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Estimation of the health and economic burden of neurocysticercosis in India

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ABSTRACT

Taenia solium is an endemic parasite in India which occurs in two forms in humans: cysticercosis (infection of soft tissues) and taeniosis (intestinal infection). Neurocysticercosis (NCC) is the most severe form of cysticercosis in which cysts develop in the central nervous system. This study was conducted to estimate health and economic impact due to human NCC-associated active epilepsy in India. Input data were sourced from published research literature, census data and other official records. Economic losses due to NCC-associated active epilepsy were estimated based on cost of treatment, hospitalisation and severe injury as well as loss of income. The disability-adjusted life years (DALYs) due to NCC were estimated by combining years of life lost due to early death and the number of years compromised due to disability taking the disease incidence into account. DALYs were estimated for five age groups, two genders and four regions, and then combined. To account for uncertainty, probability distributions were used for disease incidence data and other input parameters. In addition, sensitivity analyses were conducted to determine the impact of certain input parameters on health and economic estimates. It was estimated that in 2011, human NCC-associated active epilepsy caused an annual median loss of Rupees 12.03 billion (uncertainty interval [95% UI] Rs. 9.16–15.57 billion; US $ 185.14 million) with losses of Rs. 9.78 billion (95% UI Rs. 7.24–13.0 billion; US $ 150.56 million) from the North and Rs. 2.22 billion (95% UI Rs. 1.58–3.06 billion; US $ 34.14 million) from the South. The disease resulted in a total of 2.10 million (95% UI 0.99–4.10 million) DALYs per annum without age weighting and time discounting with 1.81 million (95% UI 0.84–3.57 million) DALYs from the North and 0.28 million (95% UI 0.13–0.55 million) from the South. The health burden per thousand persons per year was 1.73 DALYs (95% UI 0.82–3.39). The results indicate that human NCC causes significant health and economic impact in India. Programs for controlling the disease should be initiated to reduce the socio-economic impact of the disease in India.

1. Introduction

Taeniosis and cysticercosis are zoonotic diseases caused by the adult parasite *Taenia solium* and its larval form *Cysticercus cellulosae*, respectively. These diseases are endemic in many parts of the world, particularly in developing countries including India (García et al., 2003). Humans and pigs serve as hosts for the parasite *T. solium*. Pigs are the usual intermediate hosts and get infected after consuming *T. solium* eggs shed in human faeces and then harbour larval *C. cellulosae* in muscles. The consumption of pork infested by *T. solium* cysticerci, also called measly pork, leads to presence of adult worms in the human intestine, thus completing life cycle of this parasite (García et al., 2003).

Taeniosis due to *T. solium* can cause gastrointestinal symptoms including abdominal pain, distension, diarrhoea and nausea although asymptomatic infections occur in most patients (Schantz et al., 1998; Flisser, 1994; García et al., 2003). Accidental ingestion of *T. solium* eggs through contaminated food and water leads to neurocysticercosis (NCC) in human beings (Garcia and Del Brutto, 2000), the most dangerous form of the disease in humans followed by ocular, muscular and cutaneous cysticercosis. Headache, epileptic seizures and even deaths occur due to NCC (White, 2000).

The disease is prevalent in both northern (Goel et al., 2011; Raina et al., 2012; Singh et al., 2010) and southern (Murthy et al., 2004; Rajshekhar et al., 2006;) states of India (Singh and Sappal, 2012) although prevalence is higher in the North. The exceptions are Kashmir and Kerala with fewer reports, probably because Kash-

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mir is largely populated by Muslims (who do not consume pork) and Kerala has higher education and hygienic standards (Singh and Sappal, 2012). Higher prevalence of the disease has been reported in urban than rural parts (Rajshekhar et al., 2006).

Many factors influence the occurrence of this disease in India viz. presence of scavenging pigs (Singh et al., 2013), poor personal hygiene, lack of access to toilets in some rural areas and urban slums, illegal and uninspected slaughtering of pigs, and consumption of partially cooked pork (Singh et al., 2002; Singh et al., 2011). As per the official census, there were more than 11 million pigs in India producing 204,000 tonnes of pork during 2007 (DAHD, 2010). Pig rearing is generally done by lower socio-economic groups in their backyards and mostly carried out under low hygienic standards. Pigs are commonly slaughtered at home or in butcher shops. The Clean India Mission initiated by current government could prove beneficial in the prevention and control of NCC, but otherwise there is no comprehensive program aimed for the prevention and control of NCC in the country.

The disease causes a major health and economic impact across the globe. The losses occur due to health related costs i.e., treatment costs, and non-health related costs such as travel costs for visiting a doctor or a hospital (Praet et al., 2009). In India, previous studies reported a cost of Rs. 5916 for treatment of a single patient with solitary *Cysticercus* granuloma due to NCC without requiring hospitalization (Murthy and Rajshekhar, 2007). However, economic losses associated with the disease in the country have not been estimated. Also, there is very limited information available regarding impact of NCC on human health.

