POSSIBLE RELATIONSHIPS BETWEEN TRICHINELLOSIS AND ABNORMAL BEHAVIOR IN BEARS

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Abstract: Data compiled from parasite studies of grizzly bears (*Ursus arctos*) and black bears (*U. americanus*) in the Yellowstone and Glacier National Park populations and surrounding areas of Montana and Wyoming during 1969–79 are reviewed with reference to the possible influence of infection with the muscleworm *Trichinella* sp. on bear behavior. In grizzly bears, the high prevalence of this parasite (61% of 254 bears infected), the elevated larval concentrations in sensitive anatomical sites such as the tongue (average, 51 larvae per gram of tissue), and the chronic nature of bear infections as indicated by the tendency for highest infection rates to occur in older age classes (≥ 16 yrs.), suggest a potential behavior-modifying effect might exist. However, retrospective analysis of recent human attacks by 4 grizzlies and 2 black bears in the northern Rocky Mountain region failed to demonstrate a consistent connection between erratic conduct and levels of *Trichinella* larvae (trichinae) in bear tissues. Clinical similarities of trichinellosis in bears and humans are hypothesized, and possible behavioral effects of ursine trichinellosis are discussed.

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Reasons for overly aggressive behavior of some bears which periodically results in human attacks have been the subject of considerable speculation. Despite retrospective attempts to analyze confrontations which led to bear assaults (Herrero 1970, 1974; Martinka 1971; Schneider 1977), uncertainties still exist as to the factors responsible for the belligerent behavior displayed under some circumstances by both grizzly and black bears. This paper considers the possible influence of infections with the muscleworm, *Trichinella* sp. in triggering antagonistic behavior which could lead to bear-human conflicts. Recent human encounters with bears which resulted in personal injury or death in the northern Rocky Mountain region are reviewed in an attempt to determine whether this parasite might play a part in triggering atypical bear conduct for which there presently is no explanation.

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CLINICAL ASPECTS OF MAMMALIAN TRICHINELLOSIS

Course of Infection

The classical course of muscleworm infection in man and domestic animals involves a short intestinal phase lasting 7 to 10 days after initial exposure (Gould 1970) during which the ingested trichinae mature, mate, and produce a new generation of larvae. Larval invasion of striated and cardiac muscle proceeds rapidly after the 2nd week of infection and results in a variety of clinical signs including severe muscle pain, fever, periorbital edema, and localized hemorrhages (Ribas-Mujal 1971). Other disease symptoms, including myocarditis and neurologic problems related to central nervous system involvement, are prominent during this period in some instances. In man, the entire disease syndrome following larval dissemination involves a series of clinical problems resulting principally from invasion of vital areas and interference with the normal function of the affected organs such as heart, respiratory system, brain, liver, and musculature. Severe muscle pain is one of the most prominent symptoms of human trichinellosis and occurs in a majority of patients (Kratz 1866). The severity of muscle pain is proportional to the size of the infective larval dose, which is in turn dependent

upon the body size of the subject. Larval parasite concentrations greater than 1 trichina per gram of tissue are thought to be capable of inducing clinical trichinellosis in humans (Zimmermann 1977). Valid assumptions about comparative thresholds of pain and the relative severity of bear and human infections are obviously very difficult to make because of species differences in responses to stimuli. Nonetheless, an examination of the various manifestations of human trichinellosis may provide clues to the response of bears to the same disease agent in a somewhat similar physiological setting.

