TOXICITY OF CADMIUM TO SCHISTOSOMA MANSONI CERCARIAE: EFFECTS ON VITALITY AND DEVELOPMENTAL ABILITY IN WHITE MICE

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Abstract

Time-until-death studies were run on cercariae of Schistosoma mansoni in 8 concentrations of cadmium (from cadmium sulfate) ranging from 100 ppm to 0.0001 ppm. All concentrations used were found to be toxic, and at 10 ppm all cercariae were dead within 4 hours, which coincides with their period of maximum infectability following emergence from the snail host. At 2 ppm, all cercariae died within 8 hours, and at 1 ppm all died within 16 hours. In addition, groups of cercariae were exposed to cadmium concentrations of 10, 1, and 0.1 ppm for periods of 30, 20, and 10 minutes. Thereafter, cercariae from these groups were allowed to penetrate the tails of white mice or were injected subcutaneously into mice. After 8 weeks, these mice were autopsied and the adult worms collected by perfusion. Maturation of cercariae from both methods of invasion was seriously impaired. Statistical analysis using a 3 x 4 x 2 factorial design for analysis of variance showed both time of exposure and concentration of cadmium ion to be significant factors in determining number of worms developing at p = 0.01. A significant interaction between time of exposure and concentration was found to exist. The two methods of infection did not have a significant effect on the number of worms recovered. Therefore, it appears that those toxicant-exposed cercariae capable of maturing do not need assistance in traversing the skin barrier but can penetrate and migrate to reach the mesenteric venules for maturation.

Introduction

Schistosomiasis is known to be endemic in 71 countries or islands that have a total population of over a billion people. The disease occurs in all countries of Africa except Lesotho, one of the Mascarene islands (Mauritius), South West Asia, South East Asia, and the Americas. In the 71 countries or islands where the disease is endemic, 125 million people are infected (Wright, 1970). Blanc & Nosny (1967) estimate that one person in twelve of the world's population is infected with schistosomes.

Wright (1970) attempted to estimate the economic effects of schistosomiasis based on prevalence rates, representing for the most part, single stool or urine examination. His analysis referred only to resource loss attributable to reduced productivity. The annual world loss from complete and partial disability is estimated to be in excess of U.S. $640 million. This sum does not include the cost of public health programs, medical care, or compensation for illness.

Over 50 years of research has been expended on attempts to eliminate schistosomiasis from native waters without success. As the human population has increased and sources of fresh water have become more important, the disease has spread and the incidence of infection has increased. The disease occurs primarily in unindustrialized countries, and the development of extensive perennial irrigation systems to expand crop production in agricultural areas has enhanced the spread of the infection.

Industrialization of the areas in which schistosomiasis is prevalent may result in the decline of the disease for three reasons: an increase in the standard of living may bring about changes in education and human ecology; industrial waste may destroy the snail intermediate host; and the miracidial and cercarial stages of the parasite may be destroyed by industrial pollutants, or their vitality, penetration ability, and maturation may be impaired.
**Schistosoma mansoni** (Sambon, 1907) cercariae cannot survive for longer than 50 hours in untreated water (Kuntz & Stirewalt, 1946) unless they come in contact with a definitive host. The effects of toxicants on the ability of the cercaria to penetrate the host and continue its maturation is of utmost importance.

The maximum infectability of *Schistosoma mansoni* cercariae in white mice occurs between 0 and 3.6 hours after emergence from the intermediate host; however, some cercariae will continue to be infective for over 30 hours. The crucial consideration is the ability of schistosome cercariae to penetrate a host, and their ability to develop into adult worms (Oliver, 1966).

Cadmium is closely related to zinc and will be found in nature wherever zinc is found. Since zinc is an essential metal for most life forms, it is probable that no naturally occurring material will be completely free from cadmium (Friberg, Piscator & Nordberg, 1971).

