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Plague in Camels and its Prevention in the USSR *

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In 1954-56 a series of experiments was carried out in Central Asia, under the guidance of the author, in which camels were infected with plague by infesting them with Ixodes *and* Argas *ticks which had previously fed on plague-infected laboratory animals. Subcutaneous, intradermal and intravenous injection was also used. The experiments showed that the camels varied markedly in their susceptibility to plague, which in any case was relatively low.*

Special investigations on plague prevention in camels are also reported. Vaccination with dried live vaccine injected in a single dose of 30 000 million organisms created a sufficiently high degree of immunity in adult animals. Spraying of the camels' coats with insecticide is also recommended.

HISTORICAL BACKGROUND

In Russia the first suspicion that camels played a role in the occurrence of plague in human beings in the Caspian Lowlands was voiced by N. N. Klodnitski as long ago as 1907. In 1911 I. A. Deminski, and after him N. N. Klodnitski, succeeded in confirming plague bacteriologically in two camels which had been a source of infection to human beings (Klodnitski, 1911).

After this, various research workers more than once established cases of camels suffering from plague under natural conditions both in the Caspian Lowlands and in some other regions of Central Asia. It was proved that plague-infected camels sometimes directly transmitted the infection to human beings, although only when an animal dying from plague was slaughtered and skinned and the carcass was cut up. At the same time there were no recorded cases of man being infected by camels suffering from plague, even when there had been close contact with the animal, unless the slaughtering had been carried out not long before the disease would have had a fatal outcome. Cases of camels infecting one another with plague are also unknown.

Both Bactrian camels and dromedaries have been known to suffer from plague in the USSR, but there has not been a single substantiated instance of plague in camels in any other country where the disease is endemic and where the local population makes wide use of these animals. In view of this, Pollitzer (1954) indicates that reports of plague in camels observed in the USSR have been sceptically received by several research workers elsewhere.

It is an indisputable fact, however, that camels in the USSR do become infected with plague. This leads to the supposition that such cases occurring in other countries are simply not reported, one of the reasons being the inadequacy of epidemiological investigation of foci of human plague, particularly in remote places in the deserts of Asia and North Africa.

In this connexion it is worth mentioning that in early Russian books on plague (Galanin, 1897) there is a reference to a report by a Dr Kuzminski of the Russian Mission to Teheran, discussing an epidemic of plague in Mesopotamia in 1876, in which the following observation is made: " Plague was discovered first of all in the tents of one nomad Arab tribe immediately after the meat from a slaughtered camel had been eaten ". Naturally at that time nobody attached serious significance to the fact, although Sticker (1908), in his authoritative work on the history of plague, is apparently referring to the possibility of such infection when he describes the disease in settlements near Baghdad in 1876: " A striking fact was the death of a camel in one place before an outbreak of human plague. The Arabs often saw in the death of these animals a presage of the plague."

From the time when systematic epizootiological investigation began in the natural plague foci of the USSR it became evident that plague occurs in camels only in places where very severe epizootics

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are raging among local wild rodents. It was also obvious that plague in camels was ecordred much more frequently in those natural plague foci where the main vectors of the disease are gerbils (Gerbillinae) and much more rarely in places where the primary carriers are susliks and marmots (Sciuridae).

The comparative rarity of recorded cases of plague in camels, even in places where very severe and generalized epizootics have occurred among rodents, is worthy of note. At the same time it must be emphasized that until very recent days plague in camels was diagnosed only when the animals died of it. Natural infection with plague had not once been detected in living camels.

According to the data available, altogether 44 cases of plague in camels have been bacteriologically confirmed in the USSR since 1911. In 26 of these cases the camels infected human beings.

EXPERIMENTAL INVESTIGATIONS

Camels were experimentally infected with plague for the first time by Nikanorov in 1922. Basing himself on his own conceptions of possible natural routes of infection, Nikanorov administered massive doses of plague bacilli by subcutaneous injection, by inhalation, or by incorporating such doses into the animals' fodder. Before infection he subjected the camels to over-exertion (work on pasture-land).

