ORIGINAL RESEARCH ARTICLE

From science to action and from action to science: the Nunavik Trichinellosis Prevention Program

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Objectives. During the 1980s, walrus-meat consumption caused infections with the parasite *Trichinella nativa* in Nunavik inhabitants. In response to these events, stakeholders set up the community-based Nunavik Trichinellosis Prevention Program (NTPP). The objectives of the present communication are to review the NTPP, describe how science and action were interwoven in its development and identify its assets and limitations.

Study design. Descriptive study.

Methods. The NTPP relies on a pooled digestion assay of tongue samples taken from each harvested walrus. The public health recommendations depend on the results of the analyses: infected walrus meat should be destroyed; parasite-free meat may be eaten raw or cooked.

Results. All communities involved in the walrus hunt participate in the NTPP and a high percentage of harvested walruses are included in the NTPP. Infected animals account for 2.9% of the walruses tested (20/694) since 1992. The NTPP permitted the early management of a trichinellosis event in 1997. Since then, it prevented the new occurrence of outbreaks related to walruses hunted by *Nunavimmiut*.

Conclusions. The absence of recent major outbreaks of trichinellosis in Nunavik may reasonably be attributed to the NTPP. The success of the program stands on many facilitating factors such as the nature of the disease and its source, the existence of an efficient analytic method, the strong involvement of the different partners including direct resource users, as well as the comprehensive bidirectional science-to-action approach that has been followed.

Keywords: *trichinellosis*; *prevention*; *Inuit*; *walrus*; *Trichinella nativa*

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Approximately 10,000 Inuit people live in the 14 isolated communities of Nunavik, the arctic region of Québec (1). They compose 90% of the regional population. Country food represents a significant alimentary resource in the region (16% of energy intake in 2004) (2). Walrus (*Odobenus rosmarus*) is one of the animals regularly harvested for food in more than half of the communities. Walrus hunting generally takes place between the months of July and September on Ungava Bay and in September and October on Hudson Bay. Hunters travel in community boats to offshore islands (3). Walrus meat, which is widely shared within villages, is either eaten raw, fermented (*igunaq*) or cooked. It provides a good source of healthy local food, compared to highly processed commercial food. The walrus hunt is also part of the Inuit culture and plays important socio-economic roles (4).

Despite the positive impact of walrus harvesting on Inuit communities, the consumption of undercooked meat represents a zoonotic hazard since walruses are occasionally infected by *Trichinella nativa* (5).

Nunavik Inuit and trichinellosis

Trichinella nativa is the most northern species of *Trichinella* spp. This intracellular nematode parasite is mainly found in carnivores, such as bears, arctic foxes,

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wolves and walruses. In Nunavik, the estimated prevalence of *T. nativa* in walruses (2–4%) is lower than in polar bears (*Ursus marinus*) (60%), but is much higher than what has been observed in other marine mammals (3,5,6). As it is often eaten raw, walrus meat is the most frequent source of trichinellosis in the Arctic (5,7–11). After ingestion of infected meat, larvae rapidly develop into adult worms in the host intestine (12,13). First-stage larvae (L1) are shed and then migrate via the intestinal lymphatic vessels and blood circulation to the striated muscular cells (12,14). Since larvae of *T. nativa* are destroyed by heat (in 1 minute at 67°C), the consumption of properly cooked meat does not represent a risk of infection. On the other hand, in contrast to *T. spiralis*, *T. nativa* larvae resist long-term freezing. Consequently, this method of preservation does not prevent transmission of *T. nativa* in people. Infectivity of larvae decreases after meat fermentation, but their inability to survive in *igunaq* is still equivocal (15,16). Limited evidence suggests that *T. nativa* may be highly infective for humans. Clinical diseases were found in people who had eaten meat containing 1–4 larvae per gram (5,7).

Trichinellosis is classically characterized by an incubation phase of 6–20 days, followed by a short gastro-intestinal phase associated with the adult parasites. Fever, myalgia, facial oedema, rash, increased muscle-enzyme level in blood and eosinophilia are common clinical findings associated with the migrating larvae (10). A chronic gastro-intestinal syndrome, characterized by prolonged diarrhoea without prominent muscular signs, has also been described in Inuit people (9,10). Clinical and serologic evidences suggest that the classical myopathic form occurs at first infection by *T. nativa*, while the chronic gastro-intestinal form affects previously sensitized individuals. Both types are associated with occasionally severe, prolonged and debilitating forms of infection (10).

