

# Arctic Rabies – A Review

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**Mørk T, Prestrud P: Arctic rabies – a review. Acta vet. scand. 2004, 45, 1-9.** – Rabies seems to persist throughout most arctic regions, and the northern parts of Norway, Sweden and Finland, is the only part of the Arctic where rabies has not been diagnosed in recent time. The arctic fox is the main host, and the same arctic virus variant seems to infect the arctic fox throughout the range of this species. The epidemiology of rabies seems to have certain common characteristics in arctic regions, but main questions such as the maintenance and spread of the disease remains largely unknown. The virus has spread and initiated new epidemics also in other species such as the red fox and the racoon dog. Large land areas and cold climate complicate the control of the disease, but experimental oral vaccination of arctic foxes has been successful. This article summarises the current knowledge and the typical characteristics of arctic rabies including its distribution and epidemiology.

*Arctic fox rabies; epidemiology, review.*

## Introduction

The history of rabies in the Arctic before 1945 is sparsely known. The folklore of the Canadian inuits indicates that these people knew of a rabies-like disease that was transmitted from arctic foxes to dogs and people (Singleton 1969), and in Greenland epidemics among sledge dogs have been described for almost 150 years (Lassen 1962). Rabies virus was first identified in arctic regions by Williams (1949). Epidemics among sledge dogs, initiated by transmission from rabies-infected arctic foxes, have caused severe problems in several arctic areas, sometimes reducing the number of sledge dogs drastically (Sikes 1968, Holck 1989, Crandell 1991). After the onset of dog vaccination, rabies has remained mainly as a disease of the arctic fox in these regions. There are several examples of southward spread of rabies virus from arctic regions (Tabel *et al.* 1974, Webster *et al.* 1986, Johnston & Fong 1992, Selimov *et al.* 1990) and arctic rabies represents a perma-

nent potential source of infection of sub-arctic areas (Anonymous 1990).

## The arctic virus variant

Rabies virus belongs to the family *Rhabdoviridae* and the genus *Lyssavirus*. The genotype 1 consists of the classic rabies virus, while the other known genotypes consist mainly of viruses circulating among fruit and insect eating bats. By monoclonal antibody technique and genome analysis, different antigenic variants circulating in different main hosts within certain geographical areas have been identified (Webster *et al.* 1986, Nadin-Davis 1998, Bourhy *et al.* 1999). This supports the theory that rabies virus adapts to different main hosts for persistence in the host population (Wandeler *et al.* 1994).

Characterisation with monoclonal antibodies has indicated that a specific virus variant reacting with the monoclonal antibody (Mab) P-41,

circulates in arctic areas (Schneider *et al.* 1985), and the arctic fox is regarded as the main host of this virus variant (Johnston & Fong 1992). The arctic strain has also been isolated from other animal species, such as red fox (*Vulpes vulpes*), racoon dog (*Nyctereutes procyonoides*) and skunk (*Mephitis mephitis*) in sub-arctic areas (Webster *et al.* 1986, Westerling 1989, Selimov *et al.* 1990, Nyberg *et al.* 1992). However, there are examples of virus isolates from far more southern areas, not likely to be the arctic strain, which have reacted positively with Mab P-41, indicating that a more complete monoclonal antibody panel is necessary for identification of the arctic strain (Selimov *et al.* 1994). The reverse transcriptase-polymerase chain reaction (RT-PCR) methodology has facilitated genetic characterisation of rabies virus isolates and has been used both as a diagnostic and as a characterisation tool to identify different strains persisting in certain host species within geographically defined regions. In Canada, 5 different variants of the arctic strain, obtained from different geographical areas, have been identified by RT-PCR (Nadin-Davis 1998).

### Distribution

Rabies virus is endemic throughout most parts of the Arctic, and several epidemics have been reported during the last 40-50 years (Raush 1958, Kantorovich 1964, Crandell 1975, Ritter 1981, Holck 1989). In Alaska, rabies-like disease was first reported in 1887 and rabies virus was identified during an epidemic in 1945-47 (Williams 1949). Today, rabies is regarded as endemic among the red fox and the arctic fox in northern and western areas of Alaska, with a cyclic occurrence of epidemics about every 3-4 years (Ritter 1981, Follmann 1990).

