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Human and Porcine Cysticercosis: A Mathematical Approach

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Abstract: The larval stage of pork tapeworm i.e. *Taenia solium* infect human nervous system, causing neuro cysticercosis, which is one of the main causes of epileptic seizures in many less developed countries and nowadays it is also increasingly seen in more developed countries because of immigration from endemic areas. In this research article, a mathematical model of cysticercosis is proposed and analyzed. Here a four diamentional mathematical model is considered. The dynamical behavior of the system is studied analytically. Existence condition and stability analysis are performed. Our aim is to control the disease cysticercosis by using control therapeutic approach.

Keywords: Taeniasolium ; Taeniasis; Pig; Cysticercosis.

I. INTRODUCTION

Taeniasolium is the aetiological agent of human taeniasis, pig cysticercosis and human neurocysticercosis, which are serious public health problems, especially in developing countries. Taeniasoliumtaeniasis/cysticercosis infection is an important zoonosis of considerable (veterinary) public health concern that mainly affects poor communities. T. soliumtaeniasis/cysticercosis is also indicative of poor standards of sanitation and inappropriate pig husbandry practices [1][2]. T. solium is on the WHO list of neglected tropical diseases (NTD) [3]. The Taeniasolium tapeworm is responsible for cysticercosis, presenting as larvae in the body of a host following taenia egg ingestion.

Taeniasis is an intestinal infection with the adult form of the beef tapeworm, Taeniasaginata, or the pork tapeworm, T. solium. Adult T. saginata can be as long as 12 meters and contain 2,000 proglottids or segments. T. solium is about half this size. Taeniasis due to T. saginata occurs more often in the United States than that caused by T. solium. Infections with T. solium are more common in Mexico, Latin America, southern Africa, and Southeast Asia.

Humans convey three tapeworms - Taeniasolium, T. saginata and T. asiatica - as ultimate hosts, with pigs or cattle acting as their main intermediate hosts. T. solium is a particular concern because humans can also be intermediary hosts for this organism, and eggs shed by a tapeworm carrier can cause cysticercosis in people, including the carrier [4]. Canids, felids, mustelids and other mammals that eat animal tissues are the definitive hosts for other tapeworms, whose eggs can cause cysticercosis or coenurosis in livestock, pets and various captive or free-living wildlife [5]. Some of these organisms, including parasites from wildlife cycles, have been increasingly recognized in humans in recent years.

Humans can become infected with T. solium (pork tapeworm) after consumption of raw or insufficiently cooked pork meat harbouring the larval stage of this tapeworm, which subsequently develops to the adult stage in the human small intestine [7]. Likewise, T. saginata (beef tapeworm) infection occurs after eating raw or undercooked beef meat carrying the larval stage of the parasite, which again matures to the adult stage in the human small intestine. Additionally, T. solium infection in humans can occur through the accidental ingestion of the eggs of this parasite (fecal-oral route), in a similar way to the mode of infection of the intermediate hosts. In the latter case, infection with T. solium can result in the formation of cysticerci (larval stage) in the human body, which are of major importance when located in the central nervous system (neurocysticercosis, NCC).

Tapeworm (T. solium) eggs are passed in the feces of an infected person. (The eggs are too small to be seen.) Onegetscysticercosis by eating these eggs [8]. This may happen directly by having eggs on your hand and touching your mouth. It can also happen indirectly (for example, by eating food or drinking water that has had contact with human feces containing the eggs).

People who have the adult T. solium or T. saginata often do not have any symptoms. Most infected people only become aware that they have a tapeworm after seeing the segments passed in their feces. Other symptoms may include nausea, intestinal trouble, or chronic acid stomach [9].

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In many cases a person with cysticercosis does not have any symptoms. However, when the cysticerci are located in the eye, heart, or central nervous system (CNS), the results can be serious. Infections of the eye may affect the person's vision and could lead to blindness. Cysticerci in the CNS can result in seizures, headache, and dementia (reduced mental function).

There are several control methods for taeniasis. Meat inspectors must inspect all commercially processed beef and pork. This way, any meat found to contain Taenia larvae will be properly handled. For instance, the meat must either be disposed of or frozen at minus five degrees centigrade for four days [10]. This, or a similar approved freezing process, will kill the larvae. Irradiation will also kill larval cysts. All meat should be thoroughly cooked, as this will kill any living larvae. These methods are used to prevent people from getting the parasite from infected meat. There are also control measures that can be taken to prevent cattle and swine from becoming infected.

Detecting pork containing cysticercosis is important in preventing people from getting the adult tapeworm. In addition, treating people infected with the adult form of the tapeworm will reduce its spread to other people. Good sanitation (cleanliness) is important in the prevention of cysticercosis. Anybody who handles food should always wash his or her hands after going to the restroom and before preparing food. Hand washing before eating is important for everyone in case you have handled something that had T. solium eggs on it. For the same reason, if you smoke, you should wash your hands before smoking.