Diagnosis of trichinellosis is confirmed by parasitological examination of muscular biopsies or by the detection of specific antibodies (17). Medical management relies on the administration of anthelminthics (mebendazole or albendazole) and glucocorticosteroids (17).

From 1982 to 1997, 9 outbreaks of human trichinellosis linked to walrus consumption were documented in Inuit communities of Nunavik (3). In the largest one in 1987, clinical evidence of infection was found in 62% (42/68) of the persons tested among 88 consumers of an infected walrus who participated in the epidemiological investigation that was carried out at the time. Unfortunately no characterization of the strain or larvae numeration was done. It is believed that these events contributed to the decrease in walrus harvests during the 1980s in the affected communities. Since walrus hunting was viewed as an economically, culturally and socially important activity, stakeholders agreed to collaborate to prevent human trichinellosis and to promote the walrus hunt.

History of the trichinellosis prevention program in Nunavik

In response to the initial outbreaks (1982–1983), a first approach to the problem was to educate community members on the importance of cooking walrus meat to prevent trichinellosis. This recommendation was not successful since it did not take into account the cultural specificity of the communities, including the taste of the community members for raw walrus meat (4). First attempts to analyze walrus meat for the presence of *T. nativa* were conducted by sending samples to a southern laboratory, but delays between submission and the results were too long. From 1983 to 1987, a limited number of samples were locally analyzed by trichinoscopy in a few local health clinics. This method was time-consuming, had a relatively low sensitivity, suffered from the high personnel turnover at the clinics and failed to prevent new outbreaks (4).

In 1991, several partners, including the Salluit Municipal Corporation, the Makivik Renewable Resource Development Department, the Inuulitsivik Health Centre and the Laval University Public Health Department decided to conduct and evaluate a local pilot project of trichinellosis prevention in Salluit, one of the most affected communities (4). The Nunavik Trichinellosis Prevention Program (NTPP) began in 1992 in Salluit and was then progressively refined and offered to every walrus-harvesting community in 1996 (3). As will be described below, the NTPP consists of a regionally based screening program for trichinellosis in harvested walrus to achieve disease prevention.

The objective of the present communication is to describe and review the NTPP with a special focus on the interweaving of science and action involved in its development. The effects of this program on the incidence of trichinellosis in Nunavik communities and its assets and limitations will also be discussed.

Materials and methods

The NTPP, which started in 1992 in its present form, is a community-based program, involving many local partners such as the Nunavik Public Health Department, the Nunavik Research Centre (NRC) of Makivik Corporation, the Kativik Regional Government (through the Hunter Support Program), the municipal authority of each participating community and the boat captains.

Sample collection

Walrus hunters participate in the NTPP on a voluntary basis. They receive protocols and sampling kits (including identification tags, protocols and data sheets) through the NRC. They are asked (a) to securely tag all pieces of meat from each walrus to ensure future traceability,

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(b) to sample the entire tongue from each walrus harvested (from 1992 to 1999, a section of the base of the tongue, the cheek, the diaphragm and the intercostal muscles were collected), (c) to ship samples to the NRC by the next available flight to Kuujjuaq, (d) to wait for the results before distributing the meat (unless it is consumed well cooked) and (e) to follow the instructions of health and municipal authorities when results are communicated (6).