There are a number of measures of health impact such as life expectancy, mortality, incidence, disability etc., but most of them can be classified into either mortality or morbidity measures. Use of measures that combine both mortality and morbidity have increased in recent years as they provide a comprehensive picture of the burden of a disease in a society. One such measure that has been widely adopted – including by the WHO – is the Disability-Adjusted Life Year (DALY) (Murray and Lopez, 1996). This measure is based on the concept that each person is born to live a healthy life but may not be able to live life to its completion due to a disease/disability or may die prematurely. DALY combines these two aspects of disease impact and is calculated as the sum of the years of life lived with disability (YLD) and years of life lost (YLL). Although a bit controversial, some prefer to apply social weighting to these measures, believing that not all years of life lost are of equal value. In this manuscript we calculated DALY both with and without these social weightings to enable comparison with previous studies. We believe that estimation of health and economic impact will highlight the importance of the disease which will in turn help formulate better prevention and control strategies in India and other developing countries.

2. Materials and methods

2.1. Study population

Health and economic impacts due to NCC-associated active epilepsy were estimated for human populations in north and south India (Fig. 1) for the year 2011 to help develop area specific control programmes for NCC. This year was selected as latest studies on disease epidemiology were carried out in 2011.

2.2. Data collection

Data were collected by review of the national and international peer reviewed literature as well as sourced from government agencies. Details on the data are provided in Singh et al. (2016).

2.2.1. Demographic data

We used the official 2011 census data for rural and urban Indian male and female human populations (Table 1). Data on male-to-female population ratio were also sourced from official records (CBHI, 2010). Life expectancy was derived from the standard life expectancy Table introduced by Murray et al. (2012).

Weighted per capita incomes from north and south India were calculated using per capita incomes and populations of different states in north and south India, respectively (Table 1).

2.2.2. Epidemiological data

Prevalence data about active epilepsy due to NCC were sourced from in-depth door to door computed tomography (CT) scan based studies conducted in northern and southern India in 2011 and 2006, involving 14,038 and 50,617 persons, respectively (Goel et al., 2011; Rajshekhar et al., 2006). The prevalence of epilepsy without NCC, epilepsy with NCC and epilepsy with NCC along with other causes were 6.53/1000 persons, 3.48/1000 persons and 10.0/1000 persons, respectively in the north Indian study (Goel et al., 2011). The South Indian study reported the prevalence of active epilepsy with NCC and active epilepsy with NCC along with other causes to be 1.09/1000 persons and 3.83/1000 persons, respectively (Rajshekhar et al., 2006). As prevalence data for the disease in urban areas in north India was not available, we estimated this value assuming a similar ratio of prevalence in urban versus rural areas in the North as estimated in the South (Rajshekhar et al., 2006). Although the South Indian prevalence study was carried out in 2006, we assumed that prevalence would have remained the same since then (Rajshekhar et al., 2006).

Since age specific prevalence data were not available, we assumed that prevalence of NCC-associated active epilepsy cases in different age groups would vary as reported in a study for NCC in India (Sailaja and Umadevi, 2014) and extrapolated it to estimate prevalence estimates of NCC-associated active epilepsy in different age groups in rural and urban populations in North and South India. For estimating annual incidence of human NCC associated with epilepsy, we divided the prevalence of NCC-associated epilepsy by the reported duration of epilepsy for different age groups (Praet et al., 2009).

We further assumed that that 6% (range 2–10%) of the NCC epileptic patients would suffer severe injury and have to visit a physician (Sapna et al., 2008) and 7.5% (range 5–10%) of the total patients seeking medical attention would be hospitalized at least once in a year (Sapna et al., 2008).

2.2.3. Disease severity data

DALY parameters such as epilepsy disability weight and average duration of disability were sourced from published scientific literature (Praet et al., 2009) as presented in Table 2. Information about case fatality in epileptic patients with NCC (2.89%) was sourced from a recent study (Murthy et al., 2012).

2.2.4. Data associated with production losses

The costs of Rs. 5916.20 (Rs. 4159.34–7672.66) calculated for treatment of solitary *Cysticercus* granuloma due to NCC without requiring hospitalization were sourced from a published study (Murthy and Rajshekhar, 2007). These costs included costs of medications, visits to a doctor, one interictal electroencephalogram (EEG) and two CT scans. All the patients were treated with antiepileptic drug (AED) monotherapy (phenytoin or carbamazepine) for the period of CT resolution of the lesion. Additionally, a course of albendazole (15 mg/kg per day for four weeks) and steroids (1–2 mg/kg per day for four weeks with tapering dose) was also given. AEDs withdrawal was gradual over a period of two months. Patients were advised not to come for further follow-up after stopping AEDs (Murthy and Rajshekhar, 2007). The bed