MAJOR ARTICLE

Novel Prevention Program for Trichinellosis in Inuit Communities

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Repeated outbreaks of trichinellosis caused by the consumption of *Trichinella*-infected walrus *(Odobenus rosmarus)* meat, which have sometimes led to serious morbidity, have stimulated Inuit communities in Nunavik (northern Quebec), Canada, to develop an innovative trichinellosis prevention program. The program involves preconsumption testing of meat samples from harvested walrus at a regional laboratory and the rapid dissemination of the results of such testing to communities. Local health authorities in Inukjuak conducted an epidemiological investigation after testing identified *Trichinella*-positive walrus meat in September 1997. This report describes the events that occurred before, during, and after the trichinellosis outbreak and also documents how the prevention program contributed to successful resolution of the outbreak.

Trichinellosis was first reported in Canada in the 1870s, but, in the Canadian Arctic, it was not identified in animals until the 1930s or in humans until the 1940s [1–4]. Two types of clinical presentation of trichinellosis—myopathic and gastrointestinal—have been observed in the Arctic; both types are associated with occasional severe, prolonged, and debilitating forms of infection [5]. Repeated and recent outbreaks in remote communities in the eastern Arctic—in particular, in Nunavik, the northern region of Quebec—have stimulated the development and testing of new preventive measures (figure 1) [5–7].

In 1998, Nunavik had a population of 8929; of these individuals, 85% were Inuit (aboriginal) [11]. The outbreak of trichinellosis described in the present report and the public health activities that subsequently occurred involved the communities of Inukjuak and Puvirnituq, each of which has a population of ~1200 individuals. Inukjuak and Puvirnituq are located on the east coast of Hudson Bay, 1400 and 1600 km north of Montreal, respectively. Nunavik has no roads that link the region with the southern part of Quebec.

A total of 11 outbreaks of trichinellosis were documented in the region between the time of the first recorded outbreak in 1982 and that of the outbreak recorded in January 1999, which affected a total of 86 people [12]. The largest outbreak occurred in 1987 and resulted in 42 cases [5]. For 9 of the outbreaks, epidemiological investigations determined that the source of infection was raw or insufficiently cooked walrus *(Odobenus rosmarus)* meat. For the remaining 2 outbreaks, the source of infection was insufficiently cooked meat from an arctic fox *(Alopex lagopus)* and a polar bear *(Ursus maritimus)* [13, 14]. Laboratory confirmation of the presence of *Trichinella* larvae was obtained in 3 of these outbreaks [5, 12, 13]. Walrus meat and polar bear meat have been incriminated as sources of trichinellosis in humans in the Arctic, from Greenland to Alaska [3, 8, 15]. In Nunavik, it is estimated

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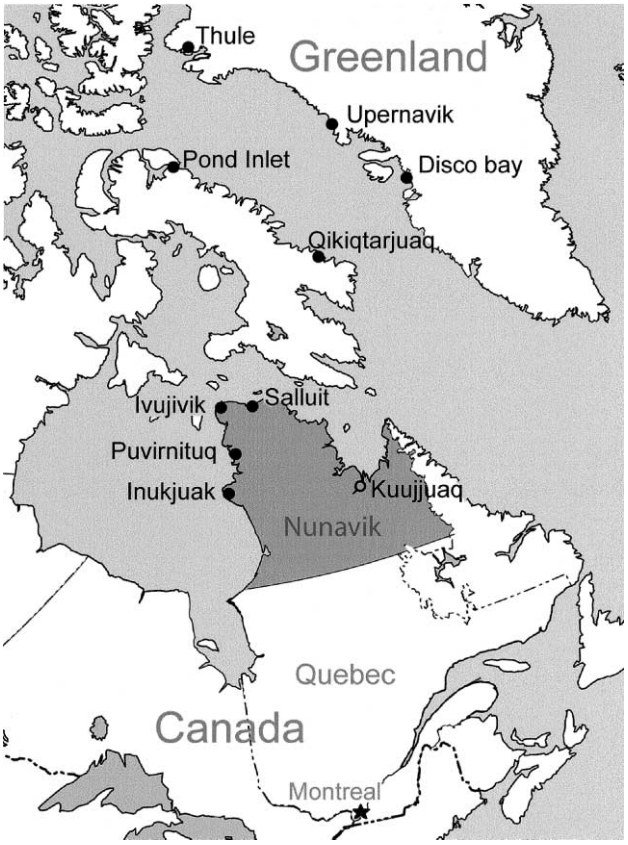