Laboratory analysis and diagnosis

The Nunavik Research Centre, in charge of the analyses, delivers results within 24 hours after sample reception. The procedure follows a protocol developed in association with the Canadian Food Inspection Agency (CFIA) from a validated method for detection of *T. spiralis* in pork and horse meat. The main differences with the latter method are the type of muscle analyzed, a decreased quantity of muscles tested and an increased digestion time (18). It consists of an enzymatic digestion coupled with a double-funnel separatory procedure (18,19). Briefly, 10 g of muscle tissue from 5 walruses are pooled together and blended in 50–100 mL of 1% HCl. Thirty grams of granular pepsin (1:10,000 US National Formulary) are dissolved in the paste. In a beaker, HCL solution is added to the mix, until it reaches 3 L. The recipient is put on a magnetic stirrer and heated at 45°C in an incubator for 90 minutes. After incubation, the solution is filtered through a 180 µm-pore sieve and it is then allowed to settle for 30 minutes in a 4 L separatory funnel. Larvae gather at the bottom of the funnel, closed by a valve. The lower 150 mL are drained into a second 500 mL separatory funnel, diluted with 350 mL of warm tap water and left to settle for 10 minutes. The lower 25 mL are poured into a Petri dish and examined under a stereomicroscope at 20 × magnification (18). If larvae are present, each walrus tongue is individually analyzed with the same protocol to identify the infected animal(s). A PCR assay is later conducted on larvae isolates at the CFIA laboratory to verify which species of *Trichinella* spp. are present (20). From 1992 to 1999, if 1 or more of the 4 targeted muscles were missing from an animal, the sample was declared unfit and of undetermined *Trichinella* status. After that, based on the work of Leclair et al. (2002), a negative result from the tongue was sufficient to grant an overall negative *Trichinella* status to an animal (18).

Communication of results and recommendations

The results of the analyses are communicated to the Nunavik Public Health officer who immediately contacts the municipal authorities to inform them and provide proper food-management advice. The municipalities usually inform villagers by local FM radio. The recommendations are as follows: meat of uninfected animals may be eaten raw or undercooked; meat of untested walruses should be thoroughly cooked before consumption (no pink centre); infected meat should not be given to dogs but should be destroyed; *igunaq* prepared from uninfected animals can be eaten without risk of trichinellosis. Each piece of tested and negative walrus meat should be marked to that effect.

Recommendations and educative content have been communicated to community members through various strategies, including video documentaries on television, messages on radio, pamphlets, articles in Makivik's magazine and direct communication in annual hunter meetings.

Trichinellosis surveillance

Passive surveillance of occurrence of human cases of trichinellosis in communities is the responsibility of local health services with the assistance of the Nunavik Public Health Department. Information regarding confirmed and probable cases of trichinellosis has been gathered since 1980 through the Quebec system for mandatory declaration of disease. A confirmed case is defined as follows: "compatible clinical manifestations with one of the following conditions: (a) identification of *Trichinella* in muscular tissue from biopsy OR, (b) detection of specific antibodies by EIA in 2 following sera collections 3 to 4 weeks apart." A probable case is defined as: "compatible clinical manifestations in a person who has eaten the incriminated meat in an outbreak context where at least one case has been confirmed." The surveillance system is enhanced through ongoing medical education and transfer of laboratory results showing high levels of oesinophils (>10%) in white blood counts to the Public Health physician, who then contacts the treating physician to ensure that trichinellosis is considered in the differential diagnosis.

Results

For the first 4 years the NTPP was implemented in only 1 community (Salluit), and then extended in 1996 to every community harvesting walruses. Since the extension of the program, members from 5 to 9 communities out of the 14 communities in Nunavik participated in the walrus hunt and the NTPP each year (Fig. 1).

An increase in the percentage of hunted animals sampled and tested was documented during the 12 first years after the implementation of the NTPP in 1992, with almost all the harvested walruses being tested from 2000 to 2004. Since the total number of harvested walruses was not recorded from 2004 to 2008, the percentage of tested animals during these years is undetermined, but is believed to have remained very high.

The prevalence of *Trichinella* in walrus varied from 0 to 12% with peaks in 1997 and 2001. All positive walruses during those peaks were all harvested in Eastern Hudson Bay. Since 2001, the community going at that location is

Fig. 1. Number of communities involved in the Nunavik Trichinellosis Prevention Program from 1992 to 2009. There are 14 communities in Nunavik in total. Some of the communities never participate to walrus hunt. The number of communities hunting walrus varies according to year because of several factors, including weather conditions and availability of boats.

going hunting every few years at a farther location in Hudson Strait. Some hunters also choose the younger walruses since they seem less infected. Figure 2 presents the results of the screening for *Trichinella* sp. larvae in walrus and walruses harvested each year. From 1992 to 2009, 20 positive animals were found in the 694 walruses tested (2.9%).

