

Botulism

*Shaker Foal Syndrome,
Limberneck,
Western Duck Sickness,
Bulbar Paralysis,
Loin Disease,
Lamziekte*

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- OIE Collaborating Centres:
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 - Day-One Veterinary Competencies and Continuing Education



Importance

Botulism is caused by botulinum toxins, neurotoxins produced by *Clostridium botulinum* and a few other clostridial species. By binding to nerve endings, these toxins cause progressive flaccid paralysis in humans and animals. Many untreated cases end in death from paralysis of the respiratory muscles. *C. botulinum* spores are common in the environment, but they can germinate and grow only under certain anaerobic conditions. Foodborne botulism results from the ingestion of preformed toxins after the organism has grown in food or other organic matter. Foodborne outbreaks may be extensive in some animals, especially farmed mink or foxes and wild waterfowl. Losses that may threaten survival of the species have been reported in endangered wild birds. Sporadic cases of botulism also occur when botulinum-producing organisms grow inside the body, particularly in the immature gastrointestinal tracts of human infants and foals, or in anaerobic wounds. Botulism can be treated successfully, but human or animal patients may require weeks or months of intensive care, sometimes including mechanical ventilation, while the nerve endings regenerate. Treatment may be impractical in adult livestock unless the case is mild. The potential for botulinum toxins to be used in bioterrorism is an additional concern.

Etiology

Botulism is caused by botulinum toxin, a potent neurotoxin produced by *Clostridium botulinum*, a few strains of *C. baratii* and *C. butyricum*, and *C. argentinense*. All of these organisms are anaerobic, Gram-positive, spore-forming rods. *C. botulinum* is currently divided into three genotypically and phenotypically distinct groups, I through III. Groups I and II, which are the usual causes of botulism in humans, differ in heat resistance, optimal growth temperatures and other characteristics that can influence the types of foods where they tend to grow. The former group IV *C. botulinum* has been reclassified as *C. argentinense*.

Seven types of botulinum toxins, A through G, and a few mosaics of these toxins are currently recognized. Mosaic toxins include C-D and D-C, detected during outbreaks in birds and ruminants, respectively, and an A-F toxin from a human infant, which was initially reported as a novel "type H." All toxin types cause the same clinical signs, but some tend to result in more severe illnesses. Knowing the toxin type is important in treatment, as the antiserum produced against one type is not protective against others. An apparently novel toxin ("type X") was described in 2017 and caused clinical signs in experimentally intoxicated mice. It is still uncertain whether this toxin is ever expressed in nature. Some *C. botulinum* strains produce additional types of toxins, including enterotoxins that can cause gastrointestinal signs.

Most of the clostridia that cause botulism produce one type of botulinum toxin, although they may contain genes for others. Human illnesses can be caused by group I or group II *C. botulinum*, which may produce toxins A, B, E or F; *C. butyricum*, which also produces type E toxin; and *C. baratii*, which produces type F. Toxin types A, B and E are found most often in people, while type F is uncommon. Type G toxin has been implicated very rarely in human disease. Illnesses that appeared to be caused by this toxin included one case of wound botulism and several sudden deaths, some of which might have resulted from foodborne botulism. Group III organisms, which make toxin types C, D and their mosaics, are usually associated with botulism in animals. However, members of groups I/II can be more prominent in some animal species or locations. For instance, type B toxin causes most cases of botulism in horses in the midwestern and mid-Atlantic states of the U.S., while type A is usually responsible for equine cases in the western states. Rare reports of human botulism were attributed to type C and D toxins in the 1950s; however, the virulence of these types for people has since been questioned.

Species Affected

Botulism is known to affect mammals, birds, reptiles and fish, although some species seem to be more susceptible than others. This disease is reported regularly in horses, domesticated ruminants, ranched mink, poultry, wild birds in aquatic.

environments, and game birds (pheasants), and occasionally in other species such as ferrets, farmed foxes, captive wildlife (e.g., nonhuman primates, sea lions) and free-living wild mammals. Cases also occur in dogs and pigs, but are uncommon, while botulism has been reported very rarely in cats. Outbreaks have been seen in farmed rainbow trout (*Oncorhynchus mykiss*), and other species of fish were shown to be susceptible in experiments. Clinical cases have also been documented in turtles. Amphibians are susceptible to experimental intoxication.

Zoonotic potential

Botulism is usually acquired from the environment and not directly from animals. However, at least two recent cases of infant botulism caused by *C. butyricum* (type E toxin) were linked to healthy pet yellow-bellied terrapins (*Trachemys scripta scripta*) and/or their environments. Whether terrapins regularly carry this organism is not yet clear; some animals were probably infected in contaminated feed.

