Scientific and practical educational aspects of modern epidemiology: a view through the prism of history

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This article presents the stages of development of epidemiology and offers their brief characteristics. We discuss the key issues pertaining to the definition of the object, subject and methods of epidemiology at each stage. A definition and characteristics are given to the epidemiological approach towards studying the human diseases. We review the structure and contents of modern epidemiology as a fundamental medical science, relating to the area of preventive medicine, the subject of which includes the entirety of human pathology – infectious and non-infectious. The paradigm of modern epidemiology is analyzed from the theoretical, practical and educational positions. We emphasize the importance of clinical epidemiology and evidence-based medicine in solving the problems in medicine at the organismic and population levels.

Keywords: *epidemiology, incidence, paradigm, conception, globalization, evidence-based medicine*

Epidemiology as a science originated as a result of society's experience fighting epidemics in ancient times. The development and establishment of epidemiology can be divided into three stages – pre-bacteriological, post-bacteriological and modern.

Initially, epidemiology's subject matter was considered to be any mass widespread disease – an epidemic. Prior to the fundamental discoveries of microbiology, the understanding of an "epidemic" in an infectious sense was not intrinsic. Different authors applied generalized names for cases of mass diseases: "plague," "pestilence," "craze," "scourge," etc. In the ancient world, it was already clear that to judge epidemics only on the basis of knowledge of specific diseases was to fail to see the wood for the trees. In this regard, initially medicine saw human diseases (clinical) studied in parallel with the incidence of disease among the population (epidemiology). Hippocrates' writings already contained generalizations concerning the characteristics of epidemics. In his collection of seven books titled Epidemics, he wrote of the "epidemic constitution of places and years," i.e., epidemics are confined to certain places and time periods. [1] Also highlighted is the third sign of the manifestation of epidemics – an uneven targeting of certain social groups. Hippocrates tried to explain the patterns and sought reasons for the "epidemic" diseases in the air. He was one of the first proponents of the miasma theory.

We now have a clear understanding of the epidemiological approach to the study of human diseases. It aims to identify the distribution patterns of disease prevalence territorially, across time and in different social and age groups, in order to clarify the cause-effect relationships. The results of these activities form the basis for the development of preventive programs working in different orientations and areas.

In the pre-bacteriological period, epidemiological studies were widely carried out both in Russia and abroad. Thanks to these studies, medicine was enriched with the knowledge necessary to prevent disease, even before there were microbiological, biochemical or other scientific evidence on the etiology of diseases. It is sufficient to recall the research of Snow, Goldberger, Doll and Hill, plus the famous Framingham Heart Study. Finally, we should not forget about

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the research conducted by zemstvo county doctors in Russia in which they studied the causes of the most common diseases in different regions of the country.

Starting from the 19th century, medical statistics reflected morbidity and mortality in quantitative terms, a significant factor in the development of epidemiology. This provided the possibility of moving from qualitative descriptions of individual episodic outbreaks to a systematic accumulation of quantitative indices characterizing the population's general health. Zemstvo county medicine played a major role in the development of epidemiology in Russia in the late 19th to early 20th century. Starting from 1870, the Epidemiological Leaflet was produced in Russia. It published data illustrating the distribution of diseases and mortality rates in connection with various social factors. In those years, domestic medicine's progressive members conceived the idea of creating special structures for preventive health care. In 1872, the position of sanitary doctor was introduced in Russia for the first time in the Perm region. Following this, these positions were introduced in other provinces. The main functions of sanitary doctors were epidemiological – the statistical processing of diseases, the analysis of epidemics, the development of preventive measures and ensuring their execution.

The next time frame in epidemiology's development was the period following the major bacteriological discoveries (Pasteur, Koch, Mechnikov, etc.), which fundamentally changed the perception of epidemics' causes. During this period, Russian epidemiology developed mainly as the epidemiology of infectious diseases, although in countries abroad along with infectious diseases research was intensively conducted on noncommunicable diseases.