From 1982 to 2009, a total of 15 trichinellosis incidents were recorded in 7 communities in Nunavik, nine of which were linked to the consumption of walrus meat.

Five of these 9 walrus-associated incidents occurred prior to the implementation of the NTPP, over a period of 10 years. Two incidents occurred at the beginning of the generalization of the NTPP and were linked to

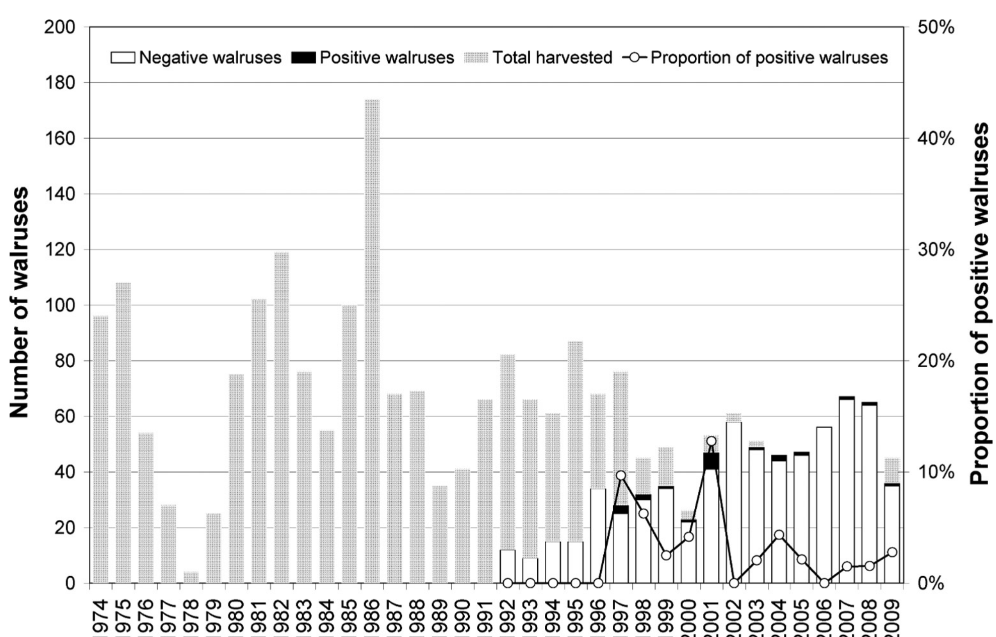

Fig. 2. Number of walruses harvested since 1974 and results of the screening for *Trichinella* sp. in walrus since the beginning of the Nunavik Trichinellosis Prevention Program. The total number of walrus harvested is not available from 2004 to 2008, but it is believed to be close to the number of walruses tested. The black line with open circles stands for the proportion of positive walruses.

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walruses that had not been tested under this screening program. One outbreak occurred in 1997 after the consumption of an infected walrus while the meat was still in quarantine pending the results of analyses. The 2 cases recorded in 2006 were infected during travel in the adjacent territory of Nunavut after eating meat from a walrus not tested and associated with a large outbreak in that jurisdiction.

Other animals involved in cases of trichinellosis in Nunavik are fox (1996), polar bear (1998) and black bear (2004). The epidemiological investigations were not successful in identifying trichinellosis sources in 3 cases (1999, 2004, 2009)

Discussion

Assets of the NTPP

The 2 main goals of the NTPP are to prevent human trichinellosis and to promote the walrus hunt. As shown in Table I, no locally acquired walrus-linked trichinellosis outbreaks have occurred in Nunavik since 1997, even though infected walruses have been detected almost yearly since then (Fig. 2). In 1997, community members ate an infected walrus prior to the quarantine release. Even if human exposures occurred in that event, the results of the analyses performed under the NTPP were communicated to the regional health services and were instrumental in the treatment of these consumers before the onset of clinical signs. The medical management of the 1997 outbreak, as described by Proulx et al. (2002), is the first report of a successful trichinellosis secondary-prevention initiative in the Arctic (3). Only 2 other incidents of walrus-linked trichinellosis were recorded since the implementation of the NTPP, both during the period of generalization of the program to all walrus-hunting communities. The 2 walruses associated with these outbreaks had not been tested. The rare occurrence of walrus-linked trichinellosis since 1992 contrasts with the situation observed in the 1980s where outbreaks occurred every other year or so on average. In addition, it was noticed that walruses from some locations seemed to be more frequently infected. This observation is supported by the apparent decrease in prevalence associated with the avoidance of those locations by hunters. Walrus trichinellosis geographical variations would warrant further studies.