Geographic Distribution

C. botulinum occurs worldwide, but the predominant toxin types can differ between areas. Type E-producing *C. botulinum* strains tend to occur in northern regions, where they are associated with coastal areas and other aquatic environments. In North America, type A strains predominate west of the Missouri River, while type B strains are more common to its east. *C. argentinense* has, to date, been reported from humans in Europe and North America, as well as from soil samples in South America.

Transmission

Botulism usually occurs when people or animals ingest preformed botulinum toxins in food or water, or when clostridial spores germinate in anaerobic tissues within the body and produce toxins as they grow. Botulinum toxins do not pass through intact skin, but they can cross mucous membranes and broken skin.

C. botulinum can grow in a wide variety of organic matter, but it requires anaerobic conditions, a relatively high water content, pH > 4.6 (Group III type C toxin-producing strains are inhibited by pH < 5.1-5.4), and the absence of inhibitory concentrations of salt or other preservatives. The optimal, minimal and maximal temperatures for growth differ between organisms. In particular, type E-producing *C. botulinum* are able to survive and grow at lower temperatures than the strains that produce types A or B. *C. botulinum* does not compete well with other bacteria and fungi, and it proliferates more readily if they have been killed or inhibited.

Clostridial spores are highly resistant to inactivation, and they can survive for many years in the environment until favorable conditions allow them to germinate and grow. *C. botulinum* spores are common in soils, and they also occur in sediments in lakes, streams and coastal waters.

Spores have been found in the intestinal tracts of healthy mammals, poultry, wild birds and fish; however, there are reports suggesting that this may be rare in some species or locations except during outbreaks.

Botulism is not transmitted between animals or people by casual contact; however, it can be acquired by ingesting contaminated tissues. If an animal dies of botulism, any spores in its intestinal tract (e.g., from contaminated food) can germinate and grow. This may result in high levels of toxin in decomposing carcasses. Such carcasses can help perpetuate and amplify outbreaks in poultry and mammals through carnivory. Particularly high levels of toxin are reported to develop in dead tortoises. Invertebrates such as snails, earthworms, maggots, darkling beetles in poultry houses, and nematodes are unaffected by botulinum toxin, but they can accumulate these toxins and cause botulism in animals that feed on them.

Sources of botulism for humans

Foodborne botulism occurs when people ingest preformed toxins. *C. botulinum* spores can survive cooking, then germinate and grow in the food if the conditions are appropriate. Some clinical cases have occurred when baked foods were left at room temperature or in a warm oven overnight. Most often, botulism is associated with home-canned, low acid foods; meat products such as sausages, pate and ham; and salted, pickled or fermented fish, seal and whale meat. However, it has also been caused by products as diverse as traditional long-fermented yogurt, soft cheeses, garlic oil and foil-wrapped baked potatoes. While the amount of toxin in the tissues of freshly-dead animals is uncertain, some clinical cases resulted from eating raw tissues from whale carcasses.

Wound botulism occurs when botulinum-producing clostridia contaminate and grow in an anaerobic wound. It is particularly common in injecting drug abusers, especially those who inject “black tar” heroin into the subcutaneous tissues.

Infant botulism is seen in children less than a year of age, when organisms germinate and grow in their intestines. Infants are thought to be susceptible because the intestinal tract, particularly the normal flora, is still immature. Honey has been associated with some cases, but spores can also be found in many other sources including dust. Some babies with infant botulism can shed *C. botulinum* for up to 7 months, long after they have recovered clinically. Spores from the environment can be ingested by most older children and adults without harm; they simply pass through the intestines without germinating. However, there are rare cases of intestinal colonization botulism in people who have altered intestinal conditions from procedures and diseases such as gastrointestinal surgery, intensive antibiotic therapy or abnormalities such as achlorhydria.

Botulism can also occur after laboratory accidents (e.g., by inhalation or accidental injection of toxin), and

rare iatrogenic cases have been reported after therapeutic or cosmetic use. In a bioterrorist attack, botulinum toxin could be delivered by aerosols, or in food or water. Person-to-person transmission of botulism has not been reported.

Botulism in animals

Some sources of preformed toxins for animals include decaying vegetable matter (grass, hay, haylage, grain, spoiled silage) or high protein garbage, animal tissues (including fish), invertebrates (e.g., maggots that have fed on carcasses) and contaminated water. Feed for herbivores is often thought to have been contaminated by the carcass of a bird or small mammal. Ruminants have developed botulism after eating contaminated poultry litter that was used as bedding or feed or spread on nearby fields. Cattle in phosphorus-deficient areas may develop pica and chew bones and scraps of attached meat; a gram of dried flesh may contain enough botulinum toxin to kill a cow. Similar cases have been reported from Australia when protein-deficient sheep ate the carcasses of small animals.