Nikanorov's experiments produced the following bacteriologically confirmed results. In two out of four cases he succeeded in causing the death of the camels by subcutaneous infection. Three camels infected by eating hay which had been moistened abundantly with a broth culture of plague bacilli (as much as 200 ml to each camel) recovered after suffering from a comparatively mild form of bubonic plague with submaxillary buboes. All six camels infected by inhalation died, showing a typical picture of primary pneumonic plague. The methods of infection with plague employed by Nikanorov are not, however, in accordance with modern knowledge of the natural mechanisms governing transmission of the disease.

It was decided to attempt to infect camels experimentally by the same means as those by which animals and human beings exposed to plague are usually infected in nature. This work was carried out under our guidance in the autumn of 1954 and 1956 in Central Asia, under approximately natural conditions.

A specially enclosed pasture was provided for the camels used in the experiments; before and during the experiments they remained in the open air on that pasture. To test their susceptibility to plague, the camels were infected in various ways (subcutaneous, intradermal and intravenous injection), but attention was directed mainly to the possibility of infesting them with *Ixodes and Argas* ticks as well as rodent fleas from *Rhombomys opimus* which had previously fed on guinea-pigs or white mice infected with a strain of *Pasteurella pestis* (No. 708) of which the LD_{100} for guinea-pigs equalled 25 organisms.

The *Ixodes* ticks used in the experiment were *Hyalomma asiaticum asiaticum* and the *Argas* ticks were *Ornithodorus tartakovskyi*. The former, in their imagal phase, are common ectoparasites of camels in Central Asia, and the latter, in all phases of their life cycle, are met with in great numbers in the burrows of *Rh. opimus*—the main carrier of *P. pestis* in the deserts of Central Asia. The persons directly in charge of these experiments on the infection of camels through tick bites were T. A. Burlachenko, I. I. Kurayev, V. A. Martynchenko and P. I. Anisimov.

Sufficient material has now been accumulated to prove the low vector efficiency of both *Ixodes* and *Argas* ticks in the transmission of *P. pestis*. During an epizootic among rodents in some natural plague foci in the USSR *Ixodes* and *Argas* ticks (*Ixodes crenulatus*, *Hyalomma asiaticum asiaticum*, *Haemophysalis numidiana turanica*, *Rhipicephalus schulzei*, *Rhipicephalus pumilio*, *Ornithodorus tartakovskyi* and *Ornithodorus alactagalis*) in all stages of metamorphosis were found fairly frequently—sometimes in large numbers—to be infected with plague. In the experiment success was obtained in transmitting *P. pestis* by means of *Ixodes* ticks from a sick laboratory animal to a healthy one only after so-called intermittent (interrupted) feeding—that is, the transference of the tick from a plague-infected laboratory animal to a healthy animal before it has finished the sucking process. In view of this, it may be deduced with a great degree of probability that *Ixodes* ticks are only capable of transmitting *P. pestis* mechanically on their piercing mouth-parts (Afanasyeva & Mikulin, 1957). The same must be said of the *Argas* ticks, in view of the fact that in the experimental attempts to transmit *P. pestis* through their bites, such transmission was only effected within the first two days after they had fed on a plague-sick laboratory animal. They did not

infect healthy animals when fed on them after a longer period (Burlachenko, 1958).

Attempts at infection by means of *Hyalomma asiaticum* ticks were made in 1954 on one camel. The animal did not develop plague.

In 1954 experiments on infection with *O. tartakovskyi* ticks were carried out on two camels. The ticks were released on the camels either on the day they had fed on a plague-infected guinea-pig or on the day after.[1] As a result of this infection a clearly marked and bacteriologically confirmed clinical picture of bubonic plague ending in recovery was observed in one camel. The second camel did not develop plague, although infected ticks were released on it three times at intervals of several days. In 1956, seven camels, two of them infected more than once, were used for experimental infection through bites of *O. tartakovskyi*. Thus altogether nine experiments to produce infection through the bites of these ticks were carried out. The experiments were divided into two groups: (1) those in which the ticks were released on the camels on the same day as they had fed on a plague-infected guinea-pig; and (2) those in which the ticks were transferred to the camels one day after they had fed on a plague-infected guinea-pig.