The numbers of harvested walruses over the years are highly variable. These inter-year changes are probably driven by variations in the availability of boats and financial resources, as well as weather conditions. Due to this high annual variability, it is difficult to assess the impact of the NTPP on the walrus-hunting effort, even though the number of walruses harvested in Nunavik appears to have stabilized over the last 10 years after an apparent decrease. Nevertheless, in general, field workers and hunters feel that the NTPP has favoured the perpetuation of the hunt.

The total cost of the program is difficult to evaluate since most of it is supported by in-kind participation of the different partners. Nevertheless, because of the very high human and financial costs associated with the

Table I. Chronology and characteristics of individual trichinellosis incidents in Nunavik from 1982 to 2009

		Number of cases		
Date/Month	Community	Clinical	Requiring hospitalization	Source of infection[a]
1982/12–1983/03	Salluit	10	4	Walrus (epid)
1983/10	Ivujivik	4	1	Walrus (epid)
1984/02	Salluit	8	2	Same walrus as 1983/10
1984/04	Ivujivik	15	4	Walrus (epid)
1987/10–11	Salluit	41	5	Walrus (epid + lab)
1995/11	Inukjuak	1	0	Walrus (epid)
1996/10	Ivujivik	1	1	Walrus (epid)
1996/11	Puvirnituq	1	1	Fox (epid)
1997/10	Inukjuak/Puvirnituq	5	2	Walrus (epid + lab)
1998	Inukjuak	1	1	Polar bear (epid + lab)
1999	Puvirnituq	1	1	Undetermined
2004	Kuujjuaq	3	1	Black bear (epid + lab)
2004	Kuujjuaraapik	1	1	Undetermined
2006	Kangiqsujuaq	2	1	Walrus[b] (epid + lab)
2009	Kangiqsujuaq	1	1	Undetermined

[a]Epid: based on epidemiologic investigation; lab: based on laboratory testing.
[b]The walrus involved in this outbreak was harvested and consumed in Nunavut, outside the Nunavik territory, and was not tested at the NRC prior to consumption.

management of a single outbreak of trichinellosis in this remote and isolated arctic territory, the investment in the NTPP is considered economically sound.

The NTPP can thus be considered as a successful and rational program, based on the absence of recent cases of trichinellosis acquired from walrus meat and the positive effect of the program on the continuation of the hunt. The motivation and empowerment of participating communities constitute another positive spin-off of the NTPP.

Many factors can account for this success. First, the NTPP participates in the public mission of ensuring health in diverse ways: directly by trichinellosis prevention and indirectly because increasing food diversity is considered as a component of nutritional-diseases prevention (2,21). The program also has positive impacts on the economic, social and cultural role of the hunt, especially because it values hunters as skilful food providers. This convergence of interest, shared by the Inuit community members, the local and regional organizations and the public health authorities, is probably a major asset as regards the perpetuation of the NTPP (22). In addition, it is recognized that effective community participation, which involves the sharing of responsibilities, contributes to the achievement of sustainable health objectives and could lead to the appropriation of research outcomes by the community (23,24). The fact that the technical operations of the program are supported by an Inuit entity (Makivik Corporation) with trained personnel (wildlife specialists and laboratory technician) actually facilitated communications and may have contributed to community empowerment (24). The communication strategies used to educate the public are also