Botulism in young foals (the shaker foal syndrome) is mostly thought to be caused by the growth of *C. botulinum* in the gastrointestinal tract, similarly to infant botulism in humans, although wound botulism has been implicated in a few cases. Toxicoinfectious botulism is also suspected to occur in the intestinal tracts of chickens (e.g., broilers intensively reared on litter) and possibly other species such as cattle.

Whether toxin can be shed in the milk of animals suffering from botulism is uncertain; however, one paper reports having found it in milk samples from some cattle, and experimentally infected, axenic (germ-free) rats with toxicoinfectious botulism shed it in milk. *C. botulinum* has been detected on eggshells during outbreaks in poultry, but it was not found in the egg contents. In one instance, contamination was detected on eggs laid 5 months after an outbreak.

Disinfection/Inactivation

Botulinum toxins are large, easily denatured proteins, and toxins exposed to sunlight are inactivated within a few hours. They can also be destroyed by treating with 0.1% sodium hypochlorite or 0.1 N NaOH, or by heating to 80°C (176°F) for 20 minutes or > 85°C (185°F) for at least 5 minutes. Their heat resistance varies with composition of the food or other medium, and the concentration of the toxin. Reports suggest that HTST pasteurization (72°C/162°F for 15 seconds) is likely to inactivate most or all of the toxin in contaminated milk, while conventional pasteurization at 63°C/145°F for 30 minutes seems to be less effective. Chlorine and other agents can destroy botulinum toxins in water.

The vegetative cells of *C. botulinum* are susceptible to many disinfectants, including 1% sodium hypochlorite and 70% ethanol, but clostridial spores are very resistant to inactivation. They can be destroyed in the autoclave with

moist heat (120°C/ 250°F for at least 15 minutes) or dry heat (160°C for 2 hours) or by irradiation. The spores of group I strains are inactivated by heating at 121°C (250°F) for 3 minutes during commercial canning. Spores of group II strains are less heat-resistant, and they are often damaged by 90°C (194°F) for 10 minutes, 85°C for 52 minutes, or 80°C for 270 minutes; however, these treatments may not be sufficient in some foods.

Botulism in Animals

Incubation Period

Reported incubation periods in animals range from 2 hours to approximately 2 weeks. In many foodborne cases, the clinical signs appear about 12 to 48 hours after ingesting botulinum toxin.

Clinical Signs

Botulism is characterized by progressive motor paralysis. In animals, it usually appears as an ascending paralysis that affects the hind legs first. Autonomic dysfunction, difficulties in chewing and swallowing, visual disturbances, and generalized weakness and incoordination may also be apparent. Loss of muscle tone around the eyes and mouth may result in an appearance of lethargy or somnolence, with drooping of the eyelids, dilation of the pupils and slow pupillary reflexes. Sensory defects are absent. Death usually results from paralysis of the respiratory muscles. Mildly affected animals may recover with minimal treatment.

Ruminants

Ascending muscle weakness and incoordination, progressing to paralysis, is the most apparent sign in cattle. The head may be held abnormally low. Other clinical signs may include difficulty chewing and swallowing, excessive salivation, protrusion of the tongue, constipation and urine retention. The tongue test, which evaluates an animal's ability to resist or retract the tongue when it is pulled laterally from the mouth, often reveals compromised function. In cattle that become recumbent, the head is often turned toward the flank, similarly to a cow with hypocalcemia. Complications such as aspiration pneumonia and pressure sores are common in cattle that are impaired by botulism for a prolonged period. Laterally recumbent animals are usually very close to death. Some animals may be found dead without preceding clinical signs. Atypical presentations with gastrointestinal signs (diarrhea, regurgitation, vomiting and profuse salivation) have been reported in a few outbreaks.

The clinical signs are similar in small ruminants, but the effects on mastication and swallowing are reported to be less apparent. An arched back, accompanied by drooping of the head, neck and tail, is a common presentation in these species, and an unusual stilted gait has been reported during the early stages of botulism in sheep.

Visceral botulism

Some authors have proposed that toxicoinfectious botulism and/or chronic exposure to botulinum toxins causes a syndrome called “visceral botulism” in cattle. Clinical signs reported in affected herds have included lethargy, decreased milk production, constipation alternating with diarrhea, dependent edema, non-infectious chronic laminitis, ataxia, paralysis, engorged veins, forced respiration, a retracted abdomen, emaciation and unexpected deaths. A more recent report described a herd with locomotor abnormalities, swollen joints, regurgitation, viscous saliva, a drooping head and tail, suppuration of skin wounds, poor suckling in calves and death after a few weeks. Most cases are reported to occur during the peripartum period. Whether visceral botulism is a real syndrome is controversial. A recent case-control study could not substantiate a link to botulism on some farms with visceral botulism signs.

Horses

The signs of intoxication by botulinum toxin in adult horses resemble those in ruminants.