Figure 1. Reported outbreaks of trichinellosis during the past 50 years *(filled circles)* [5–10]. The 1997 outbreak of trichinellosis occurred in Puvirnituq and Inukjuak. *Open circle,* Nunavik Research Centre, Kuujjuaq.

that 60% of polar bears, the meat of which is traditionally cooked before being eaten, are carriers of *Trichinella* larvae, whereas 2%–4% of walrus, the meat of which is frequently raw or fermented *(igunaq)* when eaten, appear to be infected [2, 16, 17]. Walrus are a significant proportion of the marine mammal species that are traditionally hunted for subsistence [18]. Prevention of trichinellosis in the Arctic does not depend on freezing, which is the natural and readily available form of meat storage, because exposure to freezing temperatures for several months does not affect the infectivity or the pathogenicity of *Trichinella nativa* [19].

In 1992, a trichinellosis prevention program for residents of Nunavik was initiated. It progressively offered all municipalities the opportunity to test selected samples of meat from newly harvested walrus for the presence of *Trichinella* larvae [20]. A pamphlet and a video that described the disease, the life cycle of the parasite, and the program were produced and were widely distributed to the public and local authorities. Hunters received training in sample-collection procedures.

In the communities of Inukjuak and Puvirnituq, most of the annual harvest of walrus is performed in early autumn (September–October). Hunters in 2 or 3 community boats travel to islands located 60–200 km offshore, and they usually catch 2–6 animals per boat (average weight of an adult male walrus, 900 kg). The guidelines of the prevention program state that, at the time of a hunt, all butchered pieces of meat should be tagged, and a fist-sized piece of meat should be obtained from each of 4 muscle groups (i.e., tongue, digastricus, intercostals, and pectorals) of each walrus for use in the detection of *Trichinella* larvae. Once the hunters return to the community, the collected meat samples are flown to the Nunavik Research Centre in Kuujjuaq on the next available flight. Hunters are advised not to distribute or consume any walrus meat before the results of the analyses are made available.

For the screening procedure performed at the Nunavik Research Centre, $\geqslant$20 g of meat from a minimum of 3 distinct muscle groups, including the tongue, must be available from each animal. This material is analyzed using a magnetic stirrer method for pooled digestion [21, 22]. First, a pooled sample of muscle tissue from 5 walrus is tested; if results are positive, samples from individual walrus are tested separately. Quantification and speciation are conducted at the Centre for Animal Parasitology, Canadian Food Inspection Agency (Saskatoon, Saskatchewan), by use of the same official Canadian Food Inspection Agency double separatory-funnel method that is used for the detection of *Trichinella* larvae in horse meat, with the following modifications: all digestions are conducted at a temperature of 37°C, and all samples are digested in a shaker water bath [21]. DNA is extracted from *Trichinella* larvae isolates, and species-specific primers are used in a PCR assay to determine the presence of *Trichinella* species [23].

In 1997, six of the 8 Nunavik communities that conducted a walrus hunt participated in the prevention program. Meat samples from 31 (41%) of 76 harvested walrus were obtained and analyzed. During the preceding year, 44 (65%) of 68 walrus had been tested. These 2 findings show improvement over findings obtained during the initial 4 years of the program (1992–1995), when only 1 community participated in the program (samples from 51 [16%] of 316 walrus were tested).

