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Cysts of *Giardia* spp. in Mammals and Surface Waters in Southwestern Alberta

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Cysts of *Giardia* spp. from animal sources have been correlated with several waterborne outbreaks of giardiasis in the United States (Lopez et al., 1980, Am. J. Epidemiol. 112: 495–507; Dykes et al., 1980, Ann. Intern. Med. 92: 165–170; Lippy, 1981, J. Am. Water Works Assoc. 73: 57–62). No outbreaks of giardiasis in Canada have been proven to be waterborne, although circumstantial evidence was strong after outbreaks at Banff and Edmonton, Alberta, and 100 Mile House, British Columbia. Zoonotic transmission was suspected in the case of the Banff epidemic because infected beaver (*Castor canadensis* Kuhl) were found in 40 Mile Creek which supplied the town with water (Wilson et al., 1982, Can. Dis. Wkly. Rpt. 8-20: 97–98). Faubert et al. (1983, J. Parasitol. 69: 93–100) showed that the *Giardia* isolated from one of these beaver was of the *G. duodenalis* type and they presented evidence suggesting that it was biologically similar to human *Giardia*. Over 800 people were infected during the Edmonton outbreak and the disease was centered about one of the city's water treatment plants. The water was not tested for cysts, however, so it is impossible to be sure that the epidemic was waterborne.

Cysts of *Giardia* spp. from beaver have been shown to be infective for humans (Davies and Hibler, 1979, *In* Waterborne Transmission of Giardiasis, Jakubowski and Hoff (eds.), EPA-600/9-79-001, pp. 104–126) and dogs (*Canis familiaris* L.) can harbor human *Giardia* (Hewlett et al., 1982, J. Inf. Dis. 145: 89–93). Domestic cats (*Felis domesticus* L.) can also be infected with *Giardia duodenalis* (Felice) that is potentially infective for humans as shown by Belosevic et al. (1984, Can. J. Comp. Med. 48: 241–244). Frost et al. (1982, Giardiasis in Washington State, EPA-600/1-82-016, p. 7) found that muskrats (*Ondatra zibethicus* L.) were infected commonly in Washington state but no information is available regarding their human pathogenicity. Clearly animals have the potential to transmit *Giardia* to humans and the more closely associated an infected animal is with surface water bodies, the greater the possibility for outbreaks of waterborne giardiasis.

A survey of animal feces and surface water supplies was conducted from 1983–1984 to evaluate the potential for zoonotic transmission of giardiasis by surface waters in the Kananaskis-Banff area of southwestern Alberta. Fecal samples or whole carcasses (of microtines) were collected in the Kananaskis Valley and Banff National Park. Dog feces were collected from the Calgary Animal Shelter. Fecal specimens were collected only if they were still moist, had not been exposed to direct sunlight, and were judged to be fresh. All samples were preserved in SAF preservative, cysts were detected using the sucrose centrifugation method of Roberts-Thomson et al. (1976, Gastroenterology 71: 57–61) and observed by light microscopy after staining with Lugol's iodine (Wallis et al., 1984, J. Wildl. Dis. 20: 279–283). Small rodents were killed and duodenal scrapings were examined for trophozoites using dark phase contrast microscopy for all meadow

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voles (*Microtus pennsylvanicus* Ord), red-backed voles (*Clethrionomys gapperi* Vigors), heather voles (*Phenacomys intermedius* Merriam), and deer mice (*Peromyscus maniculatus* Mearns) because it was difficult to obtain fresh feces from small rodents and low prevalences of cyst detection were found in animals known to be infected. Initial results from an animal survey in southwestern Alberta (Wallis et al., 1984, op. cit.) showed that 33% of small rodents, 3.5% of beaver, 5% of dogs, and 1% of human fecal samples contained *Giardia* cysts.

Cysts were detected in water using the filtration method of Wallis and Buchanan-Mappin (1985, Water Res. 19: 331–334). Samples were taken from 34 beaver ponds (all containing beaver), the Bow River at Exshaw and Canmore, sewage effluent from Canmore, three residential surface water supplies, and drinking water supplies at 10 public campgrounds in Banff National Park. Beaver feces were collected from the water after samples were taken from beaver ponds. Additional samples were taken at a later date if cysts were detected in either water or feces. Objects were identified as *Giardia* cysts only if they were perfectly elliptical, were from 8 to 16 μm long, and had visible internal features (nuclei, median bodies and axostyles).