In arctic Canada, rabies-like disease was reported from the North West Territory already in 1867 and the relationship between this disease

in arctic foxes and similar epidemics among sledge dogs was noted in 1916 (Elton 1931). Today, the arctic strain virus persists among arctic foxes in the north and until recently caused several epidemics among red foxes and skunks in Ontario and Qubeck in the southeast (Webster *et al.* 1986, MacInnes *et al.* 2001).

In Greenland, epidemics of rabies-like disease among sledge dogs were reported as far back as 1859, but the virus was first identified among dogs and arctic foxes in 1959. There have been several large epidemics among sledge dogs in Greenland prior to 1960, when vaccination of dogs was initiated (Holck 1989, Lassen 1962). Rabies virus is still considered as endemic among the arctic fox population.

In Arctic Russia, rabies virus was first identified during a major research study from 1954 to 1956 in the Nenets Autonomous Okrug in northwest of Russia. The study confirmed that the rabies-like disease known from arctic foxes and dogs in arctic regions of Russia, was caused by rabies virus (Kantorovich 1964). The arctic virus strain has later been found in several arctic regions of Russia and also in several different animal species south of the arctic region (Selimov *et al.* 1990, 1994). From the Kola Peninsula, which borders Finland and Norway, arctic rabies was reported in the late 1980s (Westerling 1989, Selimov 1990).

In the high-arctic Svalbard islands of Norway, rabies was detected for the first time in 1980 when there was an outbreak in the arctic fox population. Rabies was also diagnosed in 3 reindeers and 1 seal (Ødegaard & Krogsrud 1981). Only few cases were reported from 1980-1992 and during the last years there have been speculations whether the rabies virus had died out naturally. However, in an ongoing research project, rabies was diagnosed recently in one fox from 1998 and one from 1999 (Mørk & Fuglei, unpublished data).

The mainlands of Norway and Sweden have

both been regarded as rabies free countries during the last 150 years. Reports of rabies in Sweden date back to 1886 (*Wierup & Engvall* 1990), while there are no reports of rabies in the mainland of Norway.

Finland was declared free of rabies in 1936. Since then there have been several epidemics, all close to the Russian border. In 1988 there was an outbreak in southern Finland, and the main species involved was the racoon dog, a species established in Finland about 1970-80. The epidemic was caused by the arctic virus strain and was successfully stopped by bait vaccination (*Westerling* 1989, *Nyberg et al.* 1992). Except for one imported case in a horse in 2003, no cases of rabies have been reported from Finland since 1989.

### Clinical appearance

The incubation period in experimentally infected arctic foxes has been reported to vary from 8 days to 6 months (*Konovalov et al.* 1965, *Rausch* 1972). The clinical course is usually short and foxes may die within a day or 2 after the onset of symptoms. Initially, the arctic fox loses its natural timidity. It may enter villages or human settlements and there are examples of foxes having followed dog teams. In the excitatory phase, the fox becomes aggressive and may snap and bite, and sometimes runs in circles. Excessive drivelling and foaming are also typical symptoms. In the following phase, the animal becomes paralytic and eventually dies. Both the furious form of the disease, dominated by aggressive behaviour, and the dumb non-aggressive form, dominated by paralysis, have been described in the arctic fox (*Kantorovich* 1964, *Crandell* 1991).