First group : There were four of these experiments. Three of them, in which 78 plague-infected ticks were fed on one camel, 19 on another and 199 on the third, were unsuccessful. Only one camel, on which 255 ticks were fed, became infected; the animal developed bubonic plague, but finally recovered. The diagnosis of plague was confirmed bacteriologically by isolating a pure plague culture from puncture material taken from the bubo on the sixth day after the ticks had been fed on the camel.

Second group : Of the camels used in these five experiments, three failed to develop plague. The animals concerned had been infested with 71, 67 and 46 infected ticks respectively. Plague, with subsequent recovery, occurred in one camel on which 500 ticks had been released. On the third day of their presence on the camel, it was found that some of these ticks had been crushed under the pouch, but by the end of the experiment 74 infected ticks, which had sucked the blood of the camel, remained uncrushed. The camel suffered from the bubonic form of plague, the nature of the disease being confirmed bacteriologically by the isolation of a pure plague culture from puncture material taken from the bubo five days after the infected ticks had begun to feed. In the case of the second camel which developed plague (and subsequently recovered) 70 crushed ticks were found under the pouch on the third day. Among the uncrushed ticks were 33 which were infected with plague and had sucked the blood of the camel. The presence of bubonic plague in this camel was confirmed bacteriologically by the isolation of a culture of *P. pestis* from puncture material taken from the bubo on the fourth day after the infected ticks had begun to feed.

The results of experiments in which fleas whose proventriculi were blocked with *P. pestis* were fed on camels will be described in more detail.

There was every reason to suspect the participation of rodent fleas in the infection of camels with plague under natural conditions, since these fleas, as is well known, are the basic transmitters of the plague bacilli from rodent to rodent and from rodent to man in the natural foci of the disease. It was clear from the history of plague among camels in the Caspian Lowlands that cases were recorded mainly in the late autumn, when the *Ixodes* ticks are in a non-active state (the diapause), but when rodent fleas are quite active. In addition to these and a number of other considerations, which leave no room for doubt that rodent fleas play a part in the natural infection of camels with plague, the experiments carried out in 1949 and 1950 by A. A. Flegontova and N. S. Novokreshchenova revealed that rodent fleas are capable of sucking the blood of camels.[1]

The number of blood-sucking fleas depended on the time of day and their position on the camel's body. During the night 75% of the fleas placed on the camel sucked its blood. Furthermore, it is worth mentioning that, in the experiments carried out in 1956, the camels had been allowed to graze on the nearby steppe before being confined to the enclosure for infection, and single specimens of *Coptopsylla* fleas were found by chance in their

[1] The camels used for feeding ticks and fleas had a section of their skin, 25 cm × 25 cm, shaved in the region of the flank. A pouch made of fine-meshed bolting silk was glued on this shaved section. Ticks or fleas were poured into the pouch in the required quantities and it was drawn tight at the top. The glue used was made out of washed-out photographic film dissolved in equal parts of absolute alcohol and ether.

[1] Camels in the desert prefer to lie down for their night's rest on the sand or earth which has been loosened and made friable by rodents (gerbils) round their burrows. The camel sometimes covers with its body a number of the openings of rodent burrows, which contain hundreds of fleas.

hair in the evening, when their temperature was measured.

The main experiments on the infection of camels through flea bites were carried out in autumn 1956 on eight camels. The persons directly responsible for this work were the parasitologists A. A. Flegontova and A. F. Dudnikova and the bacteriologists I. I. Kurayev and L. A. Guvva.

The most numerous fleas in the gerbil burrows during the working season (October) in western Turkmenistan were of the *Xenopsylla* and *Coptopsylla* species. Observations showed that the vitality of the *Xenopsylla* population was low at that time as compared with that of the *Coptopsylla* population. It was therefore decided to use for the experiments on the camels *Coptopsylla* fleas, in whose proventriculi blocks of plague bacilli developed quite quickly after the insects had been fed on plague-infected white mice.

