THRESHOLD PARAMETERS OF THE EPIZOOTIC SITUATION IN THE NATURAL FOCI OF HANTAVIRUSES IN PRIMORSKY KRAI

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Abstract

The 1999–2012 monitoring of epizootic situation registered active natural foci of the Hantaan, Amur, Hokkaido and Vladivostok hantaviruses, the first two of which cause hemorrhagic fever with renal syndrome (HFRS). The peculiar features of the forest and forest–steppe natural foci of hantaviruses were revealed. In the southwest parts of the region in the forest–steppe foci, Apodemus agrarius and Microtus fortis infected with the Hantaan and Vladivostok hantaviruses respectively were found; in the forest foci of the central and northeast parts, Apodemus peninsulae and Myodes rufocanus infected with the Amur and Hokkaido viruses were registered. In all phases of the epizootic cycle, the indicators of number and contamination in mice populations were much higher as compared with vole populations. HFRS incidence in the forest–steppe and forest focal territories correlated with the activity of the Hantaan and Amur virus foci respectively. The results of the monitoring allowed us to determine the threshold indicators of number and contamination of small mammals (SM) at which aggravation of HFSR epidemic situation occurs in the forest–steppe and forest foci of hantaviruses. In case of increased epizootic activity in the Apodemus mice populations, it is necessary to carry out a complex of preventive measures against HFRS.

Keywords: Small mammals; epizootologic monitoring; Hantaan, Amur, Hokkaido, Vladivostok hantaviruses; hemorrhagic fever with renal syndrome (HFRS); natural foci; Primorsky Krai.

I. Introduction

Hemorrhagic fever with renal syndrome (HFRS) is a zoonotic disease, an acute viral human infection widely spread in the Eurasian continent including the territory of the Russian Federation. It is etiologically associated with the Puumala, Copyright reserved © J. Mech. Cont. & Math. Sci.
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Dobrava, Hantaan, Amur and Seoul hantaviruses (Hantavirus genus, Bunyaviridae family) [I, XIX, XX, XII]. In the 21st century HFRS has become a serious health care issue in many Palearctic countries [I, VI, XII]. The mechanisms of infecting people with hantaviruses are complex and multifactorial. The natural foci of hantaviruses, as well as other natural focal infections, are any ecosystems which include populations of pathogenic agents [III, IV]. The incidence of natural focal infections, including HFRS, is most often a sum of separate unrelated cases. Humans can get infected in different natural foci or in different parts of one focus, from different sources of infection or from one and the same source, in individual contact with pathogenic agent, unrelated to other infected persons [III, IV]. HFRS belongs to viral hemorrhagic fevers with the following common features: the pathogenic agents are RNA–containing viruses primarily affecting vascular endothelium; as a rule, they have low epidemic potential; multiorgan pathology develops in patients; the incidence increases periodically and considerably due to aggravations of epizootic situation in the natural foci and people’s contacts with the sources of infection [I, XIV, XVIII, XIX, XX, XXI, VII]. Since mid–twentieth century, the sanitary and epidemiologic service of the Russian Federation has been carrying out epidemiological surveillance and epizootologic monitoring of the natural foci of infections for the purpose of timely organization of preventive measures [XXIV, XXIII]. This work includes control of the foci of different hantavirus types and is regulated by the rules of Rospotrebnadzor — Russian Federal Service for Supervision of Consumer Rights Protection and Human Well-Being [XIII, XV, XVI]. The strategy of prevention of natural focal infections consists not in the elimination of pathogenic agent and not in the change of its role in the natural ecosystem, but in protecting people from becoming infected with pathogens [III].

