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Geospatial and age-related patterns of *Taenia solium* taeniasis in the rural health zone of Kimpese, Democratic Republic of Congo

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ABSTRACT

Background: Taenia solium infections are mostly endemic in less developed countries where poor hygiene conditions and free-range pig management favor their transmission. Knowledge on patterns of infections in both human and pig is crucial to design effective control strategies. The aim of this study was to assess the prevalence, risk factors and spatial distribution of taeniasis in a rural area of the Democratic Republic of Congo (DRC), in the prospect of upcoming control activities.

Methods: A cross-sectional study was conducted in 24 villages of the health zone of Kimpese, Bas Congo Province. Individual and household characteristics, including geographical coordinates were recorded. Stool samples were collected from willing participants and analyzed using the copro-antigen enzyme-linked immunosorbent assay (copro-Ag ELISA) for the detection of taeniasis. Blood samples were collected from pigs and analyzed using the B158/B60 monoclonal antibody-based antigen ELISA (sero-Ag ELISA) to detect porcine cysticercosis. Logistic regression and multilevel analysis were applied to identify risk factors. Global clustering and spatial correlation of taeniasis and porcine cysticercosis were assessed using K functions. Local clusters of both infections were identified using the Kulldorff's scan statistic.

Results: A total of 4751 participants above 5 years of age (median: 23 years; IQR: 11–41) were included. The overall proportion of taeniasis positivity was 23.4% (95% CI: 22.2–24.6), ranging from 1 to 60% between villages, with a significant between-household variance of 2.43 (SE = 0.29, $p < 0.05$). Taeniasis was significantly associated with age ($p < 0.05$) and the highest positivity was found in the 5–10 years age group (27.0% (95% CI: 24.4–29.7)). Overall, 45.6% (95% CI: 40.2–51) of sampled pigs were sero-positive. The K functions revealed a significant overall clustering of human and pig infections but no spatial dependence between them. Two significant clusters of taeniasis ($p<0.001$; n = 276 and n = 9) and one cluster of porcine cysticercosis ($p<0.001$; n = 24) were found.

Conclusion: This study confirms high endemicity and geographical dispersal of taeniasis in the study area. The role of age in taeniasis patterns and significant spatial clusters of both taeniasis and porcine cysticercosis were evidenced, though no spatial correlation was found between human and pig infections. Urgent control activities are needed for this endemic area.

1. Introduction

Taenia solium is a cestode parasite, infecting both human and pigs and prevailing mostly in developing countries (Sciutto et al., 2000). The adult tapeworm develops in the intestine of the human host after ingestion of undercooked infected pork, causing taenia-

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sis. Infective eggs are released via the stool of tapeworm carrier and contaminate the environment. Ingestion of these eggs by coprophagic pigs or by human through fecal-oral contamination, leads to establishment of the metacestode larval stage of the parasite (cysticerci) in hosts tissues, causing porcine and human cysticercosis, respectively. In human, the most dangerous location of cysts is the central nervous system, since neurocysticercosis can lead to epilepsy, epileptic seizures and severe neurological symptoms (Garcia et al., 2003b). Neurocysticercosis is the major cause of acquired epilepsy and is responsible for about 30% of seizures in endemic areas (Ndimubanzi et al., 2010). In addition, porcine cysticercosis is a source of economic losses due to confiscation of contaminated pork (Fan and Chung, 1997; Gonzalez et al., 2001) or significant reduction of its market value (Carabin et al., 2006; Praet et al., 2009).

Control of the complex taeniasis/cysticercosis can be achieved through different approaches, including mass treatment of adult *T. solium* tapeworm carriers (Garcia et al., 2007; Pawlowski, 2006; WHO, 2012). Mass chemotherapy has been used as a control strategy for taeniasis/cysticercosis using the anthelmintic niclosamide at 2 g (Allan et al., 1997) or praziquantel at 5–10 mg/kg (Sarti et al., 2000). Due to lack of adequate field-applicable diagnostic tools for taeniasis (Praet et al., 2013), the micro-geographical distribution of cysticercosis infected pigs has been suggested to be used as an indicator of the distribution of taeniasis infected human subjects. Clustering of porcine cysticercosis in specific households would then indicate the occurrence of tapeworm carriers in the vicinity, pointing to targeted screening and treatment, whereas a dispersed distribution would suggest a wider geographic spread of taenia carriers, pointing to the need for mass treatment.