The accumulation of stocks of blocked fleas was an exceptionally arduous task, since to select the required quantity of blocked specimens, 29 972 live plague-infected fleas had to be examined under the microscope in the course of our work.

The results of the feeding of infected fleas on camels were as follows. In all eight camels infected through the bites of plague-blocked fleas a typical picture of bubonic plague was observed after an incubation period of three to seven days. The following cases were the most noteworthy.

Camel No. 7: 134 blocked fleas were let loose on this camel, of which 90 sucked its blood. On the eighth day after the fleas had fed there appeared clinical symptoms of bubonic plague (an increase in temperature to 40°C, enlargement and severe pain in the regional lymph-nodes, generally depressed condition, loss of appetite, cessation of cud-chewing, and lameness). A culture from material obtained through puncture of the bubo showed abundant growth of plague bacilli. After five days the severity of the clinical symptoms of the disease began to diminish.

Camel No. 10: 257 blocked fleas were let loose on this camel, of which 78 sucked its blood. On the third day after the experiment had been started, the same clinical symptoms of bubonic plague appeared as in camel No. 7. In cultures of puncture material from the bubo, taken on the sixth, fifteenth and twentieth days of the illness, growth of the plague bacilli was obtained. In view of the obvious tendency to recovery after the illness, the camel was slaughtered on the twenty-sixth day after infection for pathological examination and bacteriological tests.

It should be indicated here that according to the observations of A. A. Flegontova far from all the blocked fleas which sucked the blood of the camel took part in its infection. It was noticeable that in some fleas the feeding process was limited to attempts to suck the blood of the camel without a regurgitation of the blood into the bite-wound. This circumstance does not permit accurate counting of the fleas which took an active part in the infection of the camel in each separate instance.

The experiments carried out on infecting camels with plague by various methods resulted in confirmation of the conclusion reached previously by Nikanorov that camels are susceptible to infection with plague under experimental conditions. At the same time it was noted that their susceptibility to infection was relatively low. This is obvious from the fact that even after the intradermal injection of such large doses as 4-10 thousand million virulent organisms, the camels merely developed a benign form of bubonic plague ending in recovery.

At the same time it was clear that there were marked individual differences in susceptibility to plague in different camels of the same herd. This is made most evident by the results of experiments using the intravenous route, in which eighteen camels were infected with various doses. The results are shown in the table. It will be seen that in some camels the injection of 5 million plague bacilli caused illness and death, whereas in others the injection of 500 million organisms of exactly the same strain failed to produce infection.

On the basis of the individual nature of susceptibility to plague thus established, which clearly did not depend on the age, sex or state of nutrition of the animals, it must be presumed that in nature camels are infected with plague considerably more frequently during an epizootic among rodents, but that in many cases they do not die of the disease, since it follows a mild course ending in recovery. All in all, the percentage of highly susceptible animals in a herd which die of plague is quite insignificant and this explains the comparative rarity with which cases of camels developing plague under natural conditions are reported.

The mechanism by which camels are infected does not differ from that observed in other plague-susceptible animals or in man. Their infection occurs as a result of an attack by blood-sucking

RESULTS OF INTRAVENOUS INJECTION OF CAMELS WITH PLAGUE CULTURES

Infecting dose (millions of plague bacilli)	Number of infected camels	Results		
		Did not develop plague	Developed plague but recovered	Died of plague
2.5	1	1	—	—
5	4	—	3	1
7.5	1	—	1	—
10	4	—	2	2
25	1	—	1	—
500	6	1	2	3
1000	1	—	—	1
Total	18	2	9	7

rodent ectoparasites, primarily fleas. In exceptional cases they may be infected through the bites of *O. tartakovskyi* ticks which have not long before sucked the blood of a plague-sick rodent.