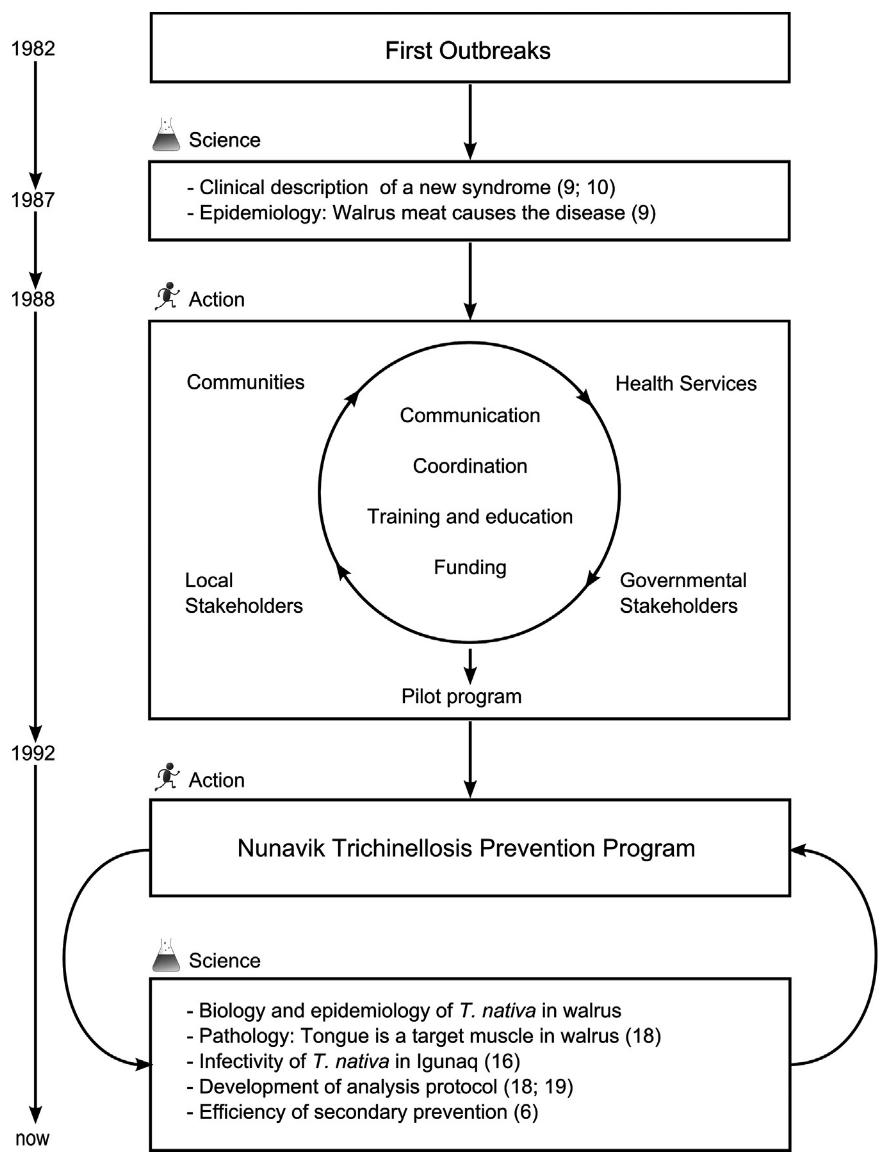

Fig. 3. Timeline of the development and implementation of the NTPP involving interwoven science and action.

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believed to have helped the understanding of trichinellosis and involvement of the community members in the NTPP.

The second factor contributing to this success: trichinellosis is caused by an agent that can be relatively easily detected in the meat. The analytic method is simple, inexpensive and rapidly provides results. Furthermore, it has proven to be reliable: Leclair et al. (2002) established that the digestion and double-funnel separatory procedure enables consistent detection of larvae at the level of 0.3 larvae per gram of tongue muscle. This level of sensitivity is considered sufficient to ensure that the walrus meat is safe for consumption (18). Timeliness of the communication of the results to the targeted population is an important aspect of an efficient prevention program.

Third, the target species, walrus, itself was a factor of success. As walruses are large animals, one single analysis is enough to know the status of a large amount of meat. Furthermore, the analyses are concentrated between July and October and these animals are harvested in limited numbers by a few captains and their crews in the same period. Consequently, the time invested in the testing is relatively limited. This program might have been more challenging to set up and maintain for small animal species that would be hunted in large numbers over a large part of the year.

