

CURRENT STATUS OF FOOD-BORNE PARASITIC ZOOSES IN THE UNITED STATES

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Abstract. Although not a major public health problem, food-borne parasitic zoonoses in the United States are the cause of numerous diseases that occur widely in the population. The most common food-borne parasitic diseases in the United States are trichinosis, toxoplasmosis, taeniasis/cysticercosis, diphyllbothriasis, and anisakiasis. Since 1947, when the US Public Health Service began to record statistics on trichinosis cases in humans, the numbers of reported cases in the United States have declined markedly, from an average of about 400 with 10-15 deaths reported each year in the late 1940s, to an average of 57 per year with three deaths overall in the 5 years 1982-1986. Each year throughout the world, *Toxoplasma gondii* infects millions of persons, who contract it either by eating raw or poorly cooked meat from infected animals such as hogs or sheep or by ingesting soil contaminated with cat feces. In the United States between 400 and 10,000 infants are born each year with congenital toxoplasmosis. Toxoplasmic encephalitis, marked by dementia and seizures, has become the most commonly recognized cause of central nervous system opportunistic infection in AIDS patients. Intestinal taeniid tapeworm infection acquired in the United States is almost entirely caused by *Taenia saginata*, the beef tapeworm. Neurocysticercosis, caused by larvae of the pork tapeworm *Taenia solium*, is diagnosed in hundreds of persons in the United States every year. Nearly all patients are immigrants or travelers from Mexico and other disease-endemic areas. Diphyllbothriasis and anisakiasis both have increased in recent years in association with increasing popularity of raw fish dishes. Adequate prevention and control of food-borne parasitic zoonoses require continued and improved programs to educate consumers, producers and medical practitioners.

INTRODUCTION

Food-borne diseases are a major cause of morbidity in the United States. Between 1973 and 1987, 7,458 outbreaks of food-borne diseases, involving 237,545 cases, were reported to the US Centers for Disease Control (CDC); diseases caused by parasites, mainly *Trichinella* sp., accounted for 5% (128 outbreaks and 843 cases) (Bean and Griffin, 1990). Costs of diagnosis and treatment of food-borne diseases during this 14-year period were estimated to be between \$7.7-\$8.4 billion per year.

In this context, none of the food-borne parasitic zoonoses is currently ranked as major public health problems in the United States; however, numerous diseases caused by these zoonoses occur widely. Some are important causes of economic losses in meat and fish production. Most are diagnosed more frequently in certain geographic areas or in certain subgroups of the

population, often in association with specific cultural practices that facilitate transmission.

Food-borne parasitic zoonoses in the United States include trichinellosis, toxoplasmosis, taeniasis, cysticercosis, diphyllbothriasis and anisakiasis. Other parasitic infections such as giardiasis and cryptosporidiosis are occasionally transmitted in food; however, these infections are more commonly transmitted by other routes and will not be considered in this paper. Only trichinellosis is a legally notifiable disease in the United States; therefore, systematically collected data are available. Information on the occurrence of others was obtained from government reports, published articles, and laboratory diagnostic reports.

Trichinosis

The United States is one of the few developed countries where trichinosis is still perceived as a public health problem. The history of this disease

is of interest from both a public health and a political perspective.

About 110 years ago, Germany, recognizing that pork from the United States contained *Trichinella* and was a danger to public health, banned the importation of this product. This action was repeated by other European countries, and the ban, with certain exceptions, continues today. Public concern about trichinellosis probably reached its peak in the 1940s, when outbreaks were common and an average of 10 to 15 deaths per year were recorded. A study of human cadavers at that time showed 16% were infected (Wright *et al*, 1944).

In 1947 the US Public Health Service began collecting statistics on trichinosis at the national level, and in 1965 trichinosis was included among the notifiable diseases that physicians report weekly to state health departments and to CDC through the National Morbidity Reporting System. Annual summaries on trichinosis have been published by the CDC *Morbidity and Mortality Weekly Report* (MMWR) since 1967 (CDC, 1989).