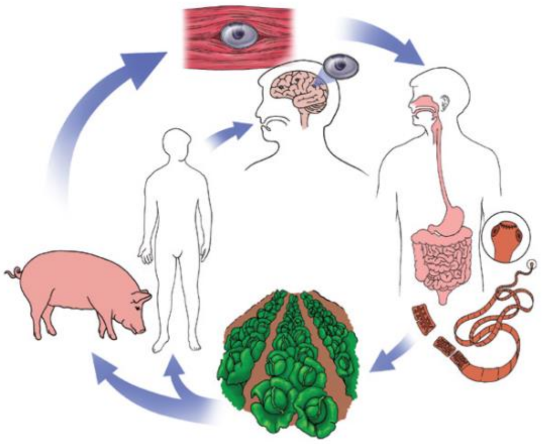

Fig. 1 Life cycle of Taeniasolium larvae. American Family Physician [1]

II. DEVELOPMENT OF MATHEMATICAL MODEL

We consider that prey population is facing an infectious disease, where the predator feeds on both healthy and infected preys. Let S_H is the susceptible human population, I_H is the infected human population, S_P is the susceptible pig population, I_P is the infected pig population, E_T is the number of Taeniasaginata eggs in the environment, P_1 is the meat of infected cattle, μ_H is the natural death rate of human.

$$\frac{dS_H}{dt} = \Lambda - \mu_h S_H$$

$$\frac{dI_H}{dt} = \beta\alpha_1 P_1 S_H - \mu_H I_H$$

$$\frac{dS_P}{dt} = \lambda - \mu_P S_P$$

$$\frac{dI_P}{dt} = \gamma_P S_P E_T - \delta I_P - \mu_P I_P$$

$$\frac{dE_T}{dt} = \omega I_H - \mu_t E_T$$

$$\frac{dP_I}{dt} = \delta I_P - \alpha_1 P_1$$

Λ is the percapita requirement of pig population, $\omega$is the slaughter rate of infected pig, $\delta$is the proportion of consumed infected pigs, α_1 is the constant growth rate of the human population, $\beta$is the rate of infection due to infected human population, μ_P is the T. Solium classes that represent susceptible pigs.

III. EXISTENCE AND LOCAL STABILITY ANALYSIS OF THE EQUILIBRIUM POINTS

There are four equilibrium points of the aggregated system, trivial equilibrium point $E_0(0,0,0,0,0,0)$,axial equilibrium points are $E_1(\frac{\Lambda}{\mu_H},0,0,0,0,0)$, $E_2(0,0,\frac{\lambda}{\mu_P},0,0,0)$,
planer equilibrium point $E_3(\frac{\Lambda}{\mu_H},0,\frac{\lambda}{\mu_P},0,0,0)$ and the interior equilibrium point E*$(S_H*, I_H*, S_P*, I_P*, E_T*, P^*)$.

The variational Matrix is:

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} & a_{26} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} & a_{36} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} & a_{46} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} & a_{66} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & a_{66} \end{bmatrix}$$

$a_{11} = -\beta\alpha_1 P_1 - \mu_H, a_{12} = 0, a_{13} = 0, a_{14} = 0, a_{15} = 0, a_{16} = -\beta\alpha_1 S_H$
$a_{21} = \beta\alpha_1 P_1, a_{22} = -\mu_H, a_{23} = 0, a_{24} = 0, a_{25} = 0, a_{26} = \beta\alpha_1 S_H$
$a_{31} = 0, a_{32} = 0, a_{33} = (-\gamma_P E_T - \mu_P), a_{34} = 0, a_{35} = -\gamma_P S_P, a_{36} = 0$
$a_{41} = 0, a_{42} = 0, a_{43} = \gamma_P E_T, a_{44} = (-\delta - \mu_P), a_{45} = \gamma_P S_P, a_{46} = 0$
$a_{51} = 0, a_{52} = \omega, a_{53} = 0, a_{54} = 0, a_{55} = -\mu_t, a_{56} = 0$
$a_{61} = 0, a_{62} = 0, a_{63} = 0, a_{64} = \delta, a_{65} = 0, a_{66} = -\alpha_1$

Lemma 1: The equilibrium point $E_0(0,0,0,0,0,0)$ is always unstable.
Lemma 2: The system around the axial equilibrium point $E_1(\frac{\Lambda}{\mu_H},0,0,0,0,0)$ is stable.
Proof : The eigenvalues about E_1 are λ_1^1= −μH,λ_2^1= −μH, λ_3^1= −μp, λ_4^1 = −δ − μp, λ_5^1= −μt, λ_6^1= −α_1. Since all the eigen values are negative, so the equilibrium point E_1has stable .

Lemma 3: The system around the axial equilibrium point $E_2(0, 0, \frac{\lambda}{\mu_P}0, 0, 0)$ is stable.

Proof: The eigenvalues about$E_2$are λ_1^2= −μH, λ_2^2= −μH, λ_3^2= −μp,λ_4^2=−δ −μp, λ_5^2= −α1, λ_6^2= −μT. Since all the eigen values are negative, so the quilibrium point E_2has stable .

Lemma 4: The system around the planer equilibrium point $E_3(\frac{\Lambda}{\mu_H}, 0, \frac{\lambda}{\mu_P}, 0, 0, 0)$is stable .
Proof: The eigenvalues about E_3 are λ_1^3= −μH, λ_2^3= −μp, λ_3^3= −δ −μp, λ_4^3=−μT, λ_5^3= −α1, λ_6^3= −μH. Since all the eigen values are negative, so the equilibrium point E_3 has stable.

Lemma 5: The system around the interior equilibrium point E$^*(S_H^*, I_H^*, S_P^*, I_P^*, E_T^*, P_1^*)$ is stable.

Proof: The eigenvalues about$E_4$are λ_1=−β$\alpha_1 P_1$−μH, λ_2−μH, λ_3 = −γpET−μP, λ_4= −δ−μP, λ_5= −μT, λ_6= −α1. Since all of the eigen value age negative, so the equilibrium point $E_4$is stable.

IV. CONCLUSION

Cysticercosis is a global public health problem because neuro cysticercosis has been identified as the most important cause of the acquired active epilepsy and ocular orbital cysticercosis as one of the preventable cause of blindness. It is considered as a biological marker of social and economic development which is potentially eradicable through surveillance and human interventions. Healthy food habits and sanitary improvements are essential to control this public health problem. There is an urgent need for effective health education campaign aimed at preventing and treating both Taeniasolium infection and cysticercosis in the community through medical institutions and medical agencies as well as mass awareness.

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