Central Nervous System Involvement in Human Trichinellosis

In human trichinellosis, a variety of neurologic manifestations have been described in the medical literature, including psychotic behavior (Campbell 1947) and acute encephalitis resulting in a generalized inflammation of the meninges and brain (Dalessio and Wolff 1961). The later authors described a fatal *Trichinella* infection in a 45-year-old woman who experienced frontal headaches and blurred vision in addition to the usual muscle pain. This patient developed an uncharacteristic irascibility, and on occasion she became uncooperative and noisy. Additional cases cited by Dalessio and Wolff (1961) included at least 6 persons in which trichinae were found in the cerebrospinal fluid. Merritt and Rosenbaum (1936) reported observations on 13 patients with involvement of the central nervous system. In a later report, Sheldon (1941) described an epidemic of trichinellosis in which 9 of 53 patients showed some involvement of the nervous system. This figure was expanded to 31 documented cases by 1953 (Hurd 1953). In all instances cited, trichinae were found in a number of different locations other than the musculature or viscera, including free in the thalamus and embedded among the layers of the retina. Pathologic changes observed included generalized inflammation of the meninges and brain, with an associated edema which caused pressure and swelling of the affected tissue. Moser (1974) observed that cerebral inflammation induces coma in some trichinous patients. A total of 55 human trichinellosis cases involving the nervous system were reviewed by Dalessio and Wolff (1961); 70% of these patients were intermittently delirious, although less than 5% exhibited frankly psychotic behavior or hallucinations. Another case in which persistent mental abberation was associated with severe *T. spiralis* infection was described by Snape et al. (1956).

BEAR INFECTION LEVELS

A program of parasite screening in wildlife from the northern Rocky Mountain region has been conducted since 1968 (Worley et al. 1974, 1976). As part of this work, data were collected on the prevalence and intensity of *Tichinella* infections in black and grizzly bears. Findings for 1969–1979 are summarized below.

Methods

Various bear tissues were examined for the presence of trichinae using a standard peptic digestion technique described previously (Worley et al. 1974). Tongue, masseter, diaphragm, femoral muscle, temporal muscle, gastrocnemius, intercostal muscle, heart, and testis were screened initially. However, trichinae were found consistently only in the first 4 tissues listed, and these were the only areas sampled routinely. Approximately 25 g of each tissue were digested for 12–20 hours at 37 C in a solution of 0.7% hydrochloric acid and 0.8% pepsin. After washing on a 150- or 200-mesh screen to remove soluble debris, the retained material was examined for trichinae with a dissecting microscope. Results were expressed as larvae per gram of host tissue (LPG).

Results

Of 254 grizzly bears examined in the Yellowstone and Glacier National Park populations and elsewhere in the Rocky Mountain region during 1969–1979, 61% were positive for trichinae (Worley et al. 1974; Worley and Greer, unpublished data). Prevalence of the parasite varied slightly in relation to age and locality, but a majority of grizzlies were positive, with larval concentrations in tongue averaging 51 LPG. Both the rate of infection and average intensity were much lower in 225 black bears (9% and 18 LPG in tongue, respectively).

Distribution of trichinae in tongue, masseter, diaphragm, and thigh was compared in 42 grizzlies (Worley et al 1974). Results indicated that the tongue was a major predilection site, with an

Table 1. Density of *Trichinella spiralis* larvae in grizzly bears suspected of fatal human attacks in Yellowstone and Glacier National Parks, 1972–1980.

Bear accession No.	Sex	Age (years)	Collection site[a]	Suspected action	Trichinae in tongue (LPG[b])
68–72	F	19	Old Faithful area, YNP	Fatal mauling of camper (Jun 1972)	1.1
216–76	M	3	Many Glacier area, GNP	"Unprovoked" attack; subject died (Sep 1976)	578.4
220–80	M	5.5	St. Mary area, GNP	Killed 2 young campers (Jul 1980)	8.6
308–80	M	6–8	Belly River area, GNP	Killed hiker, fed on body (Sep 1980)	25.0

[a] YNP = Yellowstone National Park; GNP = Glacier National Park.
[b] LPG = larvae per gram of tissue.

average of 51 LPG. Average larval densities were progressively lower in thigh (17.1 LPG), masseter (14.2 LPG), and diaphragm (10.3 LPG).

The density of trichinae found in tissues of individual grizzly bears varied from 1 to 2449 LPG. Concentrations of trichinae in tongue exceeded 100 LPG in 7.8% of the grizzlies examined. A majority of these high-intensity infections occurred in bears from Yellowstone or Glacier Parks.

INFECTIONS IN BEARS ATTACKING MAN

Data pertaining to the *Trichinella* infection status of 4 grizzly bears involved in recent fatal human attacks in the northern Rockies are summarized in Table 1. All 4 animals were positive for trichinae, with densities in tongue averaging 153 LPG and ranging from 1.1 to 578 LPG.