The number of cases of trichinosis reported annually in the United States has declined since statistics were first collected (Fig 1). In the late 1940s, more than 400 cases, with 10-15 deaths, were reported each year. In 1975-1981, the average annual number of reported cases was 152; during this period five fatalities were reported. In 1982-1986, these figures decreased to an annual average of 57 cases, with three fatalities reported

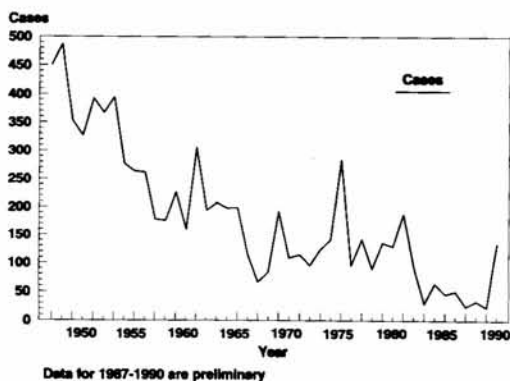


Fig 1—Reported cases of human trichinosis, United States, 1950-1990 (Centers for Disease Control).

(Bailey and Schantz, 1990). In 1987-1989, the numbers of reported cases were 40, 45, and 30, respectively, thus indicating a continuing declining trend. However, in 1990, 90 (36%) of 250 persons who attended a wedding party in Iowa developed trichinosis. The incriminated food item was uncooked, homemade pork sausage prepared from commercial fresh pork. This was the largest outbreak in many years and, at least temporarily, reversed the declining trend. The 1990 outbreak occurred in a group of refugees from Southeast Asia, primarily Laos, for whom raw, spiced pork is an ethnic delicacy. Southeast Asians are the most recent ethnic group identified at risk for trichinosis in the United States (Stehr-Green and Schantz, 1986). Historically, the largest outbreaks of human trichinosis have occurred in ethnic groups whose culinary preferences include raw pork. A 1940 autopsy survey showed that deceased persons of German or Italian descent were infected at a rate of approximately 29%, compared with a 2% rate in Jews, whose religious laws proscribe pork (Wright *et al*, 1944). Examination of the surnames of persons involved in outbreaks due to pork products revealed that the proportion of affected persons of German, Italian, Polish, or Portuguese ancestry is disproportionately higher than their overall representation in the United States population (Schantz *et al*, 1977).

Although the prevalence of trichinosis in swine has declined in recent decades, the infection persists at levels that invariably result in occasional human disease. Estimates of the current frequency of *Trichinella* infection in swine have varied from 0.01 to 0.1 per thousand slaughtered hogs; however, surveys in abattoirs in the New England and Middle Atlantic states indicated rates of 5-7 per 1,000 hogs (reviewed in Bailey and Schantz, 1990).

The recent declining trend in human trichinellosis is the result of a reduction in the number of cases acquired from domestic pork products (Bailey and Schantz, 1990). The number of cases of trichinellosis acquired from wild animal meat has always been relatively low, but has recently increased as a proportion of total cases. *Trichinella* is enzootic in scavenging carnivores throughout North America. Transmission of infection in humans occurs regularly from these sylvatic sources through ingestion of bear meat and, more rarely,

from other wild animal sources such as walrus and seal meat in Arctic regions. It has long been suspected that these sylvatic reservoirs of *Trichinella* represent an important source for reestablishing the infection in domestic swine populations. Recent studies have shown, however, that the strain or strains indigenous to sylvatic animals represent gene pools distinct from those of the parasite in domestic swine (Zarlenga and Barta, 1990). The sylvatic strains do not readily infect domestic pigs. Similarly, recent studies using repetitive DNA probes have shown that the pig-adapted strain is rarely recovered from wildlife (Minchella *et al.*, 1989). In these rare cases, wild animals appear to acquire the pig-type parasite from scavenging or being fed garbage.

Although the United States has never had a specific trichinellosis control program, multiple events, some government sponsored, have contributed to significant declines in transmission of infection between pigs and from pigs to humans (Leighty, 1983). The prohibition of feeding raw garbage to pigs was an important factor. More recent control measures include preventing pigs from scavenging on dead pigs and eliminating rats, which maintain *Trichinella* in a commensal cycle. Another important factor in the prevention of trichinellosis has been consumer education; most US citizens know that pork should be cooked well. The US Department of Agriculture further legislates that all pork marketed as ready-to-eat must be processed to destroy *Trichinella*. Low-dose ionizing radiation (30-50 kilorad) is effective for preventing *Trichinella* infection and recently has been approved by the government for processing pork and other foods. The industry, however, has shown limited interest in this safe and effective technology because of widespread consumer fear and mistrust of radiation (Sun, 1984). In the United States, routine postmortem detection of *Trichinella*-infected pigs has never been employed. A highly sensitive and specific antibody test based on first-stage larval metabolic antigens has been shown to be capable of detecting infections as low as one larva per 100 grams of meat (Madden and Murrell, 1990). The test is currently under consideration for approval as an antemortem test for trichinosis and, if approved and applied, could further reduce the public health problem of trichinosis in the United States, as has been achieved so effectively in several European

countries.