Toxicoinfectious botulism in foals (the shaker foal syndrome) is typically characterized by weakness, a stilted gait, muscle tremors and dysphagia. Affected foals are often unable to stand for more than a few minutes. Constipation, reduced eyelid, tongue and tail tone, mydriasis, frequent urination and other signs of motor or autonomic dysfunction may also be seen. Without treatment, death from respiratory paralysis generally occurs 24 to 72 hours after the initial signs. Some foals may be found dead.

Equine grass sickness

Equine grass sickness is a neurodegenerative disease seen in grazing equids. This disease, which is often fatal, has both acute and chronic presentations. It is characterized by dysfunction of the autonomic nervous system, and signs of intestinal dysmotility are prominent. Weight loss and progressive myasthenia are common in chronic cases. Equine grass sickness tends to be seen in young adult horses and is most common in the spring. Its cause is still uncertain. There is some evidence for a link to type III *C. botulinum*; however, it is possible that this is a coincidence or that intestinal dysfunction predisposes these animals to the growth of clostridia in the intestinal tract.

Pigs

Pigs are relatively resistant to botulism. Reported clinical signs include anorexia, refusal to drink, vomiting, pupillary dilation and muscle paralysis.

Foxes, mink and ferrets

Clinical signs in these species resemble those in other animals. During outbreaks of botulism in mink, many animals may be found dead, while others have various degrees of flaccid paralysis and dyspnea. In some mildly

affected foxes, only the hind legs are paralyzed. These animals may sit and drag the hind part of their bodies.

Dogs and cats

Limited studies in dogs suggest that this species is relatively insensitive to the ingestion of botulinum toxin. Reported clinical signs include vomiting and anterior abdominal pain, in addition to neurological signs (e.g., salivation, incoordination, ascending weakness of the legs, inability to urinate, diminished reflexes). Congestion of the mucous membranes of the mouth, fetid brownish saliva, cheilitis and an unusual hoarse, suppressed bark or whine were reported in some experimentally exposed dogs. Some dogs have recovered, but others died of respiratory failure. One pregnant bitch that contracted botulism soon after breeding gave birth to an apparently healthy litter, despite being hospitalized for 5 days during the illness and having some residual defects for < 1 month.

In the single outbreak described in cats, anorexia and mild depression were the first signs, followed by ascending flaccid paralysis, and in some cases, dyspnea. Some severely affected cats died, others recovered spontaneously and rapidly.

Marine mammals

Inactivity and dysphagia, followed in some cases by unexpected deaths, were reported in sea lions. Although some animals appeared to be hungry, chewing fish and attempting to swallow, they eventually released the partially chewed fish from their mouths.

Birds

Reluctance to move and dullness may be the initial signs observed in poultry. Botulism usually affects the legs of poultry and waterfowl first, followed by the wings and neck. Milder cases may be limited to paresis or paralysis of the legs. In gulls, the toxin's effects on the wing muscles may be observed initially, with delayed or uncoordinated flight. Mildly affected gulls are able to stand and run, but not fly. Birds with botulism may have diarrhea with excess urates, as well as additional neurological signs such as paralysis of the nictitating membrane. The feathers of chickens may be ruffled, and they may be shed easily when the birds are handled. Birds may die from respiratory dysfunction, and waterfowl with paralyzed necks may drown. Egg production and quality do not seem to be significantly decreased in layer chickens with botulism.

Reptiles

Loss of equilibrium and flaccid paralysis of the legs, followed by drowning, have been reported in green sea turtles (*Chelonia mydas*).

Fish

Loss of equilibrium and erratic swimming have been reported in fish with botulism. Some fish may attempt to swim in a head up/ tail down orientation, with breaching of the water surface. Increased swimming bursts were the first

sign in experimentally exposed rainbow trout. Hyperpigmentation was also seen in some experimentally infected fish, including round goby (*Neogobius melanostomus*), yellow perch (*Perca flavescens*), and some members of the carp family (Cyprinidae). Abnormal swimming behavior was not observed in these goby until the late stages of hyperpigmentation. Like other vertebrates, fish usually die from respiratory compromise. They are usually immobile at this stage. A few fish with mild clinical signs such as slight loss of equilibrium and increased swimming bursts may recover completely.

Post Mortem Lesions [Click to view images](#)

There are no pathognomonic lesions in animals that die of botulism; any lesions are usually the result of muscle paralysis, debilitation, the inability to eat and drink, or other secondary effects. Congestion may be noted in a variety of tissues, and respiratory paralysis may cause nonspecific signs in the lungs. Some strains of *C. botulinum* also produce an enterotoxin that may cause diffuse intestinal hemorrhages. Edema of the head and neck, probably associated with lowered head carriage, is reported to be a prominent but inconsistent finding in horses. In shaker foal syndrome, the most consistent lesions are excess pericardial fluid with strands of fibrin, pulmonary edema and congestion.