578 LPG in the tongue of grizzly 216–76 (Table 1) was among the highest larval density we have ever measured. It was also approximately 10 times higher than the mean larval count for other positive bears from the same area of northwestern Montana. On the other hand, the 19-year-old grizzly that killed a camper in Yellowstone Park in June 1972 had only about 1 LPG (Table 1). This bear had a previous history of threatening behavior, and few parallels existed with the 1976 Glacier Park incident.

A similar incident involved a mature black bear which unexpectedly charged 2 men in the Trout Creek area of northwestern Montana in November 1975. The erratic behavior of this bear was somewhat suggestive of a rabid animal, but laboratory tests revealed no evidence of rabies. Both tongue and masseter were negative for trichinae, so that it was not possible to establish any definite relationship between clinical trichinellosis and the belligerent behavior displayed by this animal. A related episode involved an apparently unprovoked attack by a black bear on 2 female campers in the Gallatin Canyon in southwestern Montana in May 1979. The bear tore down a tent in which the girls were sleeping and reportedly began rolling them around in their sleeping bags (Bozeman Daily Chronicle, News Rep. 20 May 1979). No food or packs were stored in the tent, and the campsite was clean and free of any obvious attractants at the time of the attack. No evidence was obtained from this incident to suggest that trichinellosis played any role in motivating the attack, since larvae were not found in a sample of skeletal muscle from a bear believed to have been involved in the raid. Other factors which could not be readily identified apparently were involved in precipitating the exaggerated antagonistic behavior displayed by this black bear, which was not a park resident and presumably had not been conditioned to associate the presence of humans with the availability of food.

DISCUSSION

Studies of human trichinellosis suggest that at least 2 opportunities exist for migrating trichinae to influence the behavior of the host: (1) while larvae are actively tunneling through the skeletal muscles, where they ultimately separate the muscle fibers and assume an intracellular orientation in nurse cells (Purkerson and Despommier 1974), and (2) in high-intensity infections where larvae are distributed in extra-skeletal sites such as heart, eye, spinal fluid, and brain. In comparing the clinical and behavioral implications of trichinellosis in bears and humans, it seems likely that several similarities exist. First, it is probable that the majority of infections are asymptomatic in both species. It is estimated from human autopsy data that about 4% of the U.S. population harbor trichinae in their tissues (Zimmermann 1970). Of these, only 100–200 clinical cases are reported to the Center for Disease Control annually (CDC 1978 Annual Summary, Trichinosis Surveillance, Public Health Serv., Atlanta, 1979),

with the fatality rate ranging from 0 to 6%. Kershaw et al. (1956) stated that neurologic signs or symptoms occur in man only in trichinellosis cases where high concentrations of muscle larvae exist. This probably accounts for the infrequent reports of focal damage to the central nervous system in the human form of the disease.

In attempting to extrapolate these clinical and statistical criteria to bears, it was necessary to make an arbitrary assumption that larval concentrations exceeding 100 larvae per gram of tissue would be adequate to trigger dissemination of larvae into the central nervous system or other anatomical sites where their presence would be likely to affect host behavior. Based on this hypothetical threshold level, our 1969–1979 data for 254 grizzlies and 225 black bears suggest that perhaps 8% of the grizzlies and 1–2% of the black bears in the northern Rockies would harbor enough trichinae in vital areas to exhibit erratic or unpredictable behavior as a result of parasite-induced lesions. However, we could find only minimal evidence from recent bear–human encounters to suggest that trichinellosis may have played a part in these incidents.

Obvious difficulties exist in attempting to correlate disease manifestations and physiologic responses in different species. Therefore, valid judgments about the behavioral implications of trichinellosis in bears must await experimental studies with penned subjects maintained under controlled conditions. Until this is done, statistical evidence documenting the widespread occurrence of trichinae in grizzly populations in Yellowstone and Glacier National Parks and surrounding areas, and the occasional simultaneous occurrence of high levels of tissue infection and aggressive behavior, will serve only as circumstantial evidence that trichinellosis may be a behavior-modifying factor and perhaps contributes to erratic responses, particularly in bears which have frequent contact with people. The significantly lower prevalence and intensity of trichinae in black bears suggest that parasite-related confrontations would be much less likely to occur with that species. However, trichinellosis is sufficiently common in western populations of both species that its relationship to bear health in general and its influence on their behavior patterns in particular deserve continuing attention from bear biologists and wildlife disease specialists alike.

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