The United States has reached a critical juncture in trichinellosis control. The low number of human cases prevents this disease from being ranked as a public health priority and lowers the level of public concern. The 1990 outbreak in Iowa reminds us, however, that the infection is still with us and the potential for severe disease remains. New technology that could be applied in routine processing to detect or inactivate infected carcasses is now available and could eliminate this public health problem. However, whether the public and the regulators have the political will to mandate implementation of the technology remains to be seen.

Toxoplasmosis

Toxoplasmosis is a ubiquitous protozoan parasite of birds and mammals. It has been estimated that approximately one third of the adult US population has been infected with *Toxoplasma gondii* (Feldman, 1982); this cumulative prevalence requires that millions acquire the infection each year.

The seroprevalence rates for *Toxoplasma* infection in the United States vary by age, race, and geographic region (Feldman, 1982). Native Americans have the lowest rate of seropositivity (< 5%), while Hispanic Americans have the highest (60%) (Feldman, 1982; Mitchell 1990, personal communication). In a study of military recruits in the United States in the late 1950s, the highest rate of seropositivity occurred in the northeast (20%) and the lowest in the mountain states (3%) (Feldman, 1965). There is evidence that rate of infection is decreasing (Remington and Desmonts, 1989).

Infection is acquired by three principal mechanisms: (1) ingestion of oocysts in material contaminated by infected cat feces, (2) ingestion of tissue cysts in raw or undercooked meat (mainly pork or mutton), or (3) transplacental passage of tachyzoites from a parasitemic woman to her fetus. Recently, iatrogenic modes of transmission, transfusion of blood containing infected leukocytes and organ transplantation, have been recognized with increasing frequency. Infection is usually asymptomatic but can cause considerable morbidity and mortality in two groups of patients, congenitally infected children and immunocompromised hosts.

Congenital toxoplasmosis occurs when a woman acquires a primary infection during pregnancy, or more rarely, when a pregnant woman is immunocompromised and reactivates a previously acquired infection. This latter situation may become increasingly common as the number of women with AIDS rises. Congenital toxoplasmosis leads to significant morbidity and mortality (Eichenwald, 1960). Although 90% of infants are asymptomatic at birth (Alford *et al.*, 1974) 50% of asymptomatic and 85% of symptomatic children with congenital toxoplasmosis have significant neurologic sequelae (Wilson *et al.*, 1980). Ninety percent of all children with congenital toxoplasmosis have chorioretinitis, with varying degrees of visual loss (Wilson *et al.*, 1980).

The number of cases of congenital toxoplasmosis occurring in the United States each year can only be estimated because it is not a nationally reportable disease, and the majority of infections are asymptomatic at birth. The estimated number of infections per year has been calculated to range from 407 to 9,500 (Roberts and Frenkel, 1990). Although this is a broad range, it cannot be narrowed at this time because of lack of adequate data. Using these figures, the cost of congenital toxoplasmosis per year in the United States was estimated to be between 369 million and 8.8 billion US dollars (Roberts and Frenkel, 1990).

Recent reports from France indicate that prevention of congenital toxoplasmosis and its clinical and pathologic sequelae may be possible through an aggressive program of screening pregnant woman for acute infection (Schantz, 1989). The need for screening programs for pregnant women in the United States has been debated in the medical literature (McCabe and Remington, 1988). However, until accurate estimates of the number of cases of congenital toxoplasmosis per year can be made, debates about the cost effectiveness of active intervention will remain unresolved.

Toxoplasmosis in the immunocompromised host is most often due to relapse of a latent infection and commonly involves the central nervous system (CNS). Toxoplasmic encephalitis is the most frequent CNS opportunistic infection in persons with AIDS and is uniformly fatal if untreated (Grant *et al.*, 1990). Therapy for toxoplasmic encephalitis in AIDS patients is often toxic but must be continued indefinitely to prevent relapse (Danneman and Remington, 1989).