Diagnostic Tests

A definitive diagnosis can be made if botulinum toxin is identified in environmental samples (e.g., feed), serum, gastrointestinal contents (stomach, crop or intestines), wounds, vomitus, feces or tissues such as the liver. Fecal samples are more likely to be diagnostic than serum, which usually contains this toxin only in the early stages of the disease and is rarely positive in some livestock. Repeated fecal sampling may improve detection. Low levels of toxin can be difficult to detect, and a presumptive diagnosis in highly sensitive species (e.g., cattle and horses) must sometimes be based on the clinical signs and the exclusion of diseases with similar signs.

Botulinum toxin is usually identified with a mouse bioassay (the mouse neutralization test), which can take up to 4 days, but ELISAs and PCR assays may be available in some laboratories. Because ELISAs detect both active and inactivated toxins, false positives are possible with this test. PCR tests may, likewise, amplify some “silent” botulinum toxin genes. Only active toxins are detected in mice. Pre-incubating samples under anaerobic conditions can improve the sensitivity of both ELISAs and PCR. One recent study reported that storing samples at room temperature or 5°C (41°F), rather than at -18°C (0°F), reduced the sensitivity of a *C. botulinum* PCR test, even when the samples were stored for only 48 hours. Other types of assays are also in development, with the goal of replacing the mouse bioassay. Some measure the toxin’s activity on synthetic peptides that mimic its targets. Botulinum toxins can be typed during the mouse neutralization test or with genetic techniques.

Botulism can also be diagnosed by recovering toxin-producing clostridia from clinical samples and/or the suspected source of the intoxication. *C. botulinum* can be cultured on various solid and liquid media, including blood or egg yolk agar, but anaerobic conditions are required. Heat and/or ethanol treatment, which destroy competing microorganisms but not clostridial spores, may aid recovery in highly contaminated samples such as food or feces. Biochemical tests, morphology and the detection of volatile metabolic products, using gas-liquid chromatography, are helpful in identification. The metabolic patterns and other characteristics vary with the strain/ group. Definitive identification is by the demonstration of botulinum toxin. Molecular techniques such as multi-locus sequence typing (MLST) or variable number tandem repeat (VNTR) analysis can help determine the source of an outbreak.

Serology is not usually helpful in diagnosis, but antibodies to botulinum toxin have been reported in some animals that recovered, including horses, cattle and a dog. In the dog, paired serum samples revealed a fourfold increase in titer. Repetitive nerve stimulation studies have been used to help diagnose botulism in foals.

Treatment

The binding of botulinum toxins to the endplates of neurons cannot be reversed; however, the endplates can regenerate if the patient can be kept alive. Mechanical ventilation has significantly reduced the death rate in foals, but it is impractical and/or unavailable for some animals such as adult livestock. Gastric lavage, emetics, cathartics and/or enemas may be used to eliminate some of the toxin from the gastrointestinal tract, and activated charcoal or other substances may help prevent absorption. Where the water supply has high salinity, giving fresh water to prairie wildfowl can improve their condition. The supraorbital gland in these birds, which functions in osmoregulation, is innervated by nerves affected by the toxin.

Antitoxins can neutralize circulating botulinum toxins in birds and mammals, provided the antibodies match the toxin type. Decisions on antitoxin treatment must often be made before the results from typing are available. In some cases, an educated guess may be made, based on the most common toxin types in that species and location. Antitoxins that neutralize more than one toxin type, including pentavalent antitoxins (types A through E), are available in some countries. Early administration of antitoxin, while the animal is still standing, has been associated with improved survival in horses. If feasible, this should be considered before a horse is referred for intensive care. Economic considerations may limit the use of antitoxins in some species. However, treatment was reported to be cost effective in one group of birds due to their small size. Guanidine hydrochloride has also been used in efforts to mitigate the neuromuscular blockade, especially in the past when antitoxins were less readily available.

Antibiotics are not needed in foodborne botulism, as the organisms are not growing in the body. They have sometimes been used in the treatment of poultry, with varying success. In foals, antibiotics are primarily used to prevent secondary complications such as aspiration pneumonia. Whether they could have any role in eliminating the organism from the intestines of foals is unclear; the treatment of this condition is mostly extrapolated from human infant botulism, where antibiotics are avoided. Drugs that have neuromuscular blocking properties, such as aminoglycosides, should be avoided.

Some animals with mild disease can survive with minimal treatment, or recover on their own.

Control

Disease reporting

Veterinarians who encounter or suspect botulism should follow their national and/or local guidelines for disease reporting. In the U.S., botulism appears on the reportable disease lists for many, but not all, states.