These bacteriological discoveries led to the formation of of microbiology, immunology and clinics for infectious diseases, as well as the new science of epidemiology – the science of epidemic processes. This period was characterized by a deepening knowledge of the mechanism by which infectious diseases emerged and spread. This saw a transformation not only in the subject but also in the method of epidemiology. An emphasis was placed on work with epidemic outbreaks to identify sources and mechanisms of infection with contagious diseases.

It was during this period that remarkable successes in Russia were achieved in theoretical generalizations that have withstood the test of time and are the theoretical basis for the fight against infectious diseases. Numerous authors have rightly said that the epidemiology of infectious diseases is a Russian science. [2] Of course, science has no nationality, but it is definitely possible to speak of a very significant national contribution to global epidemiology.

Among the most important theoretical generalizations of the 20th century, first and foremost should be the doctrine of the epidemic process, in particular, the transmission mechanism described by the patriarch of Soviet epidemiology L.V. Gromachevsky. [3] It was he who introduced the concept of an "epidemic in the broad sense of the word" or the "epidemic process." Epidemiology began to be defined not only as the science of epidemics, but also of the epidemic process in all its manifestations: from pronounced epidemics to isolated cases of infectious diseases.

Among other important theoretical generalizations of the 20th century that should also be mentioned are the theory of natural focality by E.N. Pavlovsky, the doctrine of sapronoses by V.I. Terek, the theory of self-regulation of parasitic systems by V.D. Belyakov, the theory of correspondence and etiological selectivity as main routes of transmission shigellosis by V.I. Pokrovsky and Y.P. Solodovnikov, and the socio-ecological concept of B.L. Cherkassky.

At Moscow University, the basics of prevention and control of infectious diseases were taught in different departments of the medical faculty, long before the formal establishment of the department of epidemiology. From 1884, these issues were already being dealt with in an independent academic course, which was held in a unified department of hygiene, epidemiology, medical police and medical statistics. The first head of the department was F.F. Erisman who was equally both a hygienist and epidemiologist. In his major work, "A Guide to Hygiene," he sum-

marized the data known at the time concerning epidemiology and infectious diseases and classified groups of infectious diseases by the means of their transmission, and also gave a rather detailed description of each form of transmission. It is also the first time in history that the possibility for elimination of a number of infectious diseases was suggested. [4]

In 1931, he opened the independent departments of epidemiology at the Central Institute of Medical Development and at the I.M. Sechenov First Moscow Medical Institute. The first heads of these departments were L.V. Gromashevsky and N.N. Klodnitsky. From 1932, sanitation departments that included departments of epidemiology opened in many medical institutions. In addition, associate professor courses in epidemiology were held at all medical and pediatric faculties. The inclusion of epidemiology among academic disciplines is in itself of tremendous, crucial significance. Departments of epidemiology became centers for the training of qualified personnel with epidemiological specializations.

The modern period has been characterized by the further development of infectious disease epidemiology. It faces many unsolved problems, the number of which does not decrease, but increases as a result of classic diseases that have changed their expression (clinical and epidemiological manifestations), and new, recently discovered infections. The situation is aggravated by the increasing resistance of microorganisms to medicines and disinfectants. Millions of people around the world die for this reason each year. The widespread, uncontrolled use of antibiotics has led to a change in humans' microbial ecosystems and has reduced people's resistance to microorganisms. Worsened environmental conditions and excessive psycho-emotional stress has led to a significant increase in the prevalence of immunodeficiency. The result has been a substantial increase in the significance of opportunistic pathogens and the incidence of opportunistic infections. There has been an increasing number of recorded cases of unusual combinations of known infections. In clinical and experimental studies, a wealth of facts on the characteristic development of associative diseases has been accumulated.

In recent years, there has been a lot of talk about globalization. All major aspects of globalization – economic, environmental, political, demographic and technological – are closely interrelated and affect both the prevalence of infectious diseases, and the opportunity to prevent them. [5] It has been found that globalization has largely created a favorable environment for many infectious diseases to spread and change their structure.

The risk of infectious diseases is associated not only with the "rejuvenation" of well known but already rather neglected diseases, but also with the appearance of new, previously unknown infectious diseases. In connection with this, it is appropriate to recall the words of visionary Nobel laureate Charles Nicolle: In the future, new infectious diseases will appear, some of the old will slowly disappear, and those that remain will not have exactly the same form by which we know them now.