According to statistics in the Russian Federation, HFRS is prevalent among zoonotic viral infections and is on top of the list of all natural focal diseases of people [XIV]. In the territory of Russia, the HFRS foci are located in the middle latitudes of the European part and the Far East. In the forest and forest–steppe ecosystems of PrimorskyKrai, the cases of HFRS are associated with the Amur hantavirus (genetic variants of Primorye and Primoryel–China) and Hantaan hantavirus (Far East genetic variant). The Korean field mouse (Apodemus peninsulae) and eastern subspecies of the striped field mouse (A. agrarius) serve as the reservoirs and sources of human infection [XVIII, XXVI, VII]. In recent years, data have been obtained on possible circulation in PrimorskyKrai of at least two hantaviruses whose pathogenicity for people has not yet been established — Hokkaido (HOK) and Vladivostok (VLAV). These viruses are registered in grey red–backed voles (Myodes rufocanus) and reed voles (Microtus fortis), respectively, indicating their role as reservoir hosts for the hantaviruses [XVIII, XXVI]. The sanitary and epidemiologic service is faced with an urgent issue of analyzing the epizootic situation and forecasting the HFRS incidence in the focal territories where two and more hantaviruses circulate simultaneously. Therefore, in PrimorskyKrai and in the Russian Federation on the whole, it is important to study the interaction between co-members of the parasitic “virus–rodent” system, which results in persistent
hantavirus infection in animals. Other natural focal zoogenous infections need to be assessed too [XXIV].

Among infectious diseases, natural focal infections, including HFRS, have special significance in terms of their prevention. The efficiency of the latter depends on the results of monitoring and forecasting the situation [XXV, XXIV, XXIII]. In many cases foreign researchers consider virus zoonoses as infections which are difficult or impossible to fight with at the stage of their emergence — the so-called emerging–reemerging diseases [XI, IX, X]. HFRS belongs to the “emerging” infections, which is connected with frequent identification of new hantaviruses, their role as human pathogens and a considerable problem for public health care in the world [XVII, VI]. In this connection, D. K. Lvov emphasizes that through monitoring the epidemics of “emerging–reemerging” infections can be predicted, in some cases prevented and, in any case, their consequences are reduced [XI]. The term “emerging–reemerging diseases” bears a formal meaning without any epidemiological connotation, but it is useful to practical health care [II]. Nowadays, epidemiological surveillance and epizootologic monitoring in the natural foci of hantaviruses over the territories of the Russian Federation produce the data allowing to forecast aggravations of the epizootologic and epidemic HFRS situation. A good example of forecasting such aggravations is the winter outbreak of this infection in the Central Black Earth Region [XXII]. Similar data are also accumulated for the territory of Primorsky Krai; they help to predict, prevent or, at least, significantly reduce the consequences of epizootic aggravations in the natural foci of hantaviruses. Therefore, the HFRS epidemic process can be controlled through constant epidemiological surveillance and epizootologic monitoring [VIII, XVIII, XXVI, VII].

The purpose of this research is to specify the threshold parameters of functioning of the natural foci of hantaviruses in the forest and forest–steppe zones. The parameters are necessary for forecasting the epizootic and epidemic situations in the HFRS–endemic territories of Primorsky Krai.

II. Material and Methods

We used the materials of epizootologic inspections of forest and forest–steppe territories of the region from 1999 to 2012 (Fig. 1). The works were carried out by the staff of the laboratory of hantavirus infections of Somov Research Institute of Epidemiology and Microbiology together with the Primorskaya Plague Control Station of the Federal Service for Supervision of Consumer Rights Protection and Human Well-Being. The territories for the inspection were chosen according to the natural zonality of Primorye and supposed places of human infection with HFRS agents. The population of small mammals (SMs) was assessed with use of the standard method of trap–lines [XIII, XXII]. The works were performed in 31 sites located in all enzootic zones of the Krai [V] (Fig. 1). The number of SM was calculated as a percentage of trapped animals falling into traps equivalent to 100 trap–days (TDs) [XIII]. The research covered more than 62 thousand TDs, and more than 10 thousand SM were trapped and examined. The ratio of A. peninsulae to all trapped SM made up 32.2±0.9%, A. agrarius — 34.5±0.7%. In the forest ecosystems we
noted the dominance of *A. peninsulae* (57.2±1.3%), in the forest–steppe territories *A. agrarius* prevailed (69.2±1.3%).