Prevention

Feed for mink and other ranched animals may be heat processed and/or acidified to reduce the risk of botulism. Carcasses should not be allowed to contaminate feed for herbivores, and silage should be monitored for proper acidification. Re-using broiler litter on ruminant farms, as feed or bedding, increases the risk of botulism. When broiler litter is spread on fields, it should be plowed in immediately. Ruminants should be given feed supplements to reduce the incidence of pica when dietary deficiencies exist. Vaccines may be available for horses, cattle, sheep, goats, mink and/or birds in some countries. Vaccination of the dam decreases the risk of foal botulism. A vaccine against one toxin type does not protect animals against other types.

Other measures may help control outbreaks once they begin. Carcasses should be collected promptly to prevent cannibalism of toxic carcasses, while fly control helps prevent the occurrence of “toxic” maggots (maggots that have ingested botulinum toxin). If possible, the litter should be removed from poultry houses. If this cannot be done, disinfectants or other treatments may help suppress the growth of clostridia in litter. Cleaning and disinfection of the environment is also recommended. Some farms may remain persistently contaminated after an outbreak despite this measure. Controlling outbreaks in wild birds can be difficult. Methods that have been attempted include discouraging birds from using contaminated areas, making environmental modifications that reduce the proliferation of *C. botulinum* (e.g., reducing decaying anaerobic vegetable matter), and collecting bird carcasses. One recent study suggested that meticulous collection of wild bird carcasses might not be able to significantly impact the course of an outbreak.

Morbidity and Mortality

In poultry, botulism tends to be most common during the summer. Most outbreaks occur in broiler chickens, especially in intensively reared flocks between 2 and 8 weeks of age. Chickens are reported to become less susceptible as they mature, and botulism is infrequently seen in layers. In turkeys, this disease seems to occur most often in 6 to 16 week-old birds. Flock mortality rates of 1-40% are common in poultry, but higher mortality rates have been documented. Botulism is reported to be especially severe in pen-reared pheasants, and more than 80% of the flock may die. Outbreaks of botulism are seen regularly in wild waterfowl and shorebirds, sometimes affecting up to a million or more birds. Dabbling ducks, coots and gulls are among the most commonly affected species. Vultures seem to be resistant to botulism.

Among domesticated mammals, horses and ruminants are reported to be particularly susceptible to botulinum toxin. The case fatality rate is often around 90% in cattle, as effective treatment and supportive care is not generally available and/or economically feasible in this species. Mortality rates up to 70-90% have also been described in adult horses during outbreaks. However, the case fatality rate among hospitalized horses was 50% at one referral hospital, with a high survival rate (95%) in animals that were able to stand throughout their stay. Nearly 80% of the horses in this study received antitoxin. The shaker foal syndrome had a case fatality rate of 90% at one time, but the use of intensive care, mechanical ventilation and antitoxin has significantly improved survival. Approximately 88% of the mechanically ventilated foals in one study and 96% of the treated foals in another study (some of which did not require respiratory support) recovered.

Carnivores and pigs are thought to be relatively resistant to botulism; nevertheless, they can become ill if they consume sufficient doses of the toxin. Contaminated feed has sometimes resulted in outbreaks affecting hundreds or thousands of unvaccinated farmed mink, ferrets and (rarely) foxes. During one large outbreak, more than 50,000 ranched foxes and other species died of botulism. Most of the animals affected in this outbreak were blue foxes (*Alopex lagopus*) and shadow foxes, a color variant of this species. Mortality was low (< 4%) in silver foxes and blue silver foxes, which are color variants of *Vulpes vulpes*. Cats and dogs were relatively resistant to the ingestion of botulinum toxin in a limited number of laboratory experiments. In one study, dogs did not become ill unless food was withheld for 48 hours before they were exposed to the toxin. In the only outbreak reported in cats, they had eaten tissues from a dead pelican that contained very high levels of botulinum toxin. Four of the eight cats died, but the surviving cats recovered quickly. Surviving a case of botulism is not thought to result in immunity to this disease.

There is relatively little information about botulism in fish. The mortality rates in fish administered various oral

doses of toxin were 92-100% in round goby, 83-92% in walleye (*Sander vitreus*), 42-92% in rainbow trout, and 25-67% in yellow perch. Yellow perch also survived significantly longer than the other three species.

Botulism in Humans

Incubation Period

The reported incubation period for foodborne botulism ranges from a few hours to 16 days, with many severe cases becoming symptomatic in 12-36 hours. Inhalation of botulinum toxin often becomes apparent in 12-36 hours as well, although some cases may take up to a few days. The first signs of wound botulism can appear within a few days and up to 2 weeks after exposure. There seems to be little definitive information about the incubation period for infant botulism, probably because the moment of exposure is often unknown and the symptoms can be insidious.

Clinical Signs

The neurological signs are similar in all forms of botulism, although additional symptoms may be seen in some forms. Rare cases in pregnant woman suggest that the fetus is not affected.