In 2000, the United Nations Security Council declared that infectious diseases have evolved from a public health problem to global political issue. A World Health Organization global report underlines that since the 1970s, each year one or two new infectious diseases are registered and that only a few hours are required for an infection that broke out in one region of the world to cause an emergency at the other end of the planet. The epidemiological forecast for the first half of the 21st century is unfortunately not comforting. At any moment, at any place on the planet, an epidemic or outbreak could start, with the causative agent being infectious pathogens: new pathogens, recurring pathogens and pathogens migrating into new territories. The range of possible human pathogens (including chronic infections) is constantly expanding.

Today we can talk of X-infections, i.e. diseases that are at present practically unknown or have just been described, but will certainly be widely diagnosed in the 21st century. [6] For example, in the last few years we have learned about new pathogens causing viral infections, such as metapneumovirus, bocavirus, coronavirus and in-

fluenza, including "bird" and "swine" flu. A new lethal variant of coronavirus has been discovered (MERS), causing Middle East Respiratory Syndrome, and a new variant of avian virus H7N9.

On the other hand, increasingly the etiology of classical somatic infections has been clarified. So, the infectious etiology of many malignancies has been proven – myocarditis, nervous system disorders, peptic ulcers and many other diseases. Currently, in many areas of clinical medicine (gastroenterology, urology, cardiology, obstetrics and gynecology, etc.) a greater role has begun to be played by microorganisms and, primarily, by potentially pathogenic and opportunistic microflora. [7]

The epidemiology of infectious diseases, alongside the achievements of the Russian epidemiological school, is being intensively enriched in theoretical and practical-scientific aspects.

As a result of research, over the past few years specialists from the Central Research Institute of Epidemiology at the Federal Service for Oversight of Consumer Protection and Welfare have developed a modern management concept for the epidemic process. Further improving the management of the epidemic process primarily involves the development and introduction of new techniques for epidemiological surveillance and control. This involves wide use of molecular-biological and genetic research, without which it is impossible to carry out epidemiological diagnosis and forecasting of the development of the epidemic process. Furthermore, we can say that we are on the verge of entering a metagenomic era of studying the world of pathogenic bacteria and viruses [7].

Among this period's theoretical foundations are three concepts that will influence the research of epidemiological problems: The concept of biodiversity and diversity of microorganisms, the concept of gene flow and variability of microorganisms and the concept of microbiome. [8] We are witnessing the change of the age-old paradigm of diagnosis and surveillance of infectious diseases: instead of seeking individual (target) pathogens – suspected etiologic agents – there is an opportunity to reveal in any sample of biological material or in an environmental sample an entire diverse range of genetic material (metagenom) and to follow this by identifying type, subtype and genetic lines. All this is achieved without culturing bacteria and viruses due to amplification techniques and complete sequencing of the entire metagenome.

In recent years there has been intensive research into developing methods for mathematical modeling of the epidemic process, the creation of electronic databases and atlases for numerous infections. However, the information-analytical subsystem of epidemiological surveillance needs serious modernization. Methods of collection, storage and processing, and information exchange often do not meet modern needs.

The Russian Federation's state program Health Development and Development Strategy for Medical Science in the Russian Federation Through to 2025 has determined the need for a widespread introduction into health practices of modern information technology and analytical information processing applications for management in health care, as well as the creation of a single information space to provide for timely management decisions.

Epidemiological studies provide a tool to aid management decisions in the field of public health, based on scientific evidence, causal links that are revealed and common sense. In this regard, it is no coincidence that epidemiology is called the "diagnostic discipline of public health." Epidemiological methods created using the fundamentals of infectious diseases epidemiology have proved extremely effective in the study of distribution patterns of various pathological conditions among the population. In modern conditions epidemiological research methods have been used successfully in the study of risk factors for heart disease, cancer, and many other occupational diseases.