Infected SMs were diagnosed by the presence of the antigen, hantaviral RNA in the organs, specific antibodies in the blood. To expose the hantavirus antigen, we used (1) enzyme immunoassay (EIA) (Hantagnost test system, product of Chumakov Institute of Poliomyelitis and Viral Encephalitis); (2) RNA–polymerase chain reaction with reverse transcription (RT–PCR) (“Vektor-Best” and “AmpliSensRHantavirus” reagents); (XX) antibodies to hantaviruses — the method of indirect immune fluorescent assay (IFA) (FITC–marked antispeciesimmunoglobulins, produced by Gamaley Institute of Experimental Medicine).

To analyze the epizootic situation, we used the parameters and indicators of hantavirus infection (Table 1). SMs were considered to be infected if at least one of the infection indicators was revealed: hantavirus antigen, hantaviral RNA or antibodies to hantaviruses. Animals with the hantavirus antigen or the antigen and at least one of the other hantavirus indicators had “acute” infection. Animals with no hantavirus antigen but only antibodies or antibodies and RNA had “chronic” infection.

**Table 1:** Main parameters / indicators of hantavirus infection

| Parameters | Indicators                                      |
|------------|-----------------------------------------------|
| Hantavirus infection | hantavirus antigen                          |
|            | hantaviral RNA                               |
|            | antibodies to hantaviruses                   |
| Acute hantavirus infection | hantavirus antigen                          |
| (period of active shedding the virus into the environment through saliva, urine, feces) | antigen and antibody to hantaviruses or hantaviral RNA |
| Chronic hantavirus infection | antibodies to hantaviruses                   |
| (persistence of hantavirus in the body of natural host) | antibodies and hantaviral RNA                |
| Population size of the reservoir host: | Percentage of animal trappings equivalent to 100 TDs: |
| All animals of the species | N – total                                     |
| Infected animals | N<sub>i</sub> – infected                      |
| Acutely infected animals | N<sub>ai</sub> – with acute infection           |

**III. Results and Discussion**

The territory of PrimorskyKrai is characterized by landscape variety; about 70% of it is covered with forests. Considering the features of landscapes, SMs
distribution pattern and contamination with hantaviruses in the region, three focal areas are distinguished (Fig. 1): East Manchurian rolling plains (I), Amuro-Ussuriyskysubmontane forested area (II), Sikhote-Alinsky mountainous taiga area (III) [V]. In the structure of SMs population, A. agrarius (53.6%) and M. fortis (31.9%) make up a significant part in the East Manchurian area; A. peninsulae (66.3%), A. agrarius (18.6%) and M. rufocanus (12.1%) — in the Amuro-Ussuriysky area; A. peninsulae (47.6%) and M. rufocanus (39.4%) — in the Sikhote-Alinsky mountains and taiga. The bulk of forests is in the central, northern and western focal territories of the region — II and III (Fig. 1).

![Fig. 1: Areas of SM registering and examination in the territory of PrimorskyKrai (○).](image)

I — East Manchurian rolling plain focal area; II — Amuro-Ussuriyskysubmontane forested focal area; III — Sikhote-Alinsky mountainous taiga focal area [V].

We carried out the analysis of functioning of the natural foci of hantaviruses in the forest and forest–steppe ecosystems. The comparative characteristic of the natural foci of different hantavirus types is presented in Table 2.

The Korean field mouse is most numerous in the forested part in areas II and III(Fig. 1); it prefers cedar and broad-leaved forests, polydominant broad-leaved and small-leaved forests, oak woods; it is quite often trapped in coppices and shrubbery thickets. In the periods of large population size, in the summer months it can dominate among SMs. It is seldom trapped in fir forests and in woodless areas. However, in some years it is numerous in ecotone communities of forests and

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meadows, in coppices.