Fecal specimens from meadow voles (75% positive, $n = 6$), red-backed voles (86% positive, $n = 21$), heather voles (50% positive, $n = 2$), beaver (4% positive, $n = 51$), dogs (22% positive, $n = 79$), and wood rats (*Neotoma cinerea* Ord, 7% positive, $n = 15$) contained cysts of *Giardia*. No cysts were found in specimens from deer mice ($n = 25$), black bear (*Ursus americanus* Pallas, $n = 22$), grizzly bear (*Ursus arctos* Merriam, $n = 2$), mountain goats (*Oreamnos americanus* Allen, $n = 3$), mountain sheep (*Ovis canadensis* Shaw, $n = 1$), cattle (*Bos taurus* L., $n = 8$), elk (*Cervus elaphus nelsoni* Bailey, $n = 1$), moose (*Alces alces* L., $n = 4$), human (*Homo sapiens* L., $n = 6$), or coyotes (*Canis latrans* Say, $n = 2$).

The results from 1983 (Wallis et al., 1984, op. cit.) and those reported in the present paper both show that microtines are the most commonly infected animals in this area. When all of the data were combined, the overall prevalences for microtines were as follows: meadow voles 50% ($n = 10$), deer mice 7% ($n = 75$), red-backed voles 91% ($n = 42$), and heather voles 17% ($n = 6$). Dogs were infected with a prevalence of 18% ($n = 101$). Most of the infected dogs, however, were found at the Calgary Animal Shelter and not in the Kananaskis-Banff region. It was assumed that prevalences of *Giardia* infection among the dogs that were running loose in the Kananaskis-Banff region were similar. The prevalence of infection among beaver was lower (4%, $n = 109$); humans (1%, $n = 88$) and wood rats (7%, $n = 15$) were the only other carriers of *Giardia* identified.

According to Felice (1952, Univ. Calif. Publ. Zool. 57: 53–143) there are only two species of *Giardia* that infect mammals, *G. muris* and *G. duodenalis*. We were unable to identify to species the *Giardia* we isolated on the basis of morphology. Morphometric measurements were taken from trophozoites stained with Giemsa stain but the results did not conform clearly to any one species of *Giardia* as defined by Grant and Woo (1978, Can. J. Zool. 56: 1348–1359) nor could clear distinctions be made on the basis of the shape of the median body. These findings were in agreement with those of Bertram et al. (1984, J. Parasitol. 70: 530–535) who concluded that the usefulness of morphometric measurements for speciation was at best limited. The only solid information we have regarding the identification of the *Giardia* spp. encountered during this study is that trophozoites taken from gerbils infected with *Giardia* from humans, dogs, and beaver have been cultured using Diamond's TYI-S-33 medium in our laboratory. Despite repeated attempts, we have not been able to culture *Giardia* from deer mice and voles. We believe, therefore, that we have isolated at least two distinct forms of *Giardia*, probably *G. duodenalis* and *G. muris*.

Very little experimental evidence is available regarding the pathogenicity of *G. muris* in humans, but it is generally considered non-infective to man. Very few attempts to introduce *Giardia* from humans to laboratory mice (*Mus musculus* L.), laboratory rats (*Rattus norvegicus* Berkenhout), and hamsters (*Mesocricetus auratus* Nehring) have been successful (Grant and Woo, 1978, op. cit.; Davies and Hibler, 1979, op. cit.), although the reverse experiment has not yet been undertaken. We have no evidence to suggest that the *Giardia* we isolated from mice and voles was infective to humans, but this possibility cannot be ruled out.

Giardia duodenalis is similar to human *Giardia* and includes the *Giardia* found in dogs, cats, and beaver (Belosevic et al., 1984, op. cit.; Faubert et al., 1983, op. cit.). Experimental data demonstrating cross-infection between these animals and humans are not abundant, but Hewlett et al. (1982, op. cit.) and Davies and Hibler (1979, op. cit.) have shown that dogs can become infected with *Giardia* from humans. Davies and Hibler (1979, op. cit.) were able to infect two out of three humans with *Giardia* from beaver and Dykes et al. (1980, op. cit.) infected pathogen-free beagles with *Giardia* from beaver. It was therefore possible that the *Giardia* isolated from beaver and dogs was of the *G. duodenalis* type and was infective to humans. Based on this possibility, we concluded that the potential exists for zoonotic transmission of giardiasis in the Kananaskis-Banff area, particularly from dogs and beaver.

