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ANTHRAX GLOBAL EPIZOOTOLOGY.
1. SUSCEPTIBLE ANIMALS

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SUMMARY

Anthrax is a widespread disease. Epizootic outbreaks are constantly registered worldwide. Obligatory lethality of the disease, the causative agent of which leads a parasitic mode of life, makes it possible to consider mortality as the main sign of anthrax epizootic process in animals. The paper describes susceptibility of animals to anthrax under natural conditions. The paper presents literature data on the participation of animals of different species and groups in the epizootic process, and the author's own results of analysis of the recent situation. The susceptibility of animal species to anthrax depends not only on the dose, but also on the form (vegetative or spore) of the anthrax bacterium, the mode of infection, and the site of introduction of the pathogen into the organism. Anthrax affects mammals of 19 species: mostly cattle, which are intermediate hosts and hosts in the global parasitoid system; sheep and goats, horses, pigs, many species of wild ruminants and herbivorous, mostly deer, gazelles, bisons, hippopotamuses and even elephants, as well as Carnivora. Herbivorous endemic animals play the main role in maintenance of natural (soil) foci of anthrax and provide infectious cycles and regular recontamination of the soil - the only reservoir of infection. Such multipathogenicity demonstrates the predominant host range of local parasitoid systems - cattle and small ruminants in the areas of pasture, distant-pasture, free-range cattle rearing (Africa, Asia, Australia), wild herbivores in Africa and the south of the USA, bisons in Canada, deer in the north of the Russian Federation. Infection of Equidae and particularly predators has a sporadic, dead-end character. It occurs relatively seldom and does not play any significant role in anthrax epizootology and epidemiology.

Key words: anthrax, epizootology, susceptibility, susceptible animals.

The universal susceptibility of mammals of almost every species (domestic and wild herbivores, carnivores, etc.) to anthrax, their obligatory lethality, high danger and malignancy of the disease for humans, new public health threats (bioterrorism, narcotics, various animal health requirement violations, including criminal ones), disease world-wide distribution make a non-exhaustive list of the factors of current anthrax significance [2, 3, 5].

The following forms of anthrax with different disease progression rates are generally reported in the most common animals: peracute apoplectic infection in sheep, acute infection in cattle and horses, chronic form in pigs. Other domestic animals, including small ones, as well as human beings are relatively resistant to anthrax. Data on epizootology and pathology as regards animals of other species, in particular, wild fauna, are extremely insufficient and exclusively statistical. Disease occurrence in food-producing animals, namely cattle and small ruminants, is of particular epizootological and epidemiological importance [2, 6, 7, 9].

The first sign of an anthrax outbreak is the sudden death of one or more animals in a herd as the ultimate outcome of pathogenesis characterized by extremely high bacillaemia and due to the two-phase infection cycle in the organism, though livestock keepers can note some clinical abnormalities such as feed refusal, reduced milk production, swelling in submandibular fossa in retrospect; it is at this stage that etiotropic therapy can be effectively used. The deaths of highly susceptible animals can occur within just a few hours after apparent symptoms appear. In such a case, the history of epizootic situation in the region, sudden mortality incidents, in particular those chronologically close to earthworks (ploughing, excavations, deepening of waterbodies, etc.), are of utmost importance to prompt the immediate suspicion of anthrax [6, 7, 9].

It should be noted that no carbuncular lesions similar to the cutaneous form of anthrax in humans are reported in animals. Any invasive manipulations with anaerobic infection suspected animals and carcasses are highly dangerous in terms of subsequent contamination of en-

vironment with causative agent spores and prohibited by law. Post-mortem diagnosis should focus on carcass condition. The signs giving grounds to suspect anthrax in cattle and other ruminants are as follows: the absence of rigor mortis, excessive progressing bloating, bloody discharges from body openings, unclotted ("laked") blood [1, 6, 7, 9].

The chronic form of anthrax occasionally occurs in pigs; it is accompanied by manifestations of peritonsillar pharyngeal anginose inflammation, swelling of the throat and submandibular area [6, 7, 9].

In contrast to herbivores, both domestic and wild carnivores are relatively resistant to anthrax in natural conditions. The dogs are considered to be low susceptible, however, frequent disease cases occur in dogs due to eating the fragments of anthrax infected carcasses. For example, infection and lethality occur in dogs and cats in endemic African countries, in particular during epizootic outbreaks when anthrax infected cows were slaughtered by local people for meat and slaughter wastes, comprising the spleen enlarged due to the disease, were fed to small domestic animals. Lethality is rather low in dogs; nevertheless, they become *Bacillus anthracis* antigen seropositive. Similar cases were reported in foxes in the United Kingdom [6, 7, 9, 11].