The eastern subspecies of the striped field mouse generally inhabits woodless agricultural areas and anthropogenically reorganized primary landscapes in area I(Fig. 1). It is most numerous in the wide downstream valleys of the rivers on the western macroslope of Sikhote-Alin, preferring more developed territories. In the periods of large population size, its range expands to mountainous coniferous and broad-leaved forests, mostly along river valleys.

**Table 2. Comparative characteristic of the natural foci of hantaviruses in the territory of PrimorskyKrai**

| Parameters | Indicators |
|------------|------------|
| **Type**   | FOREST     | FOREST–STEPPE |
| Range (Fig. 1) | II and III | I |
| Hantaviruses pathogenic for humans | | |
| hantavirus | *Amur*     | *Hantaan*     |
| Prevalent places of contracting HFRS | forests     | rural settlements |
| purpose for visiting the places | Short–time visit | living |
| seasonality of most HFRS cases | Spring–summer | Autumn–winter |
| periodicity of HFRS incidence increase | 3–4 years | 2–3 years |
| periodicity of high HFRS incidence | 6–10 лет | 6–7 лет |
| main sources of hantavirus | *Kp*ean field mouse *Apodemuspeninsulae* | Striped field mouse, eastern subspecies *Apodemusagrarius* |
| preferred sites of habitation | forests     | meadows and fields |
| seasonality of active circulation of the virus | spring–summer | summer–autumn |
| periodicity of epizootic activity increase | 3–4 years | 2–3 years |
| threshold parameters | | |
| Relative numbers of reservoir host: | **Increase** | **N** ≥ 8.0 | ≥ 10.0 |
| Total population size | of epizootic activity | | | |
|  | | *n* ≥ 1.8 | ≥ 1.0 |
|  | | *n*<sub>ad</sub> ≥ 1.5 | ≥ 0.6 |

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The grey red-backed vole inhabits forest territories from valleys to watershed areas — II and III(Fig. 1). The largest population density is noted in valleys in broad-leaved forests and mountainous coniferous and broad-leaved forests with thick grass stratum, and also in their derivatives — light forests and low forests. It is found in oak woods of low-hill terrains, aspen forests with abundant grass vegetation; in

Hantaviruses with unproved pathogenicity for humans

| hantavirus          | Hokkaido (HOK)           | Vladivostok (VLAV)         |
|---------------------|--------------------------|---------------------------|
| main carrier        | Grey red-backed vole     | Reed vole                 |
|                     | *Myodes rufocanus*       | *Microtus fortis*         |
| preferred sites of habitation | forests               | Meadows and fields        |
| seasonality of active virus circulation | autumn, spring           | autumn, spring            |
| periodicity of epizootic activity increase | 4 years                | 3–4 years                 |

| Increase of epizootic activity | N ≥ 1.5 | N ≥ 9.0 |
|--------------------------------|---------|---------|
|                                | n_i ≥ 0.3 | n_i ≥ 1.7 |
|                                | n.ai ≥ 0.2 | n.ai ≥ 0.8 |

| High epizootic activity | | |
|-------------------------|-----------------|---------|
|                        | n_i ≥ 0.3       | n_i ≥ 1.7 |
|                        | n.ai ≥ 0.2       | n.ai ≥ 0.8 |

| Low epizootic activity | N ≤ 1.0 | N ≤ 1.0 |
|------------------------|---------|---------|
|                        | n_i ≤ 0.2 | n_i ≤ 1.0 |
|                        | n.ai ≤ 0.1 | n.ai ≤ 0.1 |
forest–steppe landscapes it is not numerous.

The reed vole inhabits the biotopes with increased humidity: swamps, meadows, reedbeds in lowlands, inundated polydominant broad-leaved forests, thin forests and shrubby thickets. In the most part of the focal territory its population size is low. In woodless areas of the western and southern parts of the region it is a background species (area I, Fig. 1), often a co-dominant in the territory of the Korean field mouse distribution.

Considering the distribution of the main hantavirus carriers in the territory of the region, it is possible to distinguish the forest and forest–steppe hantavirus foci (Table 2).