For 1997, data from these communities also revealed an average interval of 7 days (range, 2–19 days) between the day on which the hunt occurred and the day that the test results were available. The Nunavik Research Centre had a sample-processing time of <24 h. Compliance with program recommendations varied from community to community, with some communities, such as Inukjuak, allowing the meat to be distributed to households inside and outside the village before the results of the tests are made available.

September 1997 marked the second year since the program had been implemented in the 2 study communities affected by the outbreak described here. Alerted by tests that were positive for *Trichinella* infection of walrus meat, local health authorities in Inukjuak conducted an epidemiological investigation in Sep-

tember 1997. The present report describes the events that occurred before, during, and after the trichinellosis outbreak and also documents how the prevention program contributed to the successful resolution of the outbreak.

OUTBREAK INVESTIGATION

On 10 September 1997, Inukjuak hunters harvested 5 walrus near Sleepers Islands in eastern Hudson Bay. Pieces of meat from each walrus were properly tagged and transported by air to the regional testing laboratory 5 days later. *Trichinella* larvae were found during screening of the pooled sample. This result was immediately communicated to the municipal authorities of Inukjuak, who, on the same day, informed the community by radio that no meat should be consumed until further notification was given. Two days later, retesting of samples from individual walrus confirmed that 2 of the 5 walrus were infected with *Trichinella* larvae. Confirmatory testing determined that the infection intensity levels of the tongue samples from the 2 infected walrus were 44 and 20 *Trichinella* larvae/g. PCR identified the parasite as *T. nativa*. Because all pieces of meat had been tagged, and because distribution of meat in the community had been recorded, local authorities were able to trace and recall the meat from the 40 households in which it was stored. This meat was later destroyed by incineration.

In the 6 days between the landing of the walrus harvest and the availability of the test results, it became known that a number of community members had eaten meat from one or both of the animals that tested positive for *Trichinella* larvae. Through announcements made on local radio, all consumers of infected meat were invited to the clinic for evaluation. A total of 27 community members presented at the clinic and completed a short questionnaire that documented the consumer's age and sex, the tag number of the walrus that had been eaten, the date(s) of ingestion, the amount of meat eaten and its mode of preparation (cooked vs. raw), and the presence, nature, and date(s) of onset of symptoms or signs, if any, that suggested the presence of trichinellosis (e.g., fever, skin rash, diarrhea, or muscle aches) (table 1). For evaluation of anti-*Trichinella* antibody levels (by ELISA), complete blood count, and the serum creatinine phosphokinase level, blood samples were collected from all persons who had eaten raw walrus meat ($n = 11$) or who had eaten cooked walrus meat but had presented with possible early symptoms of trichinellosis ($n = 5$). Anthelmintic chemoprophylaxis with mebendazole, 100 mg po twice daily for 3 days, was immediately started. Administration of medication was initiated at a mean of 7 days (range, 5–11 days) after consumption of the infected meat, for the group that had eaten raw meat, and at a mean of 12 days (range, 9–14 days) after consumption, for the group that had eaten cooked meat. The decision to use mebendazole was based on the known high attack rates (~50%) associated with previous outbreaks [5, 15], the potential seriousness of the disease, the availability and interest of health services personnel who provide first-line care, the limited secondary effects of the medication, and the low cost of the intervention. All 16 persons who were

Table 1. Characteristics of consumers of infected meat identified during an outbreak of trichinellosis in 2 Inuit communities in northern Quebec in September 1997.