Rabies has previously been regarded as 100% lethal. However, the ecology of rabies has been shown to be more complex. Among spotted hyenas in Serengeti of East-Africa, a rabies seroprevalence of 37% was found, and rabies

RNA was demonstrated among 13% of the hyena population. Despite this high frequency of exposure, there were no cases of symptomatic rabies or decreased survival among a group of hyenas monitored for 9 to 13 years (*East et al.* 2001). There are reports of experimental rabies cases, where dogs have recovered from the disease and have been secreting virus in the saliva for a longer period after recovery (*Fekadu et al.* 1981, *Fekadu* 1983). Apparently healthy dogs have been found to secrete rabies virus in their saliva during a period, and remained clinically normal during several years after the first virus isolation (*Nanavati* 1973, *Fekadu* 1975). Serological surveys of wild animal populations have been limited, but rabies antibodies have also been found in arctic foxes in Alaska, indicating that some foxes survive virus exposure (*Ballard et al.* 2001).

### Zoonotic aspects

There have been few human cases of rabies in the arctic regions, and it has therefore been claimed that the arctic virus strain is less pathogenic to man (*Johnston & Fong* 1992). However, there might be other explanations. An important aspect is that people rarely become infected from foxes, thus the most probable exposure is through dogs. There are several reports indicating that most dogs infected with arctic rabies develop "dumb rabies", which reduces the risk of human infection (*Kantorovich* 1964, *Holck* 1989). The fact that the Arctic is scarcely populated and that people wear protective outdoor garments in the cold climate, might be of some importance, as well as lack of rabies diagnostics facilities (*Kuzmin* 1999). In Greenland, only one single human case of rabies has been reported. During the epidemic of Egesminde in 1960, a four-year-old girl was bitten in the face by a dog and died from rabies 3 months later (*Lassen* 1962). From arctic Russia, there are reports of several human cases. A

man is reported to have developed rabies after being bitten in the nose by an arctic fox in 1982, in Anadir, Chukot of northeast Siberia (*Selimov et al.* 1990). Three human cases in 1987-98 in the Pskov and Leningrad districts, were assumed to be caused by the arctic strain, based on known occurrence of the virus in wildlife population (*Selimov et al.* 1994). In 1998, a man died of rabies in Norilsk in northwest of Siberia after being bitten by a rabid wolf. The man was given rabies vaccine but rabies immune globulin was not available and the man developed clinical rabies. Virus isolation and typing (mab) identified the virus as the arctic strain (*Kuzmin* 1999).

Naturally acquired immunity to rabies among inuit populations due to non-bite exposure from handling foxes, wolves and caribou has also been suggested as a possible explanation to the low number of human cases in the Arctic. In Alaska, one experienced arctic fox trapper was found to have a rabies serum neutralising antibody concentration as high as 2.30 IU/ml. The man had never received pre- or postexposure rabies vaccination (*Follmann et al.* 1994). Low level antibody titers have been demonstrated among Canadian inuits (0,05-0,09 IU/ml), however, it is uncertain whether the results from this study really represent antibodies against rabies virus or whether they were caused by a cross-reacting antigen (*Orr et al.* 1988).

### Epidemiology

The contact rate, which describes how many animals that will become infected on average by one infected animal, varies and depends on the social organisation, the population density and ecology of the animal species (*MacDonald & Voigt* 1985). When a population density is high and/or the animals migrate, the contact rate will increase, and it is postulated that there is a positive correlation between the prevalence of rabies and the population density. What

causes the start of an epidemic and how rabies is maintained in different animal populations, is largely unknown. The density among red foxes in Ontario, Canada, where arctic rabies was endemic until a successful campaign of bait vaccination, is lower than what is regarded as necessary to maintain the disease among red foxes in Central Europe (*Voigt & Tinline* 1982). Different virus variants with different characteristics may be a possible explanation to such geographical differences.

The ecology of the arctic fox makes it a suitable host for the rabies virus. Wild rodents such as lemmings are the most important source of food for the arctic fox throughout the Arctic, except on some islands where wild rodent populations are absent. The relationship between the well known 3-5 year cycles in wild rodent population density and the variation in numbers of arctic foxes, is well documented from most parts of the Arctic (*Ängerbjörn et al.* 1995, 1999) and, as mentioned above, several authors have made the hypothesis that there is a connection between high population densities of arctic foxes and outbreaks of rabies (*Elton* 1931, *Kantorovich* 1964, *Syuzumova* 1968, *Ritter* 1981). The number of litters being born may vary as much as from 5 to 25 per 100 km<sup>2</sup> as a result of increased food availability, and the litter size may increase 2 or 3 times (*Ängerbjörn et al.* 1999). As a result, variations in fox densities may be 10-fold between a peak and a bottom of the rodent density cycles.