Our study revealed considerable differences in the interaction of the Amur and HOK hantaviruses with their reservoir hosts A. peninsulae and M. rufocanus (Table 2). Active forest type HFRS foci function on the western and eastern slopes of Sikhote-Alin in the zones of coniferous, cedar and broad-leaved forests (Fig. 1). It was found that in the forest focal territories up to 68% of HFRS cases (of annual incidence) are registered from May to July, coinciding in time with the period of the Amur virus active circulation in the populations of its ecological host — Korean field mouse. However, in the years of significant increase and peak of the population numbers of A. peninsulae, two rises in HFRS incidence are noted: October–January — up to 38%, and May–July — up to 55% of cases.

In the forest–steppe landscapes of the Krai, the Hantaan and VLAV viruses’ circulation was found in A. agrarius and M. Fortis populations, respectively. The study of the features of these parasitic systems established the differences in the functioning of the Hantaan and VLAV viral infection foci (Table 2). Active forest–steppe type HFRS foci are situated in the Prikhanka lowland and in the valleys of large rivers where agriculture is developed and the main part of the rural population of the Krai lives. More than 70% of annual HFRS cases are registered from August till the beginning of the winter season, correlating with a small lag with the Hantaan virus active circulation in the host populations. In the periods of high population numbers and epizootic activity in A. agrarius populations, the number of HFRS cases in autumn and winter reaches 85% of the annual incidence, more often in Pogranichnyi, Ussuriysk, Chernigov and Spassky districts, indirectly indicating a wide spread of epizooty in field mice populations (Fig. 1).

IV. Conclusion

In the forest and forest–steppe ecosystems of the South of the Russian Far East, HFRS epidemiological issues are connected with the distribution and dynamics of the A. peninsulae and A. agrarius populations. The epidemic role of their co-dominants M. rufocanus and M. fortis is not yet proved. The asynchrony of the epizootic activity in the populations of ecologically different types of A. peninsulae and A. agrarius mice determines the temporary and spatial differences of epidemiological manifestations of the Amur and Hantaan virus infection foci. To improve the forecasting of HFRS incidence increase and its prevention, it is necessary...
to establish the threshold parameters of hantavirus circulation in population dynamics of their reservoir hosts.

As a result of long-term monitoring of the forest and forest–steppe hantavirus foci in the territory of PrimorskyKrai, we determined the significant indicators and threshold parameters which quantitatively characterize the development of epizootic process at different phases of population dynamics of rodents carriers of hantaviruses. It is important to emphasize that in different phases of epizootic activity the threshold parameters of SMs number and infected animals number were much higher in *A. pensinsulae* and *A.agrarius* than in *M. rufocanus* and *M. fortis*, which coincides with the data of the reservoir potential of the rodent–carriers of hantaviruses in the territory of the region.

Thus, for identification of the territories with increased risk of human infection in the foci of HFRS of different types, the threshold parameters of hantavirus circulation and the dynamics of the number of infected SMs can be used. For this purpose, it is necessary to carry out continuous epizootologic monitoring of their natural habitats. When increased epizootic activity of the natural foci of the pathogenic *Amur* and *Hantaan* hantavirus is expected, it is necessary to carry out a complex of preventive nonspecific measures.

References

I. Dzagurova T.K. Gemorragičeskaâlihoradka s počečnymsindromom: Ètiologiâ, specifičeskaâlaboratornaâdiagnostika, razrabotkadiagnostičeskih i vakcinnyhpreparatov [Hemorrhagic fever with renal syndrome: Etiology, specific laboratory diagnostics, development of diagnostic and vaccine drugs]. Dissertation. Moscow: Chumakov Institute of Poliomyelitis and Viral Encephalitides. 2014.

II. Korenberg E.I. Emergence of Tick-borne zoonoses from the standpoint of the theory of natural focality of infections. In: M. Kazimirova, M. Labuda, P.A. Nuttall (eds.), Ticks and Tick-Borne Pathogens into 21st Century. Proceedings of the 3rd International Conference. Bratislava, 2000. Pp. 43–46.

