and Asia, where pigs (the intermediate host) roam free and poor sanitation allows pigs access to human faeces.

Human taeniasis is usually asymptomatic, but cysticercosis can lead to neurocysticercosis, which manifests as seizures and epilepsy, and can be fatal (Fig. 1). Pigs usually do not show any clinical signs of infection, but heavily infected pigs can harbour larval cysts in their tongues.

Taeniasis and cysticercosis were added to WHO's list of neglected tropical diseases in 2010. Since then, progress in controlling the diseases has been slow, mainly due to a lack of adequate diagnostics, control tools and knowledge. Recently, however, new tools and guidance have become available including the Bayer donation of taenicidal medicines (praziquantel and niclosamide), the Pan American Health Organization/*WHO Guidelines for preventive chemotherapy to for the control* of T. solium *taeniasis* (1), the WHO *Guidelines on management of* T. solium *neurocysticercosis* (2), the commercial availability of the TSOL18 vaccine (and its inclusion in the World Organisation for Animal Health Terrestrial Manual (3)) and the use of the vaccine in conjunction with oxfendazole in pigs, as well as results from an increasing number of field studies evaluating control interventions.

Figure 1. *T. solium* transmission cycle



Several countries are ready to begin implementation of public health programmes for the control of *T. solium* and are requesting WHO to provide specific guidance on which diagnostic tools should be used and overall guidance on monitoring and evaluation. Currently, there is inadequate evidence available to support the development of formal WHO guidelines; however, there is an urgent need to provide interim guidance to countries. Therefore, the conclusions outlined below are meant to fill this urgent need and serve as the basis for generating evidence that can be used to support more formal WHO recommendations.

3. Methodology

Technical experts in *T. solium* were requested to provide information and supporting evidence related to the performance and feasibility of existing *T. solium* diagnostic tests in humans or pigs. The aim was to understand the potential use of these tests to support mapping and programme monitoring. A literature review, peer-reviewed publications, and unpublished data were assembled by the experts as background to the meeting. Experts were requested to provide inputs on ease of use, commercial availability and affordability in low- and middle-income countries. The responses were compiled by the secretariat, summarized and circulated before the meeting on 17 May 2022. During the virtual meeting, the compiled evidence and information were reviewed by the experts. This report provides conclusions, next steps and future considerations for the use of identified diagnostic tests to support public health programmes.

The following tests were considered.

	Sample	Tests considered
Human taeniasis	Stools	Microscopy, Copro-antigen, Copro-PCR
	Serum	ELISA, Immunoblot, LFAs, Multiplex bead assay
Human cysticercosis	Serum	Antibodies: ELISA, LFA, Multiplex bead assay, EITB Antigen: ELISA
Porcine cysticercosis	—	Tongue palpation, meat inspection
		Antibodies: ELISA, EITB Antigen: ELISA

EITB: enzyme-linked immunoelectrotransfer blot; ELISA: enzyme-linked immunosorbent assay; LFA: lateral flow assay.

4. Meeting conclusions and next steps

Conclusions

1. Currently available diagnostic tests are not well-suited for use in public health programmes. Thus, there is an urgent need to develop improved diagnostics to support programmatic decision-making.

- 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.
  - Serology for porcine cysticercosis is currently not an appropriate choice due to concerns with the specificity of available tests.

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.

- The surveys should be fit for purpose, taking into account the implementation unit, whether a specific community/village or a wider geographical area.
- Purposive sampling should be used to target high-risk humans and pigs:
  - Humans: people who live in close contact with the pigs where sanitation is lacking or inadequate
  - Pigs: pigs that have been roaming free at some point of their lives in settings where sanitation is lacking or inadequate
- Estimated sensitivity:
  - Microscopy: 33–50% (estimate based on limited data)
  - Tongue inspection:
    - < 100 cysts: 0–2.7%
    - > 100 cysts: 16–70%
  - (Enhanced) meat inspection: 22–95%

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.