As of December 31, 1989, 4,776 of the 115,784 reported patients with AIDS had toxoplasmic encephalitis. However, the total number of AIDS patients in the United States with toxoplasmic encephalitis is not known because only the illness that defines an HIV-positive individual as having AIDS is reported; subsequent opportunistic infections are not required to be reported. Reports from New York City indicate that 32% of AIDS patients are seropositive for *T. gondii* and that 24% of those who are seropositive will ultimately develop toxoplasmic encephalitis (Grant *et al.*, 1990). The overall mortality rate for these patients is 70%. Estimates based on these figures, and on the projected incidence of AIDS, suggest that in 1991 there will be 20,000-40,000 cases of toxoplasmic encephalitis in AIDS patients in the United States (Danneman and Remington, 1989).

Cestode infections

Because intestinal tapeworm infections are not legally reportable diseases in the United States, systematically collected data concerning their occurrence are not available. Some reflection of the incidence of these infections, at least in relation to other intestinal helminth infections, is obtained from diagnostic records of state public health laboratories and requests for medication to treat tapeworm infection. Until 1982, niclosamide, the drug then most widely used for treatment of tapeworm infections, was available in the United States only from CDC. Table 1 shows the numbers of physician requests for the drug by species of tapeworm for the 4-year period 1978-1981.

Taeniasis/Cysticercosis: From 1978-1981, releases for treatment of *Taenia* species varied from 21% to 54% of the total number of patients for which niclosamide was requested. The beef tapeworm *T. saginata* was diagnosed approximately five times more frequently than the pork tapeworm *T. solium*. Among patients with *Taenia* infections, males (60%) outnumbered females, and approximately 70% of patients were between 11-40 years of age. One third of these requests were from California.

Analysis of 1987 data from state diagnostic laboratories indicated that *Taenia* sp. tapeworms were diagnosed in 56 per 100,000 specimens (Kappus *et al.*, submitted), which is comparable to the rate at which they were diagnosed in state laboratories in 1976 (Ruebush *et al.*, 1978). Fifty-seven percent of the *Taenia* diagnoses were

reported from western states, which represented only 21% of total specimens.

Information provided with the diagnostic specimens suggested that the majority of *Taenia* infections were imported; however, about a third of the patients with *T. saginata* had no history of travel and thus acquired their infections in the United States (Schultz *et al.*, 1970). US Department of Agriculture abattoir pathology records indicate that persistent low-level cysticercosis infections in cattle provide sources of infections for persons who eat undercooked beef. Bovine cysticercosis has declined slightly during the past 30 years, from a mean of 50.5 infections per 100,000 slaughtered cattle in 1960-64 to 22.7 in 1985-1989 (Fig 2). However, because the number of cattle slaughtered each year has nearly doubled, from 18 million in 1960 to 31 million in 1989, the number of infected animals reaching the market has remained about the same. Although the infection is found in cattle slaughtered in all regions of the country, cysticercosis prevalence is characteristically highest in western states. In 1989, the prevalence in California (1.82 per 1,000) was 12 times higher than the national mean. Other states with prevalence greater than twice the national mean were New Mexico, Idaho, Washington, Nevada and Arizona. The highest prevalence of cysticercosis in cattle in western states can be accounted for by several factors, including the presence of immigrant workers from countries in which *Taenia saginata* infection is common, the purchase of young cattle in Mexico for fattening and finishing in the United States, and the use of recycled water and sewage effluent for irrigation and fertilization of pasture and feed crop (Schultz *et al.*, 1970).

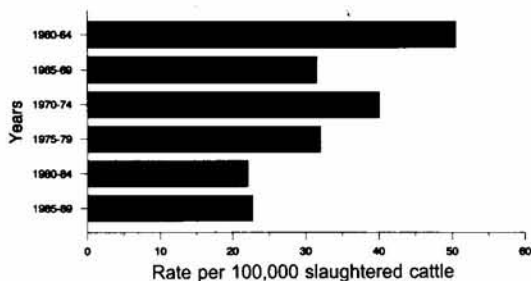


Fig 2—Mean annual prevalence of *Taenia saginata* cysticercosis in federally-inspected cattle, by 5-year periods, 1960-1989, United States. (Food Safety and Inspection Service, US Department of Agriculture)

