General Review

Early descriptions
Botulism, or sausage poisoning as it was originally termed, was first seriously studied following an 1793 outbreak in Wildbad, Germany. The outbreak involved 13 people, six of whom died, and was associated with consumption of a locally-produced blood sausage. Following this outbreak, the number of reported cases of sausage poisoning rapidly increased, prompting a study of the disease by the local health officer, Justinius Kerner, who described 230 cases, most of which were attributed to the consumption of sausage. The illness became known as “botulism” after “botulus,” the Latin word for sausage.

Many years later in Ellezelles, Belgium, Van Ermengem investigated an outbreak of botulism involving 34 individuals who had consumed raw, salted ham served at a gathering of amateur musicians. He established that botulism was an intoxication, not an infection, and that the toxin was produced by a spore-forming obligate anaerobic bacterium, Clostridium botulinum. He also found that toxin was rapidly inactivated by heating and was only toxic to certain animal species.

Later, in Darmstadt, Germany, associated with canned white beans, established that there was a second type of botulism. The new strain was type A and the Van Ermengem strain was probably type B.

In 1922, type C botulism was identified as causing disease in chickens and cattle. Robinson identified type D in cattle and type E was identified by Gunnison as causing botulism in people who consumed fish. Type F was first described by Møller and Scheibel from a Danish outbreak involving homemade liver paste. Finally, type G botulism was identified in soil from cornfields in Argentina by Gimenez and Ciccarelli. The principal types of botulism involved in human disease are types A, B, and E. Detailed historical reviews of type E botulism have been published.

Foodborne botulism in the Arctic

a. Epidemiology
For many years, outbreaks of illness associated with traditionally prepared and preserved food have been described. Early explorers reported clusters of deaths in villages among groups of northern Natives that the explorers attributed to “ptomaine” poisoning or trichinosis. However, descriptions of many of these outbreaks resemble foodborne botulism. Later, ethnographers described food preparation and storage practices that could support the production of botulinum toxin.

The first reported outbreaks of foodborne botulism in the Arctic occurred in the early 1900s. In Canada, the first reported outbreak was in 1919 and since then, over 100 outbreaks involving over 230 individuals have occurred. The first reported outbreaks in Greenland occurred in 1967, with over 20 additional outbreaks reported since then. Rabeau recorded the first Alaska outbreak that occurred in 1947 and involved beluga whale flipper consumed in the village of Kotzebue.

Newly translated Russian medical literature suggests the presence of type E botulism in Siberia and the Russian Far East. The disease “ichthyosismus” from early Russian medical journals may represent one of the earliest reported fish-related botulism descriptions. In 1938, smoked herring was associated with type E botulism cases in Leningrad. Cases of type E botulism from smoked “kunzha”, or salted fish were first reported in Kamchatka and on Sakhalin Island in the Russian north and Far East, in 1967.

The overall case fatality rate in past arctic outbreaks was about 20%. Because not all northern Native groups consume the same traditionally prepared foods, it is difficult to determine true incidence rates of disease. However, using total population as the denominator, Canadian Inuit and Alaska Native residents had annual incidence rates of 30 cases per 100,000 and 8.5 cases per 100,000 respectively. These rates are much greater than an overall estimate for the United States at one case per million, with 1.9 per 100,000 for Alaska; Idaho and Washington had the next highest rates of 0.6 and 0.3 respectively.

Most foodborne botulism in the Arctic is type E.

b. The foods, their preparation and storage
All Alaska cases have been associated with the consumption of traditional Alaska Native foods. These include “fermented” foods, dried foods and traditionally prepared condiments, such as seal oil. In other parts of the United States, foodborne botulism is usually associated with improperly canned foods or with improperly stored unrefrigerated foods.

Foods involved in Alaska botulism outbreaks are usually aged or putrefied (“fermented”). Traditionally prepared northern foods are not in fact “fermented” as fermentation requires a carbohydrate substrate and results in organic acid production.
that subsequently reduces the pH. Sea mammal food products do not contain enough carbohydrates to enable fermentation; therefore, the pH remains neutral. Instead the aging of traditional foods is really putrefaction or advanced decomposition of proteins and fat which does not inhibit growth of *Clostridium botulinum* (type E strains are inhibited at a pH of <5) or production of botulinum neurotoxin.

Whale and seal are the most frequently involved sea mammals. Salmon, including salmon eggs, are the most frequently involved fish. Semi-aquatic mammals, such as beaver, contribute to a small proportion of outbreaks.

Similar practices are still found in many areas of the Arctic. In Canada, First Nations persons living outside the Arctic, e.g., British Columbia, also age traditional foods and cases of botulism are well documented.

Dried foods, particularly dried fish, have also been implicated in foodborne botulism outbreaks. Fish are dried either with or without a brine stage. However, even if fish are put in brine prior to drying, the salt concentration is rarely high enough to inhibit botulinum toxin formation.

In addition to inadvertent spoilage, many traditional methods of food preparation lend themselves to botulinum toxin formation. Traditional “stink” foods such as aged salmon eggs (stink eggs) or salmon heads (stink heads) are prepared by burial in moss-lined pits or barrels in the ground. Nelson described the process he observed during a visit to the coastal villages of northwest Alaska in 1877–1881:

In the district between the Yukon and Kuskokwim, the heads of king salmon, taken in the summer, are placed in small pits in the ground surrounded by straw and covered with turf. They are kept there during the summer and in the autumn have decayed until even the bones have become the same consistency as the general mass. They are taken out and kneaded in a wooden tray until they form a pasty compound and are eaten as a favorite dish by some of the people.

The process described by Nelson has changed somewhat. Now, aging may be carried out in a barrel, a plastic or glass jar, or a plastic bag. These containers may increase the risk of botulinum toxin formation because most can be easily sealed, thereby increasing the likelihood of anaerobic conditions. Some foods are aged in a seal skin or fish skin bag or “poke,” which is either buried or hung up. If salmon eggs are aged in this manner, they can be left until they dry out somewhat and form a “cheese” that is firm on the outside and soft in the center.

Toxin production is temperature dependent, and is less likely to occur at the lower temperatures that were usually attained during traditional aging. Type E is more resistant to freezing than types A or B, and optimal/minimal growth occurs within temperature ranges typical of summer in coastal Alaska and ambient indoor air. Aging now may be done indoors, or in a container above ground and in the sun, which produces warmer temperatures that make aging more rapid and production of botulinum toxin more likely. In one experiment, botulinum toxin was detected in salmon heads that had been aged in a sealed plastic container kept underground for 17 days, but not in salmon heads aged in a grass-lined pit for the same length of time (personal communication 2011, Dr. Thomas Hennessy, CDC Arctic Investigations Program).

Although no commercial products have been associated with illness among Alaskans, fish products from Alaska have been implicated in cases of botulism elsewhere in the world. In 1978, four cases of botulism (two ultimately fatal) were reported in Birmingham, England, associated with consumption of canned Alaska salmon. Additionally in 1982, the U.S. Food and Drug Administration (FDA) was notified of two cases of botulism (one ultimately fatal) in Belgium that prompted a massive recall of canned Alaska salmon.