In accordance with the definition of epidemiology as a science, set out in the new standards for the scientific specialization [9], epidemiology is a fundamental medical science related to the field of preventive medicine and studies the causes and characteristics of the spread of disease in the community in order to apply the acquired knowledge to solve health problems.

It includes two sections with a unified research methodology: the epidemiology of communicable diseases and the epidemiology of noncommunicable diseases. Both of these sections are identical in nature: they have a common object of study, a unified scientific method and a common goal of disease prevention.

Besides disease prevalence, epidemiology subjects include the phenomena that reflect upon disease outcomes – mortality, lethality, disability, temporary disability and even recovery. Together they form epidemiology's subject area.

In trying to answer the important question of why diseases emerge and spread, epidemiology "chose" as the main focus of its activity the incidence of disease in the population, rather than its overall health. The specialization's new standards also identified its fields of research.

In our view, the structure of modern epidemiology includes general epidemiology (epidemiological approaches to the study of human diseases, epidemiological diagnosis and epidemiological studies, management and organization of preventive and anti-epidemic activities), the epidemiology of infectious diseases, military and hospital epidemiology and epidemiology of noncommunicable diseases. Epidemiology of infectious diseases includes such sections as "vaccinology," "disinfectology," and "parasitology," which, in turn, are largely separate disciplines.

Recent years have seen the appearance and intensive development of "hospital epidemiology" – the epidemiology of diseases associated with medical care, and not only caused by pathogens, but also opportunistic microorganisms, hospital strains of microorganisms, the distribution of which is fundamentally different from the traditional spread of infections. The strategic objective is to provide quality health care and create a safe hospital environment. Nosocomial infections are a very important component of this problem because of the widespread negative consequences for the health of patients, staff and the state's economy.

The intensive development of high-tech, invasive diagnostic and treatment methods in conjunction with the wide distribution of multidrug-resistant micro-organisms determines the need for continuous improvement of surveillance and control of infections associated with medical care. The national Concept for the Prevention of Infections Associated With Medical Care, approved by Russia's chief medical officer, lays out the strategic direction and basic concepts for research. [10]

The widespread use of epidemiological studies in clinics in the late 1990s led to the formation of a new section of epidemiology – clinical epidemiology, which, in turn, is the basis of demonstrative or science-based medicine. Clinical epidemiology is often identified with hospital epidemiology. However, this is not the case. The objects of their study are significantly different.

We can say that clinical epidemiology is a division of epidemiology, including the methodology for obtaining via epidemiological research scientifically based evidentiary information concerning diseases' patterns of clinical manifestations, methods of diagnosis, treatment and prevention, to make the best clinical decisions regarding a particular patient. [11]

The formation of clinical epidemiology was related to a need to expand the scientific basis of medical practice, the desire to provide an epidemiological foundation for clinical decisions, based on data from population studies. [12] Currently, there is more and more talk of so-called personalized medicine, where each patient's medications will be selected taking into account molecular-genetic, biochemical and immunological characteristics of the patient's individual physiology. The drugs are standard, tested in epidemiological studies in terms of efficacy and safety. Unfortunately, many clinical guidelines in Russia are built on purely empirical trials and do not have a sufficient demonstrative basis.

However, the development of clinical epidemiology is a prerequisite for progress in medical science and the improvement of practical conduct. [13] Many leading medical universities have introduced clinical epidemiology as a required course and consider it one of the fundamental disciplines. Russia cannot remain isolated from the world trends in medical science and teaching experience in epidemiology. In this regard, modern educational study programs for epidemiology require the teaching of clinical epidemiol-

ogy issues be expanded both within fundamental educational programs, and in the implementation of elective courses. Currently, there is a need to train qualified specialists with professional competence, knowledge, abilities and skills in making management decisions for conducting treatment and preventive measures using the principles of evidence-based medicine.

Over the past several years the staff of the department of epidemiology and evidence-based medicine at the I.M. Sechenov First Moscow State Medical University have developed and published a sample model program and the relevant textbooks for the teaching of clinical epidemiology and evidence-based medicine. The methodological and substantive issues of teaching clinical epidemiology were discussed at a special meeting of the educational-methodical commission on epidemiology, the proceedings of which were published in the media and provided to the Ministry of Health with the goal of informing all the country's medical universities. One of our goals for the near future is the expansion of teaching and research in clinical epidemiology in different fields of medical science and practice and improving their quality.