Community, individual	Sex	Age, years	Type of walrus meat consumed	Received mebendazole prophylaxis	Case status
Inukjuak					
1	F	41	Raw	Yes	SC
2	F	66	Raw	Yes	−
3	F	59	Raw	Yes	−
4	F	62	Cooked	Yes	−
5	M	59	Cooked	Yes	−
6	M	33	Cooked	Yes	−
7	F	65	Cooked	Yes	−
8	M	38	Raw	Yes	−
9	M	39	Raw	Yes	−
10	F	59	Raw	Yes	−
11	F	59	Raw	Yes	SC
12	F	61	Cooked	No	−
13	F	72	Raw	Yes	SC
14	F	31	Raw	Yes	−
15	F	57	Cooked	No	−
16	F	1.7	Cooked	No	−
17	F	19	Cooked	No	−
18	M	13	Cooked	No	−
19	F	23	Cooked	No	−
20	M	60	Cooked	No	−
21	F	66	Raw	Yes	−
22	M	60	Cooked	No	−
23	F	68	Cooked	No	−
24	F	65	Cooked	No	−
25	F	NA[a]	Cooked	No	−
26	NA[b]	NA[a]	Cooked	No	−
27	F	69	Cooked	Yes	−
28	F	26	Raw	Yes	−
29	F	70	Raw	No	+
Puvirnituq					
1	M	NA	Cooked	No	−
2	M	43	Raw	No	+
3	F	43	Cooked	No	+
4	F	55	Cooked	No	−
5	F	45	Raw	No	−
6	M	NA	Cooked	No	−
7	M	13	Raw	No	−

NOTE. NA, not available; SC, seroconversion; +, developed trichinellosis; −, did not develop trichinellosis.

[a] Most likely an adult.

[b] Most likely male.

offered chemoprophylaxis accepted the medication and took it as prescribed.

Active surveillance was maintained for 6 weeks and included documentation of any illnesses that were compatible with trichinellosis, in addition to collection of acute-phase and convalescent-phase serum samples for determination of anti-*Trichinella* antibody levels. Trichinellosis was defined by the presence of the following criteria: (1) clinical manifestations (muscle pain, weakness, or diarrhea) of >48 hours' duration and (2) either a single antibody titer (as determined by ELISA) with an optical density (OD) of ⩾2.0 (high positive), or seroconversion (change from a negative to a positive test result [OD cutoff value, 0.3]) between acute-phase and convalescent-phase serum samples that involved at least a 4-fold increase in the antibody titer, or a single antibody titer greater than the diagnostic titer (OD, 0.3) plus a blood eosinophil level greater than 1.5×10^9 cells/L (1–12 weeks after ingestion).

Serologic analysis for the detection of *Trichinella* larvae was performed at the National Centre for Parasitology (Serology), Montreal General Hospital, by use of an ELISA kit (LMD Laboratories) that incorporated purified excretory/secretory antigen from the larvae of *Trichinella spiralis* [24]. Serum samples were tested in duplicate, and analyses of comparative titers were done in parallel. Control serum samples included 3 samples that were provided in the kit (2 were positive and 1 was negative) and 3 samples provided by the National Centre for Parasitology (Serology) (2 of which were clinically confirmed to be positive and 1 of which was confirmed to be negative).

During the surveillance period in Inukjuak, 2 additional consumers of walrus meat were found. One was a 70-year-old woman with acute trichinellosis who had consumed raw walrus meat but who had not responded to the initial call to receive medical attention. Two additional cases of trichinellosis were confirmed in the neighboring community of Puvirnituq, located 200 km north of Inukjuak. This community had also conducted an autumn walrus hunt; however, all walrus harvested had been analyzed and had been found to be free of *Trichinella* larvae. The source of the infection became apparent after the responses to a questionnaire were reviewed. A gift of walrus meat had been received from the hunting party from Inukjuak; 7 individuals had consumed this meat (3 had eaten raw meat, and 4 had eaten cooked meat). No other local sources of infected meat were discovered. Pieces of the meat that had been given as gifts were recovered and analyzed and were confirmed to have positive test results at the Nunavik Research Centre. No chemoprophylaxis was offered to individuals in Puvirnituq because of the long delay between the time when the infected meat was consumed and the time when the consumers were identified.

