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The practice of medical cartography from a historical perspective

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This work covers the main stages in the development of medical cartography as a branch of medical geography. The author reveals the origin and early development of this analytical method when the development or preparation of maps with the inclusion of health information acquired the magnitude of a scientific activity. The late 18th-century military practice of mapping diseases is illustrated. Notable moments in the development of medical cartography in Russia from the beginning of the 18th century are considered. The Soviet-era formation of the medical-geographical branch with its anthropological orientation and the methodological approach of systematic medical-geographical mapping are described. The modern developmental period of medical cartography methods is characterized, highlighting the three types of medical maps that are currently used. Taking into account the development of modern computer technologies and geo-information systems, opportunities for the further improvement and introduction of medical cartography into everyday practice are revealed. The application of a geo-systemic approach (construction of cartographic works on the basis of cosmo-photographical maps) is described. The potential for the use of medical cartography in epidemiological and geographical studies by pairing it with the geo-monitoring processes is indicated, as is the creation of regional medical and geographical data banks, medical and geographical management and its introduction into the practice of regional management.

Keywords: *medical cartography, medical geography, epidemiological studies, mapping of diseases, geo-monitoring*

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Introduction

Medical cartography should be considered a division of medical geography – the field that becomes an independent discipline only in the 20th century. Medical geography is regarded as a branch of geography that studies the geographic environment in relation to health of a socially organized human, includes aspects and elements of studying cultures in regard of the state of health of the individual countries' population and the impact of climate, geology, hydrology [1].

However, it is important to study not just about certain diseases and territories, but also their relationship and mechanisms of interaction. In this regard, the main objective of medical geography is the study of the causes and patterns of disease. The search for these causes is a complicated, multi-step pathway, and only a multifactorial approach to the problem can help to solve it.

Medical geography is divided into following sections: medical landscape studies, medical country studies, nosogeography (the geography of diseases) and medical cartography.

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The origin and early development of the medical cartography

History of medical geography with the elements of cartography to it begins, apparently, from the time when people began to associate the state of health and diseases with the environment. The "Hippocratic Corpus" can be considered as the first medico-geographical data, mainly the "Treatise on the air, waters and places". For example, it contains ideas for the treatment of diseases caused by climatic features of the terrain, describes possible impacts of natural phenomena on human health, and notes the possible influence of local specifics.

Long before medical climatology, meteorology and geography have become areas of medicine, people took into account the peculiarities of the climate during travel, when moving, selecting a temporary residence or a new district for the construction of a permanent settlement. In general, little has changed in the perception of connection between morbidity data at any regional level and attitudes towards how the local environment, weather and climate, terrain and soil or plants and native animals affect the concept of beneficial locality.

Thus in the Age of Discovery, in addition to information of geographical, ethnographical, botanical and zoological nature, medico-geographical data and observations were described as well, but they had no scientific basis, were often fragmentary and accidental. The expedition journals carry not only the geographical objects' outline, but also the results of watching people's lives, such as areas of diseases of local population and migrants, the relation between their natural and social environments [2].

It is hard to determine the exact time when the development or preparation of maps including information on the state of health has become a scientific activity. In 1797, in New York they presented the first medical map created by sailors during the epidemic of yellow fever [3]. However, analysis of local trade journals and documents of the time indicates that the sailors apparently have previously tested this way of collecting data. It was assumed that this map will help answer questions of setting quarantine conditions. On the map the sailors noted the territories with which they associated the development of diseases. The practical importance of the maps was not only in tying every case of fever with the arrival and unloading of local ships, but also in demonstrating that other geographical features also played their part in spreading the disease, including local fixed water bodies found on the outskirts of the urban environment.

Using maps to show regional differences in medicine at a more detailed level, in latitude and longitude, climate and weather, as well as the general topography and sickness rate retained its practical value in the future. Few of these maps were published; individual copies are in private collections. For example, one of the early Dutch medical maps of the Hudson Valley includes a description of both topographic and hydrographic features of the area, indicating diseases (fever, dysentery). Thanks to it, it was possible to prevent the building of settlements in the less unsafe areas [2].

The best examples of maps that take medical features into account are plans made for military use. In the 18th century maps, containing information based on the importance of morbidity data for certain areas, were used to determine the safest and most effective ways of taking part in the forthcoming combat. The most frequently cited example is the French military maps created in the late 1700s [2].