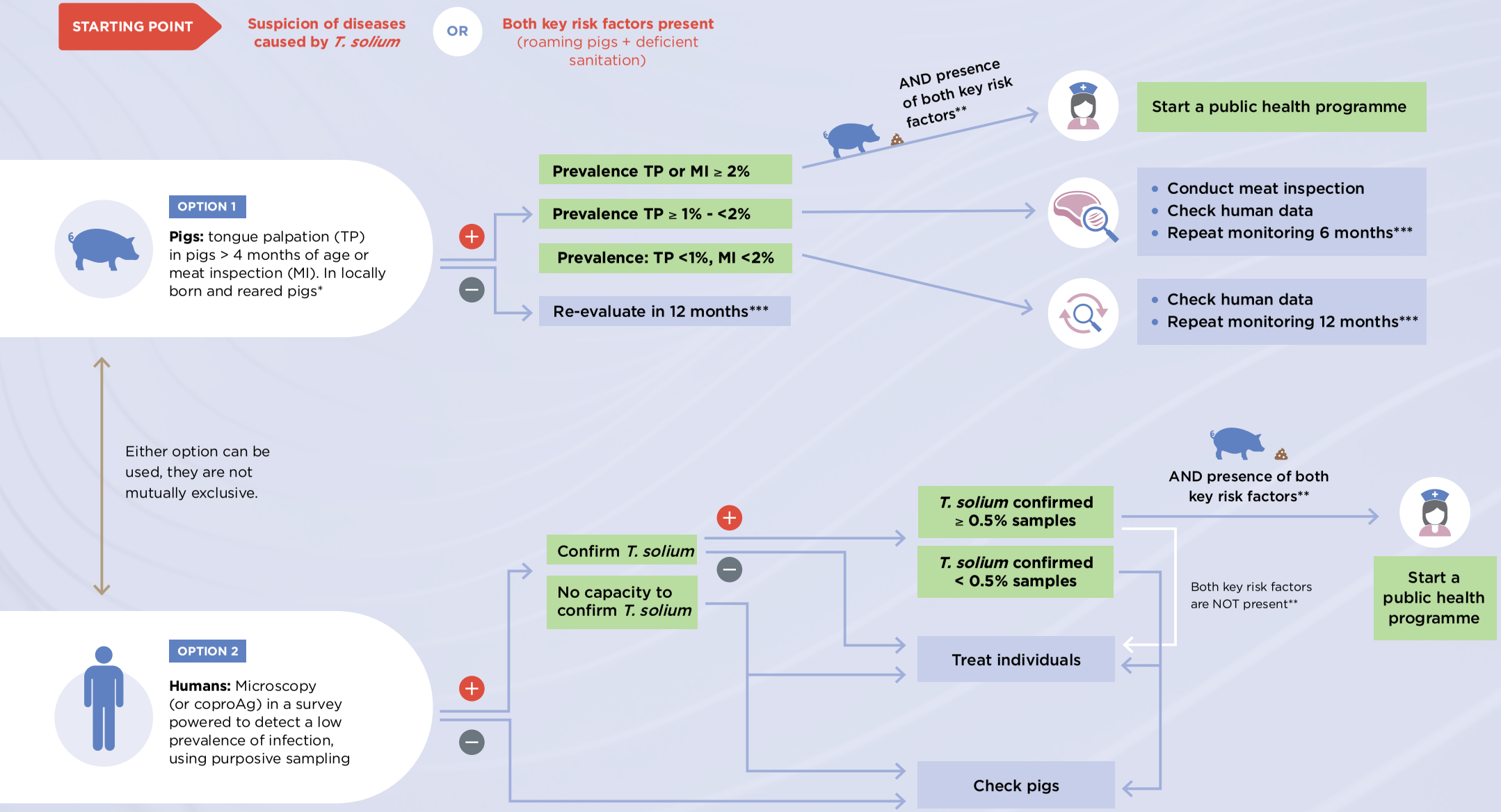
    - Kato–Katz stool examinations are used routinely in many countries and can be used to demonstrate *Taenia* spp. infections in humans.

    - Prevalence of porcine cysticercosis is usually much higher than prevalence of taeniasis, so testing pigs is advantageous due to the requirement for a smaller sample size; in addition, the presence of infection in pigs of slaughter age is indicative of recent infection. When using tongue palpation or enhanced meat inspection, it is essential to use trained and experienced staff. In a small population where only one positive animal represents the suggested threshold, it is advisable to increase the sample size or use other methods to confirm the presence of active transmission. A threshold of 1% in tongue palpation and 2% in meat inspection would represent a true prevalence of porcine cysticercosis of 10% (assuming an estimated sensitivity of 10% for tongue palpation, and 20% for meat inspection).

        - Public health action (preventive chemotherapy) should be triggered by documentation of the full transmission cycle of *T. solium*, i.e. by confirming *T. solium* taeniasis and the presence of both key risk factors (i.e. roaming pigs and deficient sanitation) or by demonstrating the presence of porcine cysticercosis. Priority should be given to the areas with higher suspected prevalence.

Fig. 2 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. Two suggested options are provided, although these are not the only options, and they are not meant to be mutually exclusive. The thresholds suggested are intended to be conservative and reflect the low sensitivity of current diagnostic approaches; they will be reviewed as more evidence is gathered. 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.

Fig. 2. Suggested flow to trigger a *T. solium* public health intervention



* Infected meat should not enter the meat chain and should follow local legislation. Tongue positive pigs should be treated with oxfendazole. If pigs are not locally born and reared, further investigations are needed.

** If both key risk factors are not present (roaming pigs + deficient sanitation), then active transmission cycle is not occurring. Infection might be sporadic or imported.

*** Repeating at 6-12 months interval will represent a new cohort of pigs. A repeat positive finding at similar levels, indicates low transmission and a public health program should be considered.