PROPHYLAXIS

The overwhelming proportion of cases of human beings catching plague from camels took place in pre-revolutionary Russia, where camels were kept on individual, and often very small, farms. Under these conditions the death of a camel caused its owner great material loss and therefore, as a rule, if a camel (or any other domestic animal) developed a disease from which recovery could not be expected, the owner tended not long before the animal would have died from the disease to slaughter it so that he could skin it and sell its meat. Attempts to apply health propaganda and administrative regulations in circumstances where so much was at stake materially were not always, of course, successful.

Different conditions were created after the collectivization of agriculture in the USSR. As a result of the concentration of livestock, including camels, on large farms, where it was considerably easier to carry out veterinary and health supervision, the slaughter of camels without preliminary examination was gradually eliminated. Among the factors which helped to achieve this effect were health education of the farm workers tending the camels, the general increase in knowledge of health matters among the Soviet people, and an improvement in the technique of livestock rearing.

In order to create more reliable barriers against the possibility of human infection arising from plague-infected camels and to prevent the camels contracting the disease in the first place, research was carried out in the USSR to determine the effectiveness of vaccinating camels with dried live plague vaccine " 1.17 ". The work was undertaken in 1954 and 1955, and the persons directly responsible for it were M. I. Sotnikov, V. N. Lobanov, I. I. Kurayev, V. A. Martynchenko, T. A. Burlachenko and L.A. Guvva.

Studies were made of the innocuity, reaction-producing properties and immunogenicity of the vaccine, and attempts were made to find out the most effective doses and methods of injection. One hundred and forty-three camels of both sexes and various ages were used for the experiment. Of these 29 were infected with *P. pestis* in the course of the work to determine the minimum lethal dose in the case of intravenous injection (10 camels), to establish the degree of immunity (14 camels) and to verify the degree of immunity (5 camels).

The results of these investigations afforded every justification for recommending the vaccination of all camels with dried live plague vaccine in places where there are intensive epizootics among rodents, since (*a*) the vaccine proved completely harmless, and (*b*) on subcutaneous injection of a single dose of 30 000 million organisms in adult camels a sufficient degree of immunity was created for not less than four months.

Vaccination of camels against plague has not yet been carried out in practice in the USSR, because since 1953 there has been no epizootic of rodent plague of sufficient intensity to cause an outbreak of plague in camels.

In addition to active immunization, it is recommended that in natural foci of plague in the USSR, in order to prevent plague, as well as other communicable diseases of camels, the animals' coats should be treated with insecticides (DDT, etc.).

CONCLUSION

Observation over a long period in some natural plague foci in the USSR (the Caspian Lowlands and other regions of Central Asia) has shown that in the past plague in camels has played a part in the

occurrence of outbreaks of plague in human beings. It has been established that people were infected only if they slaughtered a camel suffering from plague, skinned it and cut up its meat. Until recently, plague in camels was diagnosed only after the animal's death; not once was such a diagnosis established in living camels. No cases were recorded of camels infecting one another.

Nikanorov (1922) was the first to succeed in infecting camels with plague experimentally. Recently (1954, 1956) it has been proved that camels can be infected by the bites of rodent fleas blocked with *P. pestis*, and sometimes by the bites of *Argas* ticks which not long before (1-2 days before feeding on the camel) have sucked the blood of a plague-infected rodent. The experiments showed that camels in one and the same herd showed a markedly individual variation in susceptibility to plague and that this depended neither on the sex nor on the age of the animal.

In order to work out effective measures to prevent plague in camels in the USSR special investigations were undertaken which proved that vaccination with dried live vaccine " 1.17 " injected subcutaneously in a single dose of 30 000 million organisms creates an adequately high degree of immunity in adult camels. At the same time the systematic treatment of the camels' coats with insecticides (DDT, etc.) is widely recommended.