In the following decades it was the military maps that provided the necessary information about the spreading of diseases. There were several reasons to this pattern. Military operations involved a significant number of people living in close quarters or in tent cities, which contributed to the rapid spread of infectious diseases. The high density of the population and the resulting sanitary costs facilitated the spread of disease (e.g., infection, sexually transmitted diseases, and those propagating with increasing volume of domestic waste and construction debris). Military action propelled the population migration, an important factor in the spread of disease,– the time needed to spread the infection to the remote areas was significantly reduced [4].

By the end of the 18th century the mapping of diseases became available to scientists in times of peace as well. By this time, two types of maps, based mainly on military cartography methods, have been developed. The first version has been focused on certain "points" that could display

action, locations and people connected to a specific medical situation. Another type was a contour map showing the relationship between the regions. Both of these forms of medical maps became the standard by the 1840s, when some effective methods of graphical representation of morbidity were published [4].

Most often referred to is a medical map of historical significance – John Snow map showing his method of identifying the source of cholera in London, which, in his opinion, was the contaminated water [5, 6]. His map is considered one of the most important classic examples of using the map data to identify possible causes of the outbreak and includes information required for epidemiological services, public healthcare and measures preventing the spread of infections.

However, George Snow was not the first to create a map of disease. A number of historians attribute this "discovery" to French cartographers who worked on battlefields. Another map mentioned is by Thomas Shapter map, dating from 1848 – the first map allowing to analyze the spread of the cholera epidemic [7]. It reflects the data on the cholera epidemic in Exeter (England) in 1832. However, it was the work of John Snow which became the starting point for a wide use of medical mapping method which is inextricably linked with creating the institution of medical police in Western Europe [8].

Another historically important example of medical mapping is Henry L. Bowditch's map, published in 1860, which shows the relationship between certain soil features and tuberculosis morbidity rate [9]. It helped to analyze such physical and chemical characteristics of the soil as solubility of chemicals in various soil types, their diffusivity and its dependence on temperature and humidity.

Development of medical cartography in Russia

Apparently, the birth of medical cartography in Russia takes place in or around early 18th century. Russia conducts military operations far beyond the ancient Russian lands, and therefore there was a need for reliable knowledge about the environment in these areas and its impact on human health. Since the era of Peter I medico-geographical research was encouraged by the state and became a feature in the territories where walled cities were established. Both domestic and foreign scholars have become involved in the research [10].

Since the middle of 19th century, the development of medical geography, including cartography, came to a halt in Russia. The next stage of the development of medical cartography as a practical methodology coincided with the time of formation of the Soviet regime. The young Soviet state had to organize the healthcare and prevention system, which required an integrated approach to the study of every aspect of human activity. Thus came into focus of study the specific territories, regions, environment, which impacted individual and public health.

The main trend in the scientific establishment of medical cartography has become the allocation of medical and biological aspects of the Man vs. Environment issue, which later became Environment vs Health. Therefore, in the beginning there is an object model of data analysis, then the object-object one, and later – the subject-object model, that is, medical geography and, accordingly, cartography becoming more anthropocentric.

The methodological approach of systemic medical-geographical cartography, introduced in the USSR, reflects qualitative and quantitative variety of medico-geographic research results. Maps and atlases now contained visual and succinct information on the resources and their usage to improve the health of the population, development of leisure activities, healthcare and medical services [11].

It can be assumed that the primary goal of medical cartography is the full description of the conditions the human body operates in, reflected in whole geosystems and subsystems of different dimensions and hierarchical level [12].

In the domestic medical-geographical mapping of the Soviet period two directions were prominent. One of them, "illustrative", presents thematic maps and atlases, displaying location data on spreading of diseases and healthcare-related information for a given territory. The second direction in Russian medical geography began forming in the second half of the 1960s [11]. It focused on exploring the processes and phenomena not observed directly in nature, such as assessment of work and rest conditions of the people, environmental comfort, etc. The most significant works in the field at the time was

done by the team of medical geographers of the Institute of Geography at the Siberian Branch of the USSR Academy of Sciences, supervised by E.I. Ignatiev, B.B. Prokhorov, S.V. Ryashchenko, on cartographic analysis of the state of public health in geographical complexes of Siberia and the Far East.

