Research Article

Oncological diseases in St. Petersburg, Russia

Eugeny P. Kolpak*, Inna S. Frantsuzova, Elizaveta O. Evmenova

ABSTRACT

Aim: The article provides the analysis of statistical data on oncological diseases in St. Petersburg. **Methods:** The main attention was paid to the statistical analysis of tumor diseases and the methods of their diagnosis and treatment. **Results:** The main specializations have been identified, and the number of their patients is constantly increasing. The rate of patient number growth, the age structure of morbidity and mortality are estimated, and the most widespread diseases for men and women are revealed. **Conclusion:** The assessment of bed capacity at various medical institutions of the city is provided. A multilevel system of cancer patient accounting and care is described.

KEY WORDS: Cancer care, Mathematical modeling, Mortality, Simulation, Statistics, Tumor

INTRODUCTION

In Russia, oncological diseases appeared in the statistical reports of the medical department only at the end of the 19th century. At that time, the most difficult task was to reduce one of the highest infant mortality rates as compared to the most European countries. Nevertheless, the danger of cancer in the country was realized. Moreover, on March 31, 1914, the First All-Russian Congress on the fight against cancer took place in Petrograd. The main attention was paid to the statistical analysis of tumor diseases and the methods of their diagnosis and treatment. The next step was taken after the end of the civil war. In October 1925, on the initiative and an active participation by N. N. Petrov on the basis of I.I. Mechnikov's hospital in Leningrad, they established the oncology department, which became an independent scientific and practical oncological institute in 1927. Moreover, nowadays, it is the member of the international anticancer union.

The oncological service of the USSR was created in 1945 by the Resolution of the Council of People's Commissars "On the Measures for Oncological Aid Improvement to the Population." The resolution provided for the creation of a network of oncologic dispensaries whose tasks were to record and treat patients with malignant neoplasms (100 dispensaries were established in Russian Federation [RF] by 2015). The computer technology for information collection and processing developed in the second half of the 20th century allowed the development and implementation of the system to monitor and control RF population health. In 1996, they developed general regulations on the cancer register at the territorial level, and then, they developed the register management system at the federal level. The analysis of systematized information allows us to outline the measures aimed at a better solution of material support tasks for the oncological service, training, the level of diagnostics increase, and the conduct of post-rehabilitation period.

Quantitative data on morbidity and mortality in St. Petersburg due to cancer are published by the Moscow Cancer Research Institute named after P.A. Herzen at Federal Agency for High-Tech Medical Care[1-3] and the Federal State Statistics Service.[4,5] The data of these organizations differ by 3–4%, depending on the disease location. In St. Petersburg, the analysis and the processing of information on oncological diseases are carried out in the medical information and analytical center of St. Petersburg. The morbidity structure of the population is monitored in the center taking into account gender characteristics. The following analysis of statistical data was carried out per 100,000 inhabitants.

Access this article online

Website: jprsolutions.info | ISSN: 0975-7619

Department of Computational Methods in Continuum Mechanics, Faculty of Applied Mathematics and Control Process, Saint Petersburg State University, 7-9, Universitetskaya nab., St. Petersburg, 199034, Russia

***Corresponding author:** Eugeny P. Kolpak, Department of Computational Methods in Continuum Mechanics, Faculty of Applied Mathematics and Control Process, Saint Petersburg State University, Saint Petersburg, Russia. E-mail: petrovich_pmpu@mail.ru

Received on: 14-1 1-2018; Revised on: 12-12-2018; Accepted on: 07-01-2019

MORTALITY IN RF

About 2,000,000 people die in RF each year. The diseases of blood circulation system take the first place in mortality structure (53.2% of deaths). Since 2008, neoplasms occupy the second place (15.4%) and the third place is occupied by external causes (12.2%). As follows from the data analysis of the Federal Statistics Service,[4,5] the mortality rate from all causes of diseases and circulatory system diseases decreased by 30% from 2003 to 2016. The mortality from cancer was only stabilized.