Unfortunately, it needs to be acknowledged that a problem in Russian medicine is the insufficient application of the principles of evidence-based medicine in practice. "Medicine must be evidence-based." This slogan is intended not just as a declaration, and applying simply to research, but to be also the ideology of modern medicine, pervading all spheres and levels – from primary to tertiary care. This fully applies to preventive medicine.

It should also be noted that the epidemiology of noncommunicable diseases faces a lower level of development than the epidemiology of infectious diseases. Ongoing studies are mostly descriptive, whereas the causes and risk factors are not well understood.

The theoretical basis of noncommunicable disease epidemiology has not seen significant development in recent years and is still rather weak. Attempts to extend the teaching of the epidemic process and theoretical concepts belonging to the epidemiology of infectious diseases to non-infectious pathology have not been successful. Therefore, based on the accumulated substantial epidemiological evidence concerning various manifestations of noncommunicable diseases, it is necessary to implement theoretical generalizations for the formation process pattern and spread of these diseases. [14]

Another important section of the general area of the epidemiology of non-communicable diseases is the designing and building of informational-analytical systems and control systems. There is a need to move from medical statistics to a type of system of epidemiological surveillance (clinical and epidemiological monitoring) of individual non-communicable diseases and all somatic diseases; from individual preventative measures and programs to a management system for disease prevalence in the population. [14]

An equally important task is to develop a teaching concept for the epidemiology of noncommunicable diseases and methodological support for this program: the creation of textbooks for students as well as teachers. On the initiative of the department of epidemiology and evidence-based medicine, the department played a decisive role in releasing the first interdepartmental epidemiology textbook for students of the preventive medical faculty [15] and an interdepartmental collection of tests and case studies. [16] A textbook for students of the medical faculty was published.

The Epidemiology of Noncommunicable Diseases program was introduced into the curriculum for students, interns, residents and graduate students, as were the above mentioned textbooks. Work is finishing on creating a unified educational system with the identification of the five main themes: The epidemiology and prevention of cardiovascular diseases and cancer, behavioral and mental disorders, environment-related diseases and diabetes.

For each topic, a whole package of training and supervising teaching documents (sample lectures, tests, case studies, manuals, guidelines for teachers and students) are being developed. This work is being carried out as part of the training-methodical commission on epidemiology, to-

gether with various teaching staff from Russia's leading departments of epidemiology. This integrative activity allows for the development of a common methodological approach to teaching this quite complex and a new for us area of epidemiology.

In recent years, the range of professional activities in the field of epidemiology has significantly expanded and there are significant differences in its content depending on the work location of future graduates. We must consider this fact, and professional competence should be developed separately for work in the organs and institutions of Federal Service for Oversight of Consumer Protection and Welfare, medical organizations of the Ministry of Health of the Russian Federation, research institutes with epidemiological profiles, epidemiological departments and specialized medical centers involved studying the epidemiology of non-communicable diseases, health centers and so on.

The training of specialists in epidemiology should be based on a modular principle taking into account the current understanding of the structure of the discipline and focus on the whole spectrum of approaches for future professional activities. [17]

Unfortunately, the holistic perception of epidemiology as a medical science, the subject area of which includes all human pathology – both infectious and non-infectious [18] – has not been officially implemented in the practice of epidemiologists at any Federal Service for Oversight of Consumer Protection and Welfare bodies and institutions, nor in health care organizations. A gap between epidemiology as a science and epidemiology as a medical practice has formed and is growing. [14] This is compounded by problems in the field of education: we teach epidemiology, based on its current international understanding and role in medicine, but in practice, our graduates face a different situation in the practice of medicine.

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Received: 09.01.13.

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The name of the article for the quotation: Nauchno-prakticheskie i obrazovatel'nye aspekty sovremennoy epidemiologii: vzglyad cherez prizmu istorii. Istoriâ mediciny. 2014. N 1. P. 36–45.