Even at the highest peaks in numbers of reproducing arctic foxes, the population density is still low compared to the density of reproducing red foxes in Europe. In the higharctic Svalbard archipelago, rodents are present only in a small, defined area and foxes prey mainly on birds and carcasses of reindeer and seal. The arctic fox population is fairly stable and significantly smaller in this area than in most other parts of the Arctic. A rabies outbreak occurred in 1980,

and rabies virus seems to still persist in the arctic fox population. However, there were no indications of a peak in the fox population on the island during 1980-1992 (Prestrud 1992).

Some of the epidemics described from the Arctic have a similar course, which seem to differ from what is seen in other areas of the world. Extensive outbreaks, where a major part of the arctic fox population is infected, seem to last for a year or 2, followed by a period of 6-10 years where cases are decreasing, before a new epidemic emerges. There seems to be a cyclic variation through the year, with most cases in late winter and early spring (Kantorovich 1964, Syuzumova 1968, Crandell 1975). This may be explained by a plausible increase in the contact rate caused by onset of the mating season when foxes actively defend their territories against intruders. However, arctic fox populations most commonly peak during autumn when the litters leave their dens. Autumn is also a period when foxes disperse and migrate and one should assume that the contact rate would be high at this time of year. If an outbreak starts in autumn, the virus may spread in the population due to high density of foxes, and number of cases will increase throughout the winter (Raush 1972). When mating starts in late winter, the contact rate might increase further and may lead to a peak in the outbreak.

There have been several studies measuring the prevalence of rabies among trapped arctic foxes, in both the epidemic and the endemic periods (Reviewed by Prestrud *et al.* 1992). It is apparent that the prevalence varies to a great extent, and that up to 75% of the population may be infected during an epidemic. Also between epidemics, rabies virus has been demonstrated in some animals (0,7%-3%). Some authors have made the conclusion that positive diagnosis of rabies among presumably healthy foxes indicates that the arctic fox might carry the rabies virus for prolonged periods of time

without showing clinical signs of infection. (Kantorovich 1964). Others believe that the animals have been in the prodromal phase at the time of capture (Secord *et al.* 1980). Animals less than one year of age seem to dominate in these studies and several authors have concluded that rabies predominately affects young individuals (Kantorovich 1964, Secord *et al.* 1980, Ballard *et al.* 2001).

How rabies virus is maintained in arctic fox population through periods with low population densities remains unknown. Long incubation periods, prolonged periods of virus excretion and oral infection through frozen carcasses where the virus may be preserved for longer periods of time, are mentioned by several authors as possible explanations (Tabel *et al.* 1974, Cherkasskiy 1990). Peroral infection in red foxes has been reported (Ramsden & Johnston 1975), and this could be a possible route of transmission for arctic foxes as well.

There are examples of experimental infection of arctic foxes, where a few individuals have not developed clinical disease, nor seroconverted, which may suggest that these animals were less susceptible to the virus or that the incubation period was particularly long and that the animals were euthanised before development of clinical disease (Follmann *pers. comm.*).

Long time absence of the disease in a population, may be explained by a situation where the virus is no longer circulating in the population, and that new epidemics is caused by re-introduction of the virus. The arctic fox is known to be among the mammals with the longest migrations (Eberhardt & Hanson 1978) and it is not unusual to see arctic foxes out in the drift ice, where they prey on seal carcasses left by the polar bear.