Now that farm animals are concentrated on collective farms, veterinary and health supervision is markedly more effective. Health education among the population and knowledge of good livestock farming practice have improved considerably in recent times. This has meant that the slaughter of severely ill animals, including camels, without previous veterinary investigation of each individual case, has completely ceased even in the most remote desert regions of the USSR. Hence plague in camels has lost its epidemiological significance in the USSR and prophylactic measures are directed in practice towards preventing the loss of the camels themselves through plague.

RÉSUMÉ

Il est connu depuis quelques dizaines d'années que, dans les terres basses de la zone caspienne, les chameaux peuvent être atteints de peste. Quarante-quatre cas d'infection pesteuse, dont 26 ont été transmis à l'homme ont été confirmés bactériologiquement depuis 1911. L'homme s'infecte lors de l'abattage des chameaux et du découpage des carcasses. On ne connaît en revanche aucune transmission directe de l'infection d'un animal à l'autre. La peste a été observée aussi parmi les dromadaires et les chameaux de Bactriane, dans le sud-est de l'URSS. Des expériences restreintes effectuées en 1922 par injection sous-cutanée aux chameaux de doses massives de bacilles pesteux, par inhalation ou par ingestion de fourrage pollué par des cultures de bacilles pesteux ont montré que ces animaux pouvaient contracter la peste bubonique et la peste pulmonaire. Les uns guérirent, mais tous ceux qui avaient été infectés par inhalation moururent de peste pulmonaire. Toutefois ces expériences ne reproduisaient pas le mode naturel d'infection. Elles furent donc reprises, sous la direction de l'auteur de cet article, en 1954-56, dans des conditions d'infection à peu près naturelles.

On tenta de transmettre la peste à 28 chameaux, parqués dans un enclos, en les faisant piquer par des tiques et des puces infectées sur le cobaye. Les tiques étaient des *Hyalomma asiaticum*, ectoparasites normaux du chameau et des *Ornithodorus tartakovskyi*, que l'on trouve en grande quantité dans les terriers de la gerbille *Rhombomys opimus*, qui est l'hôte le plus important de *P. pestis* en Asie centrale. Les tiques n'ont transmis la peste aux chameaux que dans quelques cas, et l'on estime qu'il s'agissait plutôt d'une infection mécanique par les pièces buccales polluées par le bacille pesteux. Les tentatives d'infection par les puces — *Xenopsylla* et *Coptopsylla* — ont été plus fructueuses. Les puces préalablement gorgées et « bloquées » sur le cobaye ont transmis la maladie aux 8 chameaux qu'elles ont piqués. Ces puces bloquées avaient été choisies par examen microscopique de plus de 29 000 spécimens. On considère cependant que la sensibilité du chameau à la peste est relativement faible. D'autre part, la sensibilité à l'infection varie beaucoup d'un animal à l'autre au sein d'un même troupeau, sans que l'âge ou le sexe puisse expliquer cette variabilité. Alors que l'injection de 5 millions de bacilles causaient la maladie et la mort de certains animaux, celle de 500 millions de micro-organismes n'affectaient nullement les autres. On peut supposer dès lors que les chameaux sont infectés plus fréquemment qu'il ne paraît, lors d'épizooties pesteuses chez les rongeurs sauvages, mais qu'ils guérissent le plus souvent. La

proportion d'animaux très sensibles est infime, ce qui expliquerait la rareté des cas signalés. La voie d'infection des chameaux ne diffère pas de celle d'autres animaux sensibles à la peste, ni de celle de l'homme.

Des essais de prophylaxie ont été effectués avec une souche de vaccin vivant desséché « I.17 » administrée à 149 chameaux, dont une partie fut ensuite infectée par voie intraveineuse. Le vaccin n'a provoqué aucune réaction fâcheuse. Une dose de 30 milliards de bacilles pesteux a créé chez les chameaux adultes une immunité qui a persisté 4 mois. Ces résultats encouragent à vacciner les chameaux en cas d'épizootie pesteuse grave chez les rongeurs sauvages. On recommande également, comme mesure de routine, la destruction des ectoparasites des chameaux par des pulvérisations d'insecticides, afin de les protéger contre la peste et d'autres maladies.

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