5. The existing tests may not be adequate for monitoring public health control programmes to control *T. solium*. The following should be considered for monitoring:

a) The prevalence of *T. solium* infection (in humans and/or pigs) as assessed through mapping surveys may be used as baseline.

b) In settings where baseline prevalence of *T. solium* taeniasis or porcine cysticercosis is high (e.g. ≥ 5%), it may be possible to design monitoring surveys that are adequately powered to detect a change in prevalence from baseline.

c) If the baseline prevalence, especially of *T. solium* taeniasis, is very low, it may not be possible to power surveys to detect changes in prevalence. In these settings, monitoring surveys might only be able to identify presence or non-detection of the parasite, rather than detecting change over time.

d) Collection and storage of samples (preserved stool or proglottids, serum or dried blood spots) from cross-sectional surveys in sentinel sites might provide an opportunity to establish baseline prevalence retrospectively, when new tools are developed.

Next steps

1. Update the current target product profiles (TPPs). The existing TPPs for *T. solium* diagnostics in humans and pigs were published in 2017 (4) and should be reviewed and updated as necessary.

2. The Kato–Katz test, even if not ideal (due to sensitivity or use in non-representative populations, i.e. children), provides an opportunity for synergies with other programmes such as for schistosomiasis, soil-transmitted helminthiases and foodborne trematodiases, which use this test routinely. However, *T. solium* eggs are small compared to other helminths, and technicians might not be familiar with their identification.

a) In areas endemic for *T. solium*, a refresher training course should be provided to technicians conducting Kato–Katz test for other programmes so they become familiar with identification of *T. solium* eggs (consider also training for foodborne trematodes in co-endemic areas).

b) The Kato–Katz test should be conducted on two slides per sample. It may be possible to improve the sensitivity of Kato-Katz testing by having technicians re-read slides and focus exclusively on *Taenia*.

c) If only evaluating *Taenia*, the Kato test could be used instead of the Kato–Katz test, which uses a larger sample and is easier to conduct.

d) WHO Collaborating Centres and other institutions could assist with the microscopy training.

3. Promote One Health activities that encourage the reporting of porcine *T. solium* cysticercosis including: training of animal health technicians and meat inspectors, environmental health technicians, setting-up mechanisms for notification of porcine cysticercosis, and collaboration between the Veterinary Services from the Ministry of Livestock (or equivalent) and the Ministry of Health.

4. Additional work is needed to translate the diagnostics approaches reviewed as part of this meeting into operational guidance for country programmes. WHO should convene experts on monitoring and evaluation to review the action thresholds proposed here and to provide greater specificity on survey design, data reporting and monitoring activities.

5. Future considerations

5.1 Diagnostics development

New diagnostic tools are urgently needed. WHO should, with the Diagnostic Technical Advisory Group, review the published TPPs for taeniasis/cysticercosis to determine how these should be updated. TPPs provide potential donors with confidence that test needs have been evaluated against programme use cases. Additional efforts should also be focused on test development.

For humans, a coproantigen test based on species-specific monoclonal antibodies was of particular interest to the experts who participated in this consultation. For pigs, a species-specific circulating antigen test would be extremely valuable. It is also important to understand the potential utility of population-level testing for *T. solium* taeniasis and cysticercosis as surveillance tools. For tools to be useful for the field, a better understanding of their specificity and the duration of antibody responses will be required.

5.2 Laboratory capacity

Standardization of molecular tools to confirm *T. solium* taeniasis would facilitate confirmatory testing. It is also important to evaluate different methodologies to optimize obtaining/extracting faecal DNA for diagnosis of *T. solium* taeniasis, including the possibility of using Kato–Katz slides. WHO Collaborating Centres should be mobilized to provide diagnostic support for species-specific molecular diagnosis of *T. solium* taeniasis.

5.3 Training requirements

Expanded use of either Kato–Katz stool examinations of samples from humans or tongue inspections and meat inspection of pigs to guide *T. solium* programmes will require investment in capacity-building. Where human surveys are being conducted as part of an integrated approach to diagnosis and surveillance, additional microscopy training will be essential. Training on tongue palpation and refresher courses for meat inspectors might be needed and could be provided by the veterinary services or other organizations.

5.4 Operational research

Operational research is needed to support many of the activities proposed here, including gathering evidence to review the suggested thresholds. It is important also to document the effectiveness of mapping surveys, to measure treatment/intervention implementation and efficacy, to validate new diagnostic tools and to improve strategies to assess programme impact.

5.5 One Health

The success of efforts to control *T. solium* taeniasis and cysticercosis will require effective collaboration across the medical, public health and veterinary health sectors, as well as sanitation and environment, in a One Health approach. Prevalence data documenting infection in humans and pigs should be collected routinely and systematically and shared across all sectors concerned through routine reporting. These data have surveillance value and will inform programme decision-making. In some countries, programmes may wish to consider making *T. solium* cysticercosis a notifiable disease in both human and animal populations, in order to emphasize this effort.

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Annex. List of participants

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