In contrast to RF as a whole, there is an annual decline concerning the number of deaths from neoplasms in St. Petersburg, starting from 2010. In 2000, the death rate in the city reached its highest value and made 281 people per 100,000. The rate was 1.3 times more than in 1990. By 2013, it decreased to 250 people per year (the rate decreased by 12%). Similar results for the overall incidence of oncological diseases among Russian population are given in the study of Davydov and Aksel, Jakab *et al*., Kolpak *et al*., and Lewison and Markusova[6-9] and for individual specializations in a study of Aksel *et al*., Ignatyeva *et al*., Kolpak *et al*., Kolpak *et al*. and Pushkar *et al*.[10-14]

DYNAMICS OF ONCOLOGICAL DISEASES IN ST. PETERSBURG

The dynamics of cancer patient number change from 1970 to 2013 in Russia and St. Petersburg, based on the number of patients per 100,000 inhabitants, is shown in Figure 1. The statistical data are marked with *; solid lines correspond to exponential dependencies. Data "1" correspond to the RF and data "2" St. Petersburg. The values of the data for 1970 are taken as equal to one. As follows from the analysis of statistical data, the increase of patient number in RF and St. Petersburg is subjected to exponential dependence with the value of 0.027 for Russia (the increase in the number of patients makes 2.7% per year) and with the figure of 0.020 for St. Petersburg (the increase of 2% per year). However, the number of patients per 100,000 inhabitants in St. Petersburg is 10% more than in RF during 2013.

The mortality rate of patients of both the sexes based on the number of cases per 100,000 inhabitants of the relevant age group in 2016 in relation to the mortality of 1993 is shown in Figure 2. As follows from these data, mortality during the period under review increased by 20% in all age groups up to 39 years old and in the age groups from 59 years old and older.

In 2016, within the incidence of malignant neoplasms among the population of both the sexes, 50% of the total morbidity accounted for the following localizations:

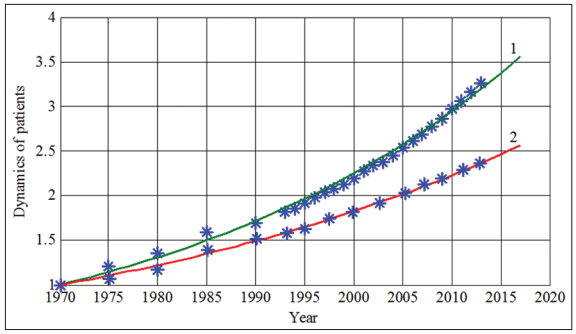

Figure 1: The dynamics of patient number in Russia and St. Petersburg from 1970 to 2013: 1 - Russia, 2 - St. Petersburg

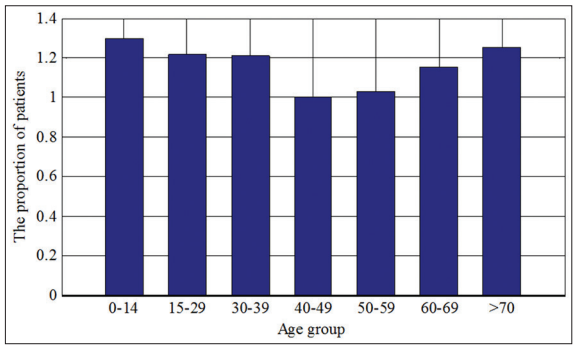

Figure 2: The mortality of patients by age cohorts: The ratio of the dead in 2016 to the dead in 1993

Mammary gland, colon, trachea, bronchi and lungs, skin except for melanoma, stomach, and lymphatic and hematopoietic tissues. Table 1 presents the data on diseases of individual organs with the maximum proportions (%) of all diseases in the aggregate constituting 80% of all diseases. Table 2 presents the data on deaths by the localization of diseases, taking into account gender characteristics (% of the total deaths in the group).