At the same time, medical cartography in Russia was not confined to USSR alone. Maps of infectious diseases on the continents and islands of the Pacific, Atlantic and Indian Oceans were published as well. The method used in these projects, of nosological forms epidemiological zoning, was the basis for selection of intercontinental trade, economic and cultural ties [11].

Medical cartography today

In our times, medical geography remains relevant. Medical maps are created to show the outbreak of diseases such as influenza, tuberculosis, or for such tasks as the analysis of trends in the spread of the disease in a particular territory.

To date, there are three types of medical maps in medical cartography:

1) medical-geographic maps showing the properties of the environment, affecting the health of the population;

2) geomedical (geographical and medical maps) showing mainly the spatial distribution of human diseases, depending on the natural and social conditions;

3) healthcare maps showing the territorial distribution of hospitals, sanitary-epidemiological points, resorts and other healthcare facilities, and availability of medical personnel of various specializations, hospital beds, and so on.

All these types of maps are developed jointly by medical geographers, geographic pathologists and public health professionals [11].

At present stage medical geography and cartography are undergoing significant changes due to paradigmatic influences of other disciplines and upgraded technology facilitating new approaches to the analysis of morbidity. Thus, one example is the rapid growth of genetic knowledge and the related development of methods of studying the prevalence of genotypes in various areas.

Development of computer technology and geographic information systems has given impetus to development and widening the range of using the geosystem approach in modern medical cartography. At the moment, a large share of cartographic work is based on satellite photographs, they have become an indispensable part of territorial and urban planning.

Today there are a large number of health atlases allowing to study the diseases in depth on a national, regional or local level. Paper maps are increasingly supplemented or replaced with digital and online ones, allowing for faster updates. In recent years we have witnessed the emergence of user-level cartographic products.

A number of health-mapping studies are conducted to determine the sources of outbreaks of certain diseases. For example, the Center for Disease Control and Prevention (CDC) in the United States uses the so-called Atlas of United States Mortality which allows to consider a wide range of health factors throughout the United States. The data presented in the system are varied and range from the spatial distribution of people of various ages to air quality by location. These figures are important because they affect the subsequent growing number of respiratory diseases among the population. Local authorities those risk factors into account in construction planning and / or determining the optimal use of resources [13].

The US Center for Disease Control and Prevention created a travelers' health website [14]. Here users can get information about the spread of disease in the world and learn about vaccination necessary for international travel. Such use of medical mapping helps preventing the spread of disease.

In addition to the Center for Disease Control and Prevention, the World Health Organization has similar data about health of the world, which are accounted for in the "Global Health Atlas" [15]. By using it, health professionals, researchers and other interested parties can obtain data on the prevalence of disease in the world in order to identify patterns of transmission and possibly the treatment of diseases.

A striking example of the combination of modern digital technologies and medical cartography aimed at practical health is the "Antimicrobial resistance map of Russia" project (first version is of 2006), which provides a

synthesis of published data on antibiotic resistance of the main bacterial pathogens of community-acquired and nosocomial infections. The main idea of the project is to provide users with the ability to visualize and easily comprehensible way to get useful information on the antimicrobial resistance of clinically relevant microorganisms. Currently, the analysis and presentation paradigm in this project were radically revised and a new web application was released, taking into account modern approaches to data analysis [16].

Conclusion

Thus, medical cartography has come a long way (from the military maps that give an approximate idea of the incidence of diseases in certain areas, to science-based medical maps, using modern digital technology); it has reached a new stage in its development. Today, medical cartography is widely used both in epidemiological studies and in geographic ones, allowing to solve new problems. Medical cartography facilitates the testing of hypotheses determining the factors associated with the spread of diseases (e.g., sources of exposure, social determinants). As a means of communication, the map is used to isolate populations at risk of disease, or to predict the development of the situation. These capabilities of medical maps are often supplemented with geostatistical tools of spatial analysis and visualization.

In any case, the map is an interpretation and graphic translation of the external in the real world with minimal distortion. Mapping diseases is now a daily practice. This is facilitated by the development of digital technologies, including geographic information systems and Internet mapping systems, such as Google Earth, which ultimately increases the information availability for both national health systems and the general population. Ensuring further development in this type of work calls for establishing geomonitoring, regional medical geography data banks, medical-geographical management, and their introduction into the practice of regional management.

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