If results from both communities are combined, there were more female ($n = 24$) than male ($n = 12$) consumers of infected meat; the average age of these 36 individuals was 57 years, which is significantly higher than the average age of the entire population (~22 years). Cases of trichinellosis resulted from the consumption of meat from both walrus that tested positive for *Trichinella* larvae and from the consumption of large as well as small amounts of meat. None of the individuals who were receiving chemoprophylaxis ($n = 16$) developed the disease, but 3 (15%) of the 20 who did not receive chemoprophylaxis *did* develop the disease. Of the 15 individuals who had consumed raw walrus meat, 2 of 4 individuals who had not received chemoprophylaxis and 0 of 11 individuals who had received chemoprophylaxis developed the disease. One case of trichinellosis was related to the consumption of cooked walrus meat.

Paired acute-phase and convalescent-phase serum samples were collected from 10 of the 27 consumers of walrus meat in Inukjuak; 3 of these paired samples revealed seroconversion. These 3 samples were obtained from among 11 asymptomatic individuals who had eaten raw walrus meat and who had received mebendazole prophylaxis.

DISCUSSION

To our knowledge, Nunavik is the only Arctic region in which a primary prevention program for trichinellosis in humans is based on laboratory analysis of meat samples from wild animal species. This program is strongly supported by local and regional Inuit organizations, because the cultural practice of consuming raw walrus meat is widely prevalent, particularly among adults, and because there is a heightened community awareness of trichinellosis as a result of the numerous recent outbreaks that have occurred. It is a commonly shared goal of regional Inuit community and public health authorities to promote the use of regional food sources, including marine mammals, as the optimal nutrition base in the northern region, despite documentation of high levels of contaminants, such as mercury and organochlorines [25, 26], in such foods and despite the risks of botulism [14, 27] and trichinellosis [5–7, 11–14]. This study records the first preconsumption identification of *Trichinella*-positive walrus meat since a trichinellosis prevention program was implemented in 1992 and also provides insight into the program's effectiveness. The effectiveness of the program depends on several factors, including the validity of the tests used, the proportion of harvested walrus from which samples are tested, compliance with the distribution and restrictions on consumption of temporarily stored walrus meat, the delay between the arrival of the walrus harvest in the community and the availability of test results, the efficiency of the local communication system, and compliance with any subsequent health advisory, in the event that positive test results are obtained.

The digestion test procedure used in this program has limitations. The preferred tissue localization sites for *T. nativa* larvae in walrus are not known. They may be similar to those of *T. spiralis* larvae, but localization sites for this species differ according to the host animal. For example, the most heavily parasitized tissue is the tongue or masseter muscle in horses and the diaphragm or tongue in swine [28]. Determination of the preferred localization sites in walrus is important for optimizing the sensitivity of the test as well as simplifying the sample-collection procedure used by the hunters. Also, the digestion test used for the recovery of *Trichinella* larvae from walrus meat is based on methods developed for other species. The existing procedure has a slow sample throughput, is inefficient, and lacks the quality controls appropriate for walrus meat. *Trichinella* test-validation data and quality-assurance systems that meet internationally accepted guidelines have been developed for pork and for horse meat, and they need to be established for walrus meat as well [29, 30].

In the 2 communities that were affected by the trichinellosis outbreak in 1997, samples of meat from all walrus (5 in Inukjuak and 4 in Puvirnituq) were submitted for analysis immediately after the hunt occurred. However, although the program permitted the early identification of 2 *Trichinella*-infected walrus, it failed to prevent 36 individuals from consuming infected meat before test results became available. It is likely that additional individuals would have been infected if there had been any delays in the reporting of the results and in communicating them to the community.