Cysts were found once in the Bow River at Exshaw and twice in Lusk Creek Pond. Beaver feces containing cysts were found in Lusk Creek Pond on both occasions, but no feces were found at the Bow River site. All other water samples and fecal samples taken from them did not contain *Giardia* cysts. Despite their low prevalence of infection, beaver are probably the most important animal reservoir of the parasite in the waterborne transmission of giardiasis because they inhabit surface water used for drinking purposes. The detection of cysts in Lusk Creek Pond, which was known to be inhabited by an infected beaver, demonstrated the potential for waterborne transmission of giardiasis in this area.

Samples were taken from the Bow River at Exshaw in response to a request from the Mountview Health Unit (Canmore). A local factory was using untreated Bow River water for drinking purposes and nine workers came down with giardiasis in June 1984. Three of these men had positive stool examinations and the rest were treated without laboratory confirmation. The water supply for the plant was changed soon after cysts were found in the water and no further cases occurred. The men who contracted giardiasis were living in three different communities in the area and had no other common activities except employment at this factory. Beaver are known to inhabit the banks of the Bow River above and below the plant, but no fecal specimens were found because the river is too large for beaver dams and feces are quickly washed away. The town of Canmore discharges its treated sewage into the Bow River 15 km upstream of Exshaw and a number of cases of giardiasis were known to be present in the town at the time. It is therefore uncertain whether the cysts in the water were from human or animal sources.

It is difficult to prove that an outbreak of giardiasis was caused by transmission through water and even more difficult to show that the source of *Giardia* was nonhuman. The detection of cysts in water is difficult, even when efficient filters are used, because of the problems in distinguishing cysts from all of the other similarly shaped objects in the same size range. The results from the survey of water bodies, therefore, are probably underestimates of the actual occurrence of *Giardia* cysts. For example, three samples were taken from Lusk Creek Pond in 1984, two of which were positive. Beaver feces were taken from the pond on a number of occasions and negative specimens were often found. Apparently beaver, like humans, do not excrete cysts continuously. The beaver in Lusk Creek Pond were found to be passing cysts intermittently from May to December 1984, but four samples taken in the spring of 1985 were all negative. Despite the occurrence of negative beaver feces, it is probable that cysts were present in the pond at all times and the fact that cysts were not always detected may have been caused by the insensitivity of the method rather than the intermittent passage of cysts.

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Cysticerci of *Taenia regis* Baer, 1923 in Reedbucks, *Redunca redunca*, in Eldindir National Park, Sudan

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A visit was made to Eldindir National Park in the southeastern part of the Sudan to investigate mortalities among reedbucks (*Redunca redunca*). Four animals (three males and one female) were examined at necropsy. The postmortem revealed a generalized parasitic infection. Many cysticerci were recovered from liver, lung, skeletal muscles, heart and spleen. In the liver capsule, many cysticerci were located between the liver and gall bladder and on the diaphragmatic surface. The ventral parts of the apical, cardiac and diaphragmatic lobes of both lungs contained many cysticerci as did the skeletal muscles of the hind limbs. In one case two cysticerci were detected in the left ventricle of the heart attached to the endocardium and in another the splenic capsule contained many cysticerci. Several were seen in the kidney capsule and the fat around it and also around the urinary bladder.

The reddish brown elongated cysticercus measured 2–3 cm in length and 0.4–0.6 cm in width and was filled with watery fluid. The scolex was invaginated into a long separated neck. Microscopically, the rostellum had 30 to 36 hooks in two rows. This description is closely similar to that of Verster (1969, Onderstepoort J. Vet. Res. 36: 3–58). The cysticercus was identified by L. F. Khalil (Commonwealth Institute of Parasitology, 395A Hatfield Road, St. Albans, Herts AL4 0XU, England) as *Taenia regis*. Voucher specimens have been deposited in the Commonwealth In-

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