Foodborne botulism

Gastrointestinal disturbances such as nausea, vomiting and abdominal pain are common in the early stages of foodborne botulism. Botulinum toxin causes constipation, but some contaminated foods can result in diarrhea. As the disease progresses, a descending flaccid paralysis develops in the motor and autonomic nerves. The effects are usually symmetrical; however, asymmetrical signs have occasionally been noted, such as during the initial stages of a case of wound botulism on the head. Common symptoms of botulism include blurred or double vision, photophobia, drooping eyelids, an expressionless face, slurred speech, dysphagia, dysuria, reduced lacrimation, a dry mouth, somnolence and muscle weakness. There are also reports of mild cases that were primarily characterized by gastrointestinal signs, with or without mild cranial nerve involvement. Fever is usually absent, and cognitive function and the senses are almost always unaffected.

Untreated cases may progress to descending paralysis of the respiratory muscles, arms and legs. Fatal respiratory paralysis can occur within 24 hours in severe cases. The pharynx may collapse from cranial nerve paralysis, resulting in dyspnea even if the respiratory muscles are not affected. Death is usually caused by respiratory compromise. Recovery typically takes weeks to months, although some patients begin improving within days. Some survivors experience fatigue and shortness of breath for up to a year after recovery.

Wound botulism

Wound botulism is very similar to the foodborne form; however, gastrointestinal signs are uncommon and patients may have a wound exudate or develop a fever. In other cases, the abscess can be minor (e.g., a small furuncle or mild cellulitis) or clinically inapparent.

Infant botulism

Most cases of infant botulism occur before the age of 6 months, but babies up to a year of age are susceptible. The onset may be insidious or sudden, and the symptoms and severity can vary considerably. The first sign is usually constipation, which can persist for several days before neurological signs develop. Lethargy, weakness, excessively long sleep periods, difficulty suckling and swallowing, diminished gag reflexes, dysphagia with drooling, drooping eyelids and poor pupillary light reflexes may also be apparent. Some babies have a weak or altered cry. In progressive cases, the infant may develop flaccid paralysis; a “floppy head” is typical. In severe cases, respiratory dysfunction or arrest is possible. A rare syndrome caused by type F toxin is characterized by rapid progression and severe signs in very young infants, and constipation is reported to be less common than with other toxin types. Botulism might also be responsible for some sudden deaths. Supportive care may be needed for several weeks to months in some hospitalized infants; however, mildly affected babies can recover quickly. Relapses are occasionally seen after the symptoms have resolved.

Intestinal colonization botulism in adults

Intestinal colonization botulism resembles foodborne botulism, but the course of the disease may be prolonged and relapses can occur. The initial signs may include lassitude, weakness and vertigo. As the disease progresses, patients may experience blurred or double vision, progressive difficulty speaking and swallowing, descending flaccid paralysis, and other symptoms characteristic of botulism. Abdominal distention and constipation may also be seen.

Inhalational botulism

Inhalational botulism was reported in laboratory workers in 1962. It resembled foodborne botulism.

Chronic botulism

One survey of farmers whose cattle herds had been diagnosed with “visceral botulism” found that many of them self-reported various nonspecific signs such as weakness, dizziness, nausea, dry mouth, speech problems, blurred vision and respiratory difficulties. The researchers found botulinum toxins in the feces of some farmers, and have proposed the existence of “chronic botulism” resulting from persistent exposure to botulinum toxins. However, no systematic diagnostic investigation of the farmers’ symptoms has been reported, and the botulinum toxins found in their feces often differed from the toxin types in their cattle.

Diagnostic Tests

Most, but not all, cases of botulism in people can be diagnosed by detecting toxins and/or organisms in feces, other clinical samples (e.g., serum, vomitus, gastric aspirates, wound samples) or food, as in animals. Botulinum toxin may disappear sooner from the feces than the spores ingested in contaminated food, and assays to detect both are recommended. In a minority of cases, the toxin or organism cannot be found, and a presumptive diagnosis is based on clinical signs and the exclusion of diseases with similar symptoms. Nerve conduction studies and electromyography may be helpful in supporting the diagnosis or excluding other causes of flaccid paralysis.

Treatment

People with botulism can recover if they receive supportive treatment until the endplates of the neurons regenerate. Depending on the severity of the illness, the respiratory system may need to be sustained with supplemental oxygen, intubation to keep the airway open and/or mechanical ventilation. Supportive care may be necessary for several weeks or months in some cases. Botulinum antitoxin neutralizes toxins that have not yet bound to the nerve endings. It can prevent the disease from progressing and decrease the duration of the illness. It should be given as soon as possible, preferably within the first 24 hours. How late antitoxin administration should be considered is uncertain, but some reports suggest that it is still beneficial when given after 48 hours. Equine source antitoxin, which may contain antibodies against one or more toxin types, is used in adults. One recent formulation is a heptavalent antitoxin that can neutralize all known toxin types (A to G). Human-derived antitoxin, usually employed only in infants, is available from the California Department of Public Health's Infant Botulism Treatment and Prevention Program. This unit accepts international requests as well as those from the U.S. Most sources do not recommend the use of equine source antitoxins in infants, due to concerns about side effects and the possibility of lifelong sensitization to equid proteins. However, a review of infants treated with these products in Argentina suggested that they might be considered in some cases where human-source antitoxin is unavailable.