Few cases of *T. solium* taeniasis are acquired in the United States because the infection is extremely rare in US swine. Of more than 83 million hogs examined at slaughter in 1990, only three were restricted or condemned because of cysticercosis (Food Safety and Inspection Service, US Department of Agriculture 1990 personal communication). Occasional small-scale outbreaks occur, including one in a swine feedlot in Colorado in which infected immigrant workers were the suspected source (Emerson and Schantz, 1981). Although *T. solium* is rarely acquired in the United States, *T. solium* disease in humans, neurocysticercosis, has long been diagnosed in the United States, and the problem has increased greatly in the past 15 years. A four-fold increase in the number of cases diagnosed annually in four Los Angeles hospitals occurred between 1973 and 1983. This increase was largely associated with improved diagnosis made possible by the introduction of CT scans (Richards *et al.*, 1985). The same phenomenon has been experienced in other major US cities. A review of the histories of the patients in Los Angeles revealed that less than 6% had been born and resided continuously in the United States. About 79% were from Mexico; the remainder came from other Latin American countries, Asia and Africa. No evidence exists that the proportion of locally acquired cases is increasing. Patients with neurocysticercosis, many of whom require repeated hospitalizations, expensive surgery, and chemotherapy, have a significant impact on medical care expenditures (Richards *et al.*, 1985).

Table 1

Physician requests for niclosamide by tapeworm species, United States, 1978-1981. Parasitic Disease Drug Service, Centers for Disease Control.

Species	No. requests
<i>Taenia saginata</i>	2,076
<i>Taenia solium</i>	487
<i>Taenia</i> spp. (?)	1,851
<i>Hymenolepis nana</i>	6,614
<i>Hymenolepis diminuta</i>	102
<i>Diphyllobothrium</i> spp.	797
<i>Dipylidium caninum</i>	190
Miscellaneous	104
Total	12,221

Diphyllobothriasis: *Diphyllobothrium* infections are acquired from ingestion of raw fish. Fish tapeworm infections represented approximately 8% of requests for niclosamide from 1978-81 (Table 1). The incidence of this tapeworm infection increased markedly in the Pacific coast states in 1980 in association with a change in market practices that resulted in the shipping of fresh salmon from Alaska, where *Diphyllobothrium* spp. infection in fish is relatively common (CDC, 1981). The increasing popularity of raw fish dishes such as Japanese sushi and sashimi and Latin American ceviche has been identified as a risk factor associated with the increasing incidence of diphyllobothriasis.

Anisakiasis and other fish-borne nematode infections

Second to fish tapeworms, the parasitic infections most commonly acquired from raw seafood in the United States are larval nematodes of the family Anisakidae; somewhere between 25 and 50 infections caused by two anisakine genera, *Pseudoterranova* and *Anisakis*, have been documented since 1960 (reviewed in Schantz, 1989). The larval worms are highly prevalent in many commonly consumed varieties of fish, and most authorities believe that infections are greatly underdiagnosed and underreported. A recent survey of sushi restaurants in Seattle revealed anisakid larvae in approximately 1 of every 13 slices of sushi examined, indicating the potential for transmission (Adams *et al*, 1990). Interestingly, all the larvae were dead, suggesting that most Seattle restaurants are freezing fish prior to serving, even though such processing is not currently required by law.

Fortunately, most cases of fish-borne parasitic infection in the United States have been trivial in terms of morbidity; however, the rare instances of intestinal perforations due to *Eustrongylides* infection and the occasional case of invasive anisakiasis indicate that the consequences of infection can be severe (Schantz, 1989).

Fish-borne parasitic infections may be recognized more frequently in the future, however, they are unlikely to become a major problem in the United States because most fish is cooked, frozen, or otherwise processed adequately to eliminate larval helminths before being consumed.

CONCLUSIONS

Although none of the food-borne parasitic zoonoses ranks as a major public health problem in the United States, some of them, especially trichinosis and cysticercosis, are the causes of significant economic losses as a result of reductions in demand for the product, condemnation of infected carcasses and costs of prevention. In addition, most of these infections present unique problems in diagnosis and treatment which is often complicated because physicians and others on the medical team lack experience with them. Adequate prevention and control of food-borne parasitic zoonoses require continued and improved programs to educate consumers, producers and medical practitioners.

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