III. Korenberg E.I. Prirodnaâočagovost' infekcij: sovremennyeproblemy i perspektivyissledovanij [Natural focality of infections: Modern problems and prospects of research]. Russian Journal of Zoology. 2010; 89(1): 5–17.
IV. Korenberg E.I. Úbileteoriakademika E.N. Pavlovskogo o prirodnnojočagovostibleznej (1939–2014) [Anniversary of the theory of academician E.N. Pavlovsky about the natural focality of diseases (1939–2014)]. Epidemiology and Vaccinal Prevention. 2015; 1(80): 9–16.

V. Kosoy M.Y., Slonova R.A., Mills J.N., Mandel E., Childs J.E. Community structure and prevalence of Hantavirus infection in rodents: A geographic division of the enzootic area in Far Eastern Russia. J. Vector Écol. 1997; 22(1): 52–63.

VI. Kruger D.H., Figueiredo L.T.M., Song J-W., Clempa B. et al. Hantaviruses — Globally emerging pathogens. J. Clin. Virol. 2016; 64: 128–136.

VII. Kushnareva T.V. New aspects of ecology of hantaviruses and hantaviral infections. East European Science Journal. 2016; 1: 21–26.

VIII. Kushnareva T.V., Slonova R.A. Rezervuarnypotencialprirodnynyhozâevhantavirusov v dinamik eüpizootièeskogoprocessa v èkosistemahPrimorskogokraâ [Reservoir potential of natural hosts of hantavirus within a framework of epizootic process in the ecosystems of PrimorskyKrai]. Contemporary Problems of Ecology. 2014; 7(1): 19–25.

IX. Lvov D.K. Novye i vnov' vozvrašaûñieinfekçii [Emerging–reemerging viral infections]. Problems of Virology. 2000; 4: 4–7.

X. Lvov D.K. Roždenie i razvitievirologii – istoriâizučeniânovyh i vozvrašaûñieinfekçij [Birth and development of Virology — the history of studying of emerging–reemerging viral infection investigation]. Problems of Virology. 2012; S1: 5–20.

XI. Lvov D.K. Značenievnov' vozvrašaûñieinfekçij v biobezopasnosti [Significance of emerging–reemerging infections in biosafety]. Problems of Virology. 2002; 5: 4–7.

XII. Manigold T., Vial P. Human hantavirus infections: epidemiology, clinical features, pathogenesis and immunology. Swiss Med. Wkly. 2014; 144: w13937.

XIII. Ministry of Health and Medicine of the Russian Federation. Otlov, učet i prognozâlsennostimelkihmlekopaûûâîh i ptîc v prirodnnyhočagahinfekçij [Trapping, censuring and forecasting the numbers of small mammals and birds in natural foci of infections]. Recommended practices 3.1.1029-01. Approved 06 April 2001.

Copyright reserved © J. Mech. Cont. & Math. Sci.
Tatyana V. Kushnareva
XIV. Onishchenko G.G., Simkalova L.M. Soveršenstvovanie federal'nogo epidemiologičeskogo nadzora, obespečenie biologic eskojbezo pasnostinaseleñienâRossijskoj Federacii [Improvement of federal epidemiological surveillance, provision of biologic security of population of Russian Federation]. Journal of Microbiology, Epidemiology and Immunobiology. 2013; 5: 27–35.

XV. Order of Main State Sanitary Physician of Russian Federation from 14.01.2013 № 6 “Ob utverždenii instrukciipoformleniûobzora i prognozačislennostimelkikhlekopitaûših i členistonogih [About regulation approval of review and forecast appearance in population of small mammal and arthropods]”. Disinfection Affairs. 2013: 1(83): 51–56.