Anthrax infection is well known as a disease of wild mammals in Central and Southern Africa, North America, the Russian Subarctic. Over hundreds of years, multiple hypersporadic outbreaks and epizootics (often widespread) have been reported among the Cervidae species and bisons in the Northern hemisphere, among different herbivores (antelopes, zebras, hippopotamuses, rhinoceroses, elephants) and carnivores (especially, cheetahs) in Africa. A large number of *Bac. anthracis* antigen seropositive animals among predators, scavengers and other carnivores due to their feeding preferences is indirectly indicative of the environmental activity of anthrax infection and deteriorated epizootic situation [6, 7, 9].

Natural anthrax infection in camels, buffalos, minks, badgers, ferrets, raccoons, chimpanzees, as well as numerous inadvertent infection and death cases among captive animals due to eating offal and slaughter wastes (pumas, leopards, lions, wolves, lynxes, servals, coypus, anteaters, polar bears, etc.) have been reported [6, 7].

In their fundamental analytical paper specifically dedicated to anthrax in wild animals, M. Hugh-Jones and V. De Vos report that anthrax cases were registered among turtles, birds (ostriches, ducks, cranes), various predators (about 30 species) and mammals of other categories with unusual susceptibility (over 20 species) kept in zoological gardens and on ostrich farms. In addition to sporadic cases in free or captive animals (this epizootic pattern is typical for anthrax infection); the possibility of occurrence and spread of enzootics and epizootics in gregarious animals (zebras, antelopes, bisons, and deer) was mentioned [11].

The infection and lethality of wild animals, especially herbivorous ones, were accompanied by the canonical signs of anthrax infection. Terminal blood bacilli counts should range from tens of thousands to one billion CFU/ml in order to maintain the infection cycle and for efficient post-mortem contamination. According to published data, *Bac. anthracis* blood titres were as follows: 10^6–10^8 CFU/ml in zebras, 10^8 CFU/ml in antelopes, 10^8 CFU/ml in cheetahs, 10^4–10^9 CFU/ml in rhesus monkeys, 10^9 CFU/ml in chimpanzees, 10^6–10^8 CFU/ml in elephants, 10^8 CFU/ml in sheep and goats [6, 7, 11].

In general, the disease occurrence in domestic animals is controlled worldwide, at least in the countries with adequate veterinary surveillance (diagnosis, vaccination, appropriate response measures). However, in the exotic regions of Africa and Asia, as well as in North America (Canada and the USA) long-term persistent infection characterized by periodic hyperenzootic manifestations and sustained high risk for domestic animals and humans is maintained mostly through wildlife reservoirs. Various national parks located in sub-Saharan Africa (the Kruger National Park in the Republic of South Africa, the Etosha National Park and the Bwabwata National Park in Namibia, Parc national de Taï in Côte d'Ivoire, Little Makololo in Zimbabwe, etc.), in the centre of Canada (the provinces of Alberta, Saskatchewan and Manitoba), ranches and deer parks in the south-east of the USA (the states of Texas, Louisiana) are of particular importance in this context [6, 7, 9]. A hypersporadic outbreak that occurred in the north of the Russian Federation in 2016 is illustrative of the stereotype character of the situation [5]. According to a number of credible experts, anthrax ecology (spore survival in soil, including "sporulation → germination → resporulation" cycle, spore isolation and identification, genotyping, spontaneous infection on pastures, field diagnosis) is the highest priority area in studying anthrax[1] [6, 7, 8, 10].

It is generally accepted that the susceptibility of animals of each species to anthrax is characterized by specific patterns in the development of septicaemia, the toxin level in blood, lethality. To a certain extent, infection doses required to induce anthrax reflect animal susceptibility level. The table summarizes published data on LD_{50}s for different animals.

The results of unique experiments for the assessment of animal susceptibility described by A. N. Kulichenko et al. are of interest [4]. Three cows were infected parenterally in the base of the tongue with the very high doses of the causative agent (about 10 billion spores, at least 10 LD_{50}) and, in addition to that, subcutaneously; they became diseased but survived. Mastitis occurred in one cow out of three that shed a large amount of encapsulated *Bac. anthracis* (virulent form) with its milk. The agent persisted in the blood of the other two cows for three days, but in their feces it was detected for up to twenty days. These two massively infected cows survived without any inflammatory complications and did not shed the pathogen in the amounts sufficient for the further infection transmission and epizootic spread. The pre-vaccinated fourth cow similarly infected parenterally with spores, as well as inoculated subcutaneously with the broth culture of the agent, died. The view was expressed that "the character of anthrax infection in animals depends not only on the dose, but also on the form (vegetative or spore) of the anthrax bacterium entering the body", i.e. infection with the vegetative form of the agent played a critical role. Generally speaking, based on the data obtained it can be supposed that infection is of complicated character and LD_{50} determination is somewhat approximate.