The test turnaround time of 6 days was affected by delays in the transportation of collected meat samples on scheduled local flights and by weather conditions. The <24-h processing time for pooled samples at the Nunavik Research Centre was excellent, as was same-day communication of test results to the community. That no reports of consumption of infected walrus meat in Inukjuak occurred subsequent to the radio broadcast confirms that the collection of infected meat was complete in both communities. The primary prevention program was successful because of the excellent compliance of hunters with tagging, sampling, and shipping requirements; the relatively rapid and reliable performance of the laboratory procedures; and the quality of the recall system used in both communities. Problems remain regarding the distance of the test laboratory from the hunting communities and the as-yet-incomplete compliance of community members with the ban on consumption of walrus meat before test results become available. The compliance of hunters and municipalities with voluntary measures, such as avoidance of the distribution and consumption of meat before testing, may prove more difficult to achieve in communities in which the program is new and in which outbreaks of trichinellosis are not frequent.

It is reasonable to consider that a major outbreak of trichinellosis was prevented in Inukjuak and Puvirnituq in the fall of 1997. Past Nunavik and Alaskan outbreaks have recorded up to 88 consumers of meat from a single walrus, with attack rates of 62% and 64%, respectively [5, 15]. With no prevention program in place, and with the potential for widespread consumption of meat from infected animals (as could occur on the occasion of community feasts), an outbreak involving ⩾100 people was possible. The small size of the current outbreak was attributed to the primary prevention program that has been implemented by both communities since 1996. This prevention program probably restricted massive consumption of untested infected meat and permitted the early identification of 2 *Trichinella*-positive animals and the consumers of their meat. This allowed for the introduction and evaluation of a secondary prevention measure that appears to have further limited the magnitude of the outbreak.

There have been few descriptions of secondary prevention of clinical trichinellosis by use of chemoprophylaxis during the incubation period [31, 32]. A large study from Russia described the successful prevention of symptomatic trichinellosis in 148 cases that were treated with thiabendazole or mebendazole during the incubation period [32]. The timing of treatment was not clear, and, in severe cases, the incubation period was unusually long (19 days), compared with the standard incubation periods noted for cases reported from Europe (7.6 days for severe infections, 16 days for moderate infections, and 21 days for minor infections) and for other documented outbreaks in the Arctic (10–13 days) [5, 33]. These studies have reported that there is a window of opportunity of up to 2 weeks for the use of chemoprophylaxis during the incubation period. In the present study, chemoprophylaxis was administered ~7 days after the infected meat was consumed. In a previously reported study from Nunavik, it was determined that the incubation period varies from 6 to 20 days for the classic primary form of *Trichinella* infection (myopathic form) and from 5 to 16 days for the secondary (gastrointestinal) form of the disease [5]. The success of mebendazole prophylaxis is suggested by the lack of clinical cases among individuals who received such prophylaxis and by confirmation of exposure to *Trichinella* larvae after seroconversion was revealed in 3 paired acute-phase and convalescent-phase serum samples from asymptomatic individuals.

Reports of this 1997 trichinellosis outbreak and the efforts that were made to control it were widely communicated to the public, and all regional hunting communities expressed the intention to join the prevention program in 1998. By 2001, all 8 communities that were involved in the hunting of walrus were participating in the control program, resulting in submission of meat samples from 98% ($n = 53$) of harvested wal-

rus. The control program found that 6 (11%) of 53 walrus were infected with *Trichinella* species; no cases of trichinellosis occurred in humans. Outside of the Nunavik control region, trichinellosis outbreaks continue to occur [10]. Challenges lie ahead, especially in maintaining the full compliance of hunters and communities with regard to all aspects of the prevention program. One immediate research need concerns the development of procedures for conducting screening tests in the field. Although serodiagnostic screening tests, such as the recently developed lateral flow card test, hold some promise, other important considerations remain, including those regarding intensity of infection, *Trichinella* species, and host specificity [34]. Nevertheless, the feasibility of the current program suggests that it could be implemented in other Arctic or remote regions that are supported by well-developed flight networks that could ensure the transport of tissue samples obtained from walrus or other wild animals to local or central diagnostic facilities.

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