Additional treatments depend on the form of botulism. Agents that bind or eliminate any remaining toxins in the gastrointestinal tract may be employed in foodborne botulism. Treatment for wound botulism includes surgical debridement of the wound and antibiotics, which are generally started after antitoxin has been administered. Aerobic conditions may be induced in the wound with hydrogen peroxide or hyperbaric oxygen therapy. Antibiotics are not recommended in infant botulism because the death of the causative organisms might release additional toxins, and antibiotics might alter the intestinal flora, potentially enhancing the organism's growth. In addition, attempts to eradicate botulinum-producing

clostridia from infants' intestines with antibiotics were unsuccessful in the past. If antibiotics are used to treat secondary infections in patients with botulism, drugs that have neuromuscular blocking properties should be avoided.

Prevention

Commercial canning processes are designed to destroy *C. botulinum* spores, but some common home canning techniques are ineffective and should not be used with non-acidic foods. The risk of botulism in foods can also be reduced by acidification, reductions in the amount of moisture, and treatment with salt or other compounds known to inhibit clostridial germination and/or growth. Refrigeration can inhibit the growth of group I strains, but some nonproteolytic group II strains may grow at 3-4°C (37-39°F). Preformed toxins in foods can be destroyed by heating the food before serving. Food safety guidelines generally recommend heating canned foods to 80°C for 30 minutes or to 100°C (212°F) for 10 minutes. Some *C. botulinum* strains can break down sugars and ferment proteins, and foods with "off" odors or flavors should not be eaten; however, other strains grow without changing the food's flavor, odor or appearance.

Honey should not be fed to infants less than a year of age, as some batches contain *C. botulinum* spores. Tissues from animals with botulism, including meat and milk, should not be eaten. In laboratories, *C. botulinum* must be handled under BSL-2 conditions or greater, with BSL-3 precautions recommended for some procedures. A vaccine was used to help protect laboratory workers in the U.S. at one time, but it was withdrawn due to concerns about its efficacy. New vaccines are in development.

Person-to-person transmission of botulinum has never been described, but precautions should be taken to avoid exposure to toxins in body fluids and feces, and anyone who has been exposed should remain alert for the onset of symptoms. Babies may shed *C. botulinum* in the feces for several months after recovery from infant botulism.

Morbidity and Mortality

Botulism tends to occur as sporadic cases and small outbreaks affecting a few people; however, large outbreaks are possible, especially when commercially prepared foods are involved. Wound botulism, which was once very rare, has been increasing with certain types of drug abuse. The severity of botulism can be influenced by the dose of the toxin, the toxin type and concurrent illnesses. Cases caused by type B toxin tend to be milder than those caused by type A. The physical and chemical characteristics of a food, as well as the conditions under which it is held, can affect the amount of toxin produced.

Untreated botulism is often fatal, but supportive care has a high success rate when the disease is diagnosed in time. The case fatality rate for foodborne botulism was approximately 60-70% before 1950, but it has now dropped to about 5-10% in developed countries. The case fatality

rate for infant botulism is estimated to be less than 1-2%, while wound botulism is reported to kill approximately 10-15% of patients, even with aggressive treatment. People who survive botulism do not become immune to this disease.

Internet Resources

California Department of Public Health Infant Botulism Treatment and Prevention Program
<https://www.cdph.ca.gov/Programs/CID/DCDC/Pages/InfantBotulism.aspx>

Centers for Disease Control and Prevention (CDC). Botulism
<https://www.cdc.gov/botulism/>

eMedicine.com. Botulism
<http://emedicine.medscape.com/article/213311-overview>

eMedicine.com. Pediatric Botulism
<https://emedicine.medscape.com/article/961833-overview>

European Centre for Disease Control and Prevention. Botulism
<https://ecdc.europa.eu/en/botulism>

Food and Drug Administration (FDA). Bacteriological Analytical Manual Online
<https://www.fda.gov/Food/FoodScienceResearch/LaboratoryMethods/ucm2006949.htm>

Public Health Agency of Canada. Pathogen Safety Data Sheets
<https://www.canada.ca/en/public-health/services/laboratory-biosafety-biosecurity/pathogen-safety-data-sheets-risk-assessment.html>

The Merck Manual
<http://www.merckmanuals.com/professional>

The Merck Veterinary Manual
<http://www.merckvetmanual.com/>

World Health Organization
<http://www.who.int/about/en/>

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