Cadmium is obtained by the refining of zinc and other metals. Since it is difficult to separate zinc and cadmium, the latter will often be found in small amounts in commercially available zinc compounds (Schroeder, Nason, Tipton & Balassa, 1962).

Though cadmium has been used in industry for a short period of time, copper, lead, zinc, and some other metals have been used for several thousand years. Therefore, as soon as man started to produce metals, he also started to pollute the environment with cadmium. In this century, cadmium and cadmium compounds have been used increasingly by industries, causing a sharp increase in environmental contamination. Cadmium is emitted to air and water by mines, by metal smelters (especially lead, copper, and zinc smelters), and by industries using cadmium in alkaline accumulators, alloys, paints, and plastics. The burning of oil and treatment of waste and scrap metal also contribute to pollution of the environment with cadmium. Its use in agriculture in fertilizers, either as chemicals or sludge from sewage plants, and the use of pesticides containing cadmium may contribute to the contamination.

Some cadmium is emitted to the air, but most is deposited in soil and water. The cadmium deposited in water may then increase the concentrations of cadmium in edible water organisms. In the event of flooding and irrigation, cadmium in water may also concentrate in soil, in turn causing an increased concentration in agricultural products such as rice and wheat. However, very little is known about the transfer of cadmium from deposits in soil or water to microorganisms or plants, or about the forms in which cadmium exists (Friberg, Piscator & Nordberg, 1971).

In areas not known to be polluted by cadmium, values of less than 1 ppb have been reported in water. Values exceeding 10 ppb have been recorded both in natural waters and in water for human consumption. Increased amounts of cadmium can be due to the contamination of the water either by industrial discharges or by the metal or plastic pipes used in distribution of water (Schroeder, Nason, Tipton & Balassa, 1962).

Yamagata & Shigematsu (1970) pointed out that in rivers polluted by cadmium, the metal will often be undetectable in the water phase, while large concentrations will be found in suspended particles and in the bottom sediments. This is especially true at neutral or alkaline pH. A similar finding was obtained in Sweden, where 500 meters downstream from a cadmium-emitting factory, 4 ppb of cadmium were found in water, while 80 ppm (dry weight) were found in the mud (Friberg, Piscator & Nordberg, 1971). To avoid errors when determining the degree of contamination in water, cadmium in the suspended particles or the sediments must be measured. The contamination of rice fields bordering the Jintsu River, Japan, causing the degenerating bone disease, Itai-itai, is probably due to the transport of cadmium-containing suspended particles to the paddy soil by irrigation with river water (Yamagata & Shigematsu, 1970).

The toxic effects of various compounds on schistosome cercariae have been documented. Griffith-Jones, Atkinson & Hassan (1930) reported that 1 ppm available chlorine and 1 ppm chloramine killed all cercariae in 2.5 to 3 hours and 1 hour, respectively. Hassan (1931) tested the toxicity of Ca, Au, Sb, As, Cu, I, Bi, Fe, Ag, Mn, Hg, and CaCl₂ to cercariae of *Schistosoma mansoni* and *S. hematobium* in triple-distilled water. Total kill of cercariae in one hour ranged from 10 ppm Ca to 50,000 ppm CaCl₂. Effects of aluminum sulfate, lime [Ca(OH)₂], and chloride on schistosome cercariae in river water were tested by Witenberg & Yofe (1938). Lime and aluminum sulfate were ineffective cercaricidal agents, while a concentration of 0.40 ppm available chlorine killed all cercariae in 1.5 hours. Jones & Brady (1947) found copper sulfate to be cercaricidal at a concentration of 50 ppm. DDT was found not to be sufficiently cercaricidal during practical applications. Cercariae were killed in 10 minutes in a chlorammine solution with 1 ppm residual chlorine at 1 minute. One tablet of potassium permanganate/iodine/iodate-citric acid in 1 liter of water killed cercariae in 5 minutes or less. A concentration of one gram per liter of