Within the scope of this paper, a detailed statistical analysis of the world anthrax-related mortality rates for the animals of various species registered in the international ProMED database [12] in the period from 2007 to 2017 was undertaken. Obligatory lethality of the disease, the causative agent of which has a parasitic life cycle, makes it

[1] In the national science, this is referred to as "natural nidality".

Table
Summarized data on Bac. anthracis spore LD_{50}s for different animal species

Animals	Infection route	LD_{50}	References	Infection route	LD_{50}	References	Infection route	LD_{50}	References
Guinea pigs	parenteral	<10–50	Lincoln et al. (1967); Schlingman et al. (1956); Watson, Keir (1994); De Vos (1990); de Vos, Scheepers (1996)	inhalation	$2–4 \times 10^4$	Watson, Keir (1994); Zaucha et al. (1998); Lincoln et al. (1967); Fildes (1943)	ingestion	10^8	Fildes (1943); Druett et al. (1953); Carter, Pearson (1999); Schlingman et al. (1956); Redmond et al. (1997); De Vos (1990); de Vos, Scheepers (1996)
Mice		<10–150			1.5×10^4			–	
Sheep		100			–			5×10^8	
Antelopes		100–250			–			1.7×10^7	
Rhesus monkeys		3×10^3			–			–	
Rabbits		5×10^3			10^5			10^8	
Rats		10^6			–			–	
Pigs		10^9			2.7×10^7			–	
Dogs		5×10^{10}			1.8×10^7			–	
Monkeys	–	–	–		$4–750 \times 10^3$			–	
Cattle	–	–	–	–	–	–	–	5×10^8	
Horses	–	–	–	–	–	–	–	5×10^8	

possible to consider mortality as the main sign of epidemic anthrax in animals.

Anthrax was registered in mammals of 19 species. The figure shows the actual susceptibility to infection by animal species.

Anthrax affects domestic animals of almost all species – cattle in the absolute majority of cases (this reaffirms their role as co-actants and hosts in the global parasitoid system), sheep and goats, pigs, horses, many wild ruminants and herbivores, mostly deer, gazelles, bisons, hippopotamuses and even elephants, as well as carnivores and predators.

Judging from the qualitative characteristic of mortality, the roles of different animal species in the epizootic process are still different. Herbivorous endemic animals of certain territories and zones play the key role in the persistence of anthrax spores in nature (soil), maintaining infection cycles and the recurrent recontamination of soil as the only reservoir of infection.

Such multipathogenicity demonstrates the predominant host range of local parasitoid systems – cattle and small ruminants in the areas of pasture, distant-pasture, free-range cattle rearing (Africa, Asia, Australia), wild herbivores in Africa and in the south of the USA, bisons in Canada, deer in the north of the Russian Federation. Infection of Equidae and especially predators has a sporadic, dead-end character; it occurs relatively seldom and does not play any significant role in anthrax epizootology and epidemiology.

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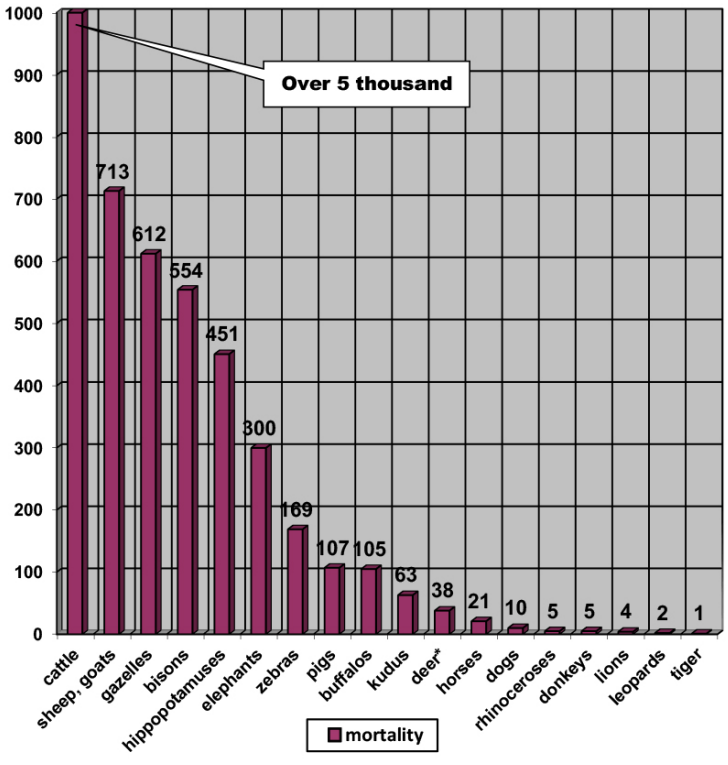
Fig. World anthrax-related mortality in animal species registered in 2007–2017

** Excluding 2600 deer that died in the Russian Federation in 2016 [5].*



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