The timeline of the development and implementation of the NTPP and the bidirectional interweaving between science and action involved in this exercise are schematized in Fig. 3.

The scientific characterization of the first outbreaks was essential in the development of a pilot program that evolved into the current NTPP. The new scientific knowledge generated by the program has been used as a base to continuously refine the protocols. Besides scientific knowledge, the feedback of the hunters has been recorded through annual surveys, and relevant suggestions have been implemented.

Limitations of the NTPP

Although successful, the NTPP had its shortcomings at the beginning of the project. Firstly, the program fully relies on hunters for proper sampling and identification of each animal. Sampling problems occurred in the beginning of the extension of the NTPP, making some of the samples unfit for determination of *Trichinella* status. These difficulties were resolved by enhanced communication with the hunters and by the modification of the sampling protocol to reduce the number of needed samples per animal. This change in the protocol was supported by program-generated scientific knowledge. Traceability of meat during the quarantine period could still be improved. Tags, used to identify walrus meat, are sometimes unavailable or lost, which makes tracking back infected meat pieces complicated. This problem with the tag availability is overcome by experienced hunters, who will use handmade marks. Luckily, so far the occasional failures in traceability have not hampered the elimination of infected meat.

Secondly, compliance with the prescribed quarantine for the meat until results of analyses are known might not be optimal. At the beginning of the program, in 1997, several people ate improperly cooked or raw meat from an infected walrus during the quarantine period. Discussion with community members suggests that compliance with the quarantine has been improved since then, although this most likely remains variable between communities (Simard, personal observation). Some boat captains leave the meat on the boat and anchor it away from the community until results are known. In some cases the meat is quarantined in a locked building or a household freezer or shack. In other cases, community members gather when boats return from a hunt and take pieces of walrus meat that they consume, presumably cooked, prior to the release of the quarantine. Unfortunately, no reliable data are available regarding people's perception of and compliance with the ban period on freshly landed meat. The absence of recent outbreaks is indirect evidence that the NTPP is well understood and accepted by the communities; however, more precise insight on Inuit perception of the NTPP would help document and improve how people deal with meat during the quarantine period.

Promptness of the communication of the results is an important aspect of an efficient prevention program. The time elapsed between the landing of a walrus and the release of the results is a limitation of the NTPP. On-site analysis is not feasible because of difficulties to maintain the equipment and keep ongoing expertise in multiple local testing centres. Transport of samples to established parasitology laboratories in the South was done in the 1980s but led to unacceptably long delays and did not favour implication of the population concerned in the process. Consequently, the centralization of the analyses in a regional laboratory in Kuujjuaq appears to be the optimal compromise, even if aerial transport of samples from local communities is still highly dependent on weather conditions. To minimize delays, samples are processed and results communicated within 24 hours of reception (6).

Future prospects

The different stakeholders involved in the NTPP feel strongly that the program should be perpetuated. As suggested above, there is a need to better evaluate compliance with quarantine and traceability and come up with measures to further limit the risks inherent to the quarantine period. Increasing our comprehension of the epidemiology and geographic distribution of *T. nativa* in walrus and marine wildlife may also help to improve the prevention of this disease in the Arctic and should therefore be supported. Further studies on other regional sources of the parasite such as polar bear, black bear, wolf and fox meat are currently being conducted. The further prevention of trichinellosis may require either the testing of the new species involved in trichinellosis incidents or additional education. The development of tourism in the Arctic will also require informing tourists on trichinellosis. Two incidents linked to bear meat have indeed been identified in tourists (25,26). It will be essential to involve community leaders in such programs.

Direct implication of the Inuit in the scientific process of the NTPP and other health initiatives should be increased. This will greatly contribute to the appropriation of these programs by Nunavimmiut and will hopefully increase the interest of Inuit students in the scientific and health professions. The need to be involved in wildlife research has been expressed by native people in other regions (27).

The authors consider that the NTPP can be used as a model for a successful health-related prevention program in the Arctic. The success of the program relies on many facilitating factors such as the nature of the disease and its source, the existence of an efficient analytic method, the strong involvement of the different partners including direct resource users, as well as the comprehensive bidirectional science-to-action approach that has been followed.

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