XVI. Sanitary and epidemiologic rules 3.1.7.2614-10. “Profiltaktigemorragičeskoi-lihoradki s počeñnym sinirom [Prevention of hemorrhagic fever with renal syndrome]”. Approved 26 April 2010 by Main State Sanitary Physician of Russian Federation.

XVII. Sergiev V.P., Malyshev N.A., Drynov I.D. Infekcionnye bolezni i civilizacija: Prošloe, nastoâšee, buduŝee [Infectious diseases and civilization: Past, present, future]. Moscow: 2000.

XVIII. Slonova R.A., Kushnareva T.V., Kompanets G.G., Maksema I.G., Simonova T.L., Simonov S.B. Hantavirusnaâ infekciâ v Primorskom krae – èpidemiologičeskaâsituaciâ v očagahcirkulâciiraznyhserotipovvirusa [Hantavirus infection in Primorskiy Region of Russia: Epidemiological situation in foci of different hantavirus serotypes circulation]. Journal of Microbiology, Epidemiology and Immunobiology. 2006; 3: 74–77.

XIX. Tkachenko E.A., Bernstein A.D., Dzagurova T.K. et al. Aktual'nyeproblemysovremennogoètapaizučeniâ gemorragičeskojlihoradki s počeñnym sinirom vRossii [Actual problems of hemorrhagic fever with renal syndrome]. Journal of Microbiology, Epidemiology and Immunobiology. 2013; 1: 51–58.

XX. Tkachenko E.A., Dzagurova T.K., Bernstein A.D. et al. Gemorragičeskaâlihoradka s počeñnym sinirom: Prošloe i nastoâšee. [Hemorrhagic fever with renal syndrome: Past and present]. Medical Virology. 2015; 29(2): 33–53.

XXI. Tkachenko E.A., Dzagurova T.K., Bernstein A.D. et al. Gemorragičeskaâlihoradka s počeñnym sinirom: Istoriâ, problemy i perspektivyizučeniâ [Hemorrhagic fever with renal syndrome: History, problems and prospects for studying]. Epidemiology and Vaccinal Prevention. 2016; 3(88): 23–34.
XXII. Trankvilevsky D.V., BakhmetyevaYu.O., Dzagurova T.K. et al. Ob aktivnosti očagov hemorrágicheskoi lihoradki s počechnyms indromom v Voronežskoj oblasti i prognozirovanii za bolevaemosti očagova hemorrágicheskoi lihoradki kciej pered poslednej v spyškoj 2006 goda [On activity of the foci of hemorrhagic fever with renal syndrome in Voronezh Oblast and forecasting the incidence of this infection before the outbreak of 2006]. Public Health and the Environment. 2012; 5(230): 35–38.

XXIII. Trankvilevsky D.V., Tsarenko V.A., Zhukov V.I. Sovremennoesosto āniepizootologičes kogonmonitoringaza prirodnym očagami infekcij v Rossii [The current state of epizootologic monitoring of natural foci of infections in the Russian Federation]. Medical Parasitology and Parasitic Diseases. 2016; 2: 19–24.

XXIV. Trankvilevsky D.V., Zhukov, V.I., Romashov B.V. et al. Aktual'nyevoprosy medicinskoi teriologii v rabote X S"ezda Teriologičeskoj obšestva RAN [Actual problems of medical teriology in the work of the X Congress of Teriologic society of RAS]. Public Health and the Environment. 2016; 4(277): 51–56.

XXV. Verzhutski D.B. Sovremennoesostoanie zoologičes rabotypoobesčeni epidemologičeskogoblagopoščeniRossii [The present situation of zoological service in providing epidemiological welfare of Russia]. Baikalskij zoologičeskij žurnal. 2013; 1(12): 109–112.

XXVI. Yashina L.N. Genetičeskoeraznoobraziehantavirusov v populâciâh grizunov i nasekomoâdnyhaziatskoj častiRossii [Genetic variety of hantaviruses in populations of rodents and insectivores in Asian Russia]. Dissertation. Novosibirsk: State Research Center of Virology and Biotechnology VECTOR, 2012.