In the Democratic Republic of Congo (DRC), the Ministry of Health has adopted, but not yet implemented a national plan against neglected tropical diseases (NTDs), including mass drug administration (MDA) against helminthiasis according to WHO guidelines (http://www.nyankunde.org/documentation/doc_22.pdf). However, data on most of those NTDs in DRC are still scarce (Rimoin and Hotez, 2013). Specifically for taeniasis/cysticercosis, a study recently conducted in 5 villages of the rural health zone of Kimpese in the west of the DRC, reported a 5.2% and a 41.2% porcine cysticercosis prevalence by lingual examination and circulating antigen detection respectively (Praet et al., 2010). Another study conducted in one of these villages reported a 21.6% prevalence of active human cysticercosis by circulating antigen detection with a 12.7‰ adjusted prevalence of active epilepsy and a 0.3% prevalence of taeniasis by coprology (Kanobana et al., 2011). These data suggest that *T. solium* infections may be (highly) endemic in this area. The current study aims to assess the prevalence, risk factors and spatial distribution of taeniasis in order to contribute in designing control strategies tailored to this setting.

2. Methods

2.1. Study area and population

The study was conducted in the rural health zone of Kimpese, in the Bas-Congo Province (Fig. 1). In DRC, a health zone is the operational unit of the health system, in charge of implementation of primary health care strategies developed at the central level. Each health zone comprises health areas, which include a number of villages depending on one health center for primary health care (http://www.who.int/medicines/areas/coordination/drc_pharmaceutical_profile.pdf). Early 2011, the population of Kimpese health zone comprised around 150,482 inhabitants distributed over 20 health areas, including 519 villages (P. Lukanu, personal data). Agriculture represents the most important source of income in this area where pigs, goats and chickens are the most reared animals by farmers. Previous studies in this health zone reported a high number of free roaming pigs and occurrence of both human and porcine cysticercosis (Kanobana et al., 2011; Praet et al., 2010). Villages share cultural, commercial, social and economic characteristics. There is no piped water, roads are not paved and there is no electricity. Poor hygiene is widespread in the Bas-Congo province as only 26.8% of the population use toilets (http://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/DRC).

2.1.1. Study design and data collection

This study used cross-sectional baseline data from a community-based interventional study assessing the impact of MDA using praziquantel at 40 mg/kg (the dose used against schistosomiasis) on the prevalence of taeniasis and porcine cysticercosis. It is part of a multi-country project aiming to assess the safety and impact of MDA-based control in areas co-endemic for taeniasis/cysticercosis and schistosomiasis (Bill and Melinda Gates Foundation funded "Integrated control of taeniasis and cysticercosis" coordinated by Imperial College, London). The baseline survey took place between November 2011 and November 2012. Briefly, 24 villages in a radius of 50 km around Kimpese city were selected based on pre-determined inclusion criteria. These criteria included the presence of commonly known taeniasis/cysticercosis risk factors such as free roaming pigs, insufficient number and use of latrines; and the absence of other control initiatives such as sanitation programmes. All households of included villages were visited and all household members were invited to participate in the study, except children younger than 5 years, pregnant women, people with a history of epilepsy or seizures and people who had received a praziquantel treatment in the past 2 months. The head of each household was interviewed about the presence of household level risk factors of taeniasis/cysticercosis infection (e.g. pig breeding and presence of a latrine in the household). Geographic coordinates of each participating household were recorded using a Global Positioning System (GPS) receiver (eTrex LegendH Cx, Garmin). Another form was used to record individual data (age, gender, toilet use) from each participant.

2.1.2. Sample collection and storage

Upon written inform consent, each participant was given one plastic sample bottle and requested to deliver a stool sample. Submitted stool samples were transported to the laboratory of Kimpese health zone where they were divided into two aliquots; one placed in 10% formalin and the other in 70% ethanol. The formalin aliquots were kept at room temperature while ethanol aliquots were kept at −20 °C for future molecular analysis.

Blood samples were collected from the cranial vena cava of each pig older than 3 months, after written informed consent from pig holders. The blood samples were placed in a cooler box immediately after collection and transported to the laboratory of the Health Zone of Kimpese where they were allowed to clot overnight at 4 °C. Then, the blood was centrifuged and the serum dispensed into 2 ml aliquots and stored in labeled cryogenic vials at −20 °C. All samples were shipped to the Regional Reference Laboratory for Cysticercosis in the School of Veterinary Medicine, University of Zambia, Lusaka, Zambia for subsequent analyses.

2.1.3. Laboratory analysis

Human stool samples were tested for the presence of taenia antigen, by an in-house copro-antigen detection ELISA (copro-Ag ELISA) as described by Allan et al. (Allan et al., 1990), with slight modifications, as described by Mwape et al. (Mwape et al., 2012). The test results were obtained by comparing the optical density