Other animal species in the Arctic seem to be infected by rabies more sporadically. In Svalbard, there have been several cases reported among the Svalbard reindeer (*Rangifer taran-*

*plathyrynchus*) (Ødegaard & Krogsrud 1981), and also from Russia there are reported cases among reindeer (Anonymous 2000). Rabies in seals is probably rare. In addition to one confirmed case of rabies in a ringed seal (*Phoca hispida*) on Svalbard (Ødegaard & Krogsrud 1981), there is only one report of a seropositive grey seal (*Halichoerus grypus*) on the Estonian island Ösel (Westerling & Stenmann 1992). Bears are considered as less susceptible to rabies, and only one single case of rabies in a polar bear (*Ursus maritimus*) has been reported in Canada. (Taylor *et al.* 1991).

The wolf (*Canis lupus*) seems to be of more importance. Both in Russia and in Alaska there are examples of wolves infecting humans. Rabies epidemics are known from certain wolf populations in Alaska, which seem to coincide with epidemics in the arctic fox population (Weiler *et al.* 1995). In periods with large wolf populations, this species has had an important role in rabies epidemics both in northern and southern parts of Russia. Populations of wolf-dog-hybrids have also been known from several areas of Russia. Furious wolves and wolf-dog-hybrids are extremely dangerous to man, because of a tendency to bite in the head, and the bites are often multiple and deep (Cherkasskiy 1988).

The red fox, as well as the racoon dog, may be involved in arctic rabies epidemics (Webster *et al.* 1986, Nyberg *et al.* 1992). The racoon dog is quite common in Russia and has been established in the south and middle parts of Finland and the Baltic states. It has also been observed in Sweden and in Norway.

### Control

Rabies control by bait vaccination of wild animals has shown to be successful in several areas, such as Central-Europe, Finland and Canada (Nyberg *et al.* 1992, Müller 2000, MacInnes *et al.* 2001). Experimental oral vac-

ination of captured arctic foxes in Alaska has shown to be effective (Follmann *et al.* 1988, 1992) and limited trials on bait vaccination has shown that there is a potential for field vaccination of arctic foxes (Anonymous 1990). However, the existing vaccines have little effect in frozen condition, which is a limiting factor in arctic regions. The vaccine is distributed inside a capsule, which is punctured when the animal eats the bait. The vaccine will then be released in the oral cavity and absorbed through buccal mucosae. In frozen condition the vaccine will first thaw in the stomach, where previous experimental work has shown absorption to be limited and subsequent immune response to be rare (Anonymous 1990). The amount of infective virus in the bait will also be reduced or eliminated after repeatedly freezing and thawing. Knowledge of the etiology and ecology of the animal species in question and the relative number of animals being vaccinated, is vital to succeed with bait vaccination.

### Concluding remarks

The arctic fox rabies virus seems to persist in most arctic areas. Exposure rates to humans and domestic animals are in general relatively low. However, risk of exposure might be high during periods of larger outbreaks or in certain areas. Clearly, problems are connected to control of rabies in arctic areas, mainly due to the size of land areas and lack of infrastructure. The most realistic aim in controlling rabies would probably be to stop spread of the disease to rabies-free areas and to eliminate the disease or reduce cases in limited areas.

Many questions concerning the epidemiology of arctic rabies remain unsolved and these questions are most likely closely related to the characteristics of the arctic virus strain and the ecology of the arctic fox.

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**Sammendrag***Arktisk rabies - en oversikt*

Rabies synes å opprettholdes i de fleste arktiske regioner, og de nordlige deler av Norge, Sverige og Finland er de eneste områder av Arktis hvor rabies ikke har vært diagnostisert i nyere tid. Fjellreven er hovedvert og ser ut til å være infisert med den samme virusvarianten i hele sitt utbredelsesområde. Epidemiologien i arktiske områder synes å ha enkelte

fellestrekk, men svar på essensielle spørsmål slik som opprettholdelse og spredning av sykdommen, er fortsatt ukjent. Spredning av viruset har forårsaket nye epidemier også hos andre arter som rødrev og mårhund. Store landområder og kaldt klima kompliserer kontroll av sykdommen, men eksperimentell oral vaksinasjon av fjellrev har vært vellykket. Artikkelen summerer opp typiske egenskaper ved arktisk rabies samt utbredelse og epidemiologi.

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