Table 3 presents the data on the increase (in percentage with plus sign) and the decrease (in percentage with minus sign) of sick men and women in St. Petersburg and RF from 2007 to 2016 for trachea, mammary and prostate gland, skin, and stomach diseases. As follows from these data, the total number of cancer patients for all nosologies in St. Petersburg increases more slowly than in Russia. Similar changes occur for the diseases of the prostate and mammary glands, as well as skin among men. The number of tracheal diseases among the male contingent in St. Petersburg decreases faster than in RF. Despite some differences in the quantitative characteristics of individual diseases, the total number of patients increases both in St. Petersburg and RF [Figure 1]. Most of the morbidity characteristics of St. Petersburg residents in terms of 100,000 inhabitants are close to the corresponding characteristics for other regions of Russia,[15-17] as well as for the neighboring countries of Belarus and Ukraine.[18]

MAN DISEASES

The rate of individual neoplasm incidence increase among men may be both more and less than the overall dynamics of the considered population incidence in St. Petersburg [Figure 1]. Since 2001, there has been a steady increase in the number of prostate gland diseases by the exponential dependence $y = Aexp(\mu t)$ with $\mu = 0.1$ (with the growth rate of about 10% per year). According to the localization of trachea, bronchi, and lungs, there is the tendency of linear dependence incidence reduction at the rate of 0.021 patients per year for 100,000 inhabitants.

Table 4 presents the data on the incidence of malignant tumors among men with the largest shares in the overall structure of the diseases (per 100,000 of male population). A greatest number of diseases are the diseases of trachea, bronchi, and lungs with a specific weight of 15.8% from the total incidence. The neoplasia of the prostate gland and stomach are located below (13.1% and 9.5%, respectively).

Table 1: The structure of malignant neoplasm incidence in St. Petersburg during 2016

MNP localization	Share from the total number of diseases (%)
Breast	11.7
Colon	9.0
Trachea, bronchi, lungs	8.9
Other skin neoplasms	7.6
Stomach	7.4
Lymphatic and hematopoietic tissue	5.8
Rectum	5.5
Prostate	5.4
Uterus body	4.2
Pancreas	4.1
Kidney	3.9
Ovaries	3.0
Bladder	2.8
Total: % of all diseases	80

MNP: Magnetic nanoparticle

WOMAN DISEASES

Figure 3 demonstrates the dynamics of the overall incidence of women in St. Petersburg and the dynamics of cervix and mammary gland cancer (the values of the indicators for 1980 were taken to be equal to one). The dependence 1 corresponds to the mammary gland, the dependence 2 to all oncological diseases, and the dependence 3 to the diseases of the female genital organs. The total number of tumor cases among women increases in a linear relationship with an average growth rate of 0.081/year. Since 1990, the incidence of cervical neoplasia has increased 1.2 times by 2010 and then stabilized with the value of about 16 cases a year per 100,000 women of St. Petersburg. Since 2005, the number of patients with the breast pathology among the female population of St. Petersburg is ranged from 82.5 and 90.6 women per 100,000 of female population.

Table 5 presents the data on the incidence of malignant tumors among women with the largest shares in the overall structure of diseases (per 100,000 of female population). The greatest number of diseases is represented by breast cancer with the specific weight of 20% from the total incidence. Colon neoplasia and skin diseases (9.8% and 8.5%, respectively) are located below. Over the past 30 years, the number of cases of tumor diseases per 100,000 women has significantly increased in the following locations: The thyroid gland (2.9 times), skin melanoma (2.2 times), and other skin neoplasms (2.6 times). Breast disease is the most dangerous for women.[19-21]

AGE STRUCTURE OF DISEASES

The distribution of patients by age as the dependence of the proportion of patients of the corresponding age on the total number of patients in 2016 is shown in Figure 4. The symbols * and o mark statistical data. The age structure of sick men corresponds to the

Table 2: Lethal outcomes by disease localization, taking into account gender characteristics (% of total deaths in the group)

Localization, men	Fatal outcome (%)	Localization, women	Fatal outcome (%)
Trachea, bronchi, lungs	21.4	Breast	16.9
Stomach	11.6	Colon	11.3
Colon	8.5	Pancreas	6.9
Prostate	7.7	Trachea, bronchi, lungs	6.5
Pancreas	7.2	Ovaries	5.6

Table 3: Patient number percentage change in St. Petersburg and Russia from 2007 to 2016

Men	СПб (%)	РФ (%)	Women	СПб (%)	РФ (%)
All neoplasms	3	17	All neoplasms	8	26
Trachea	−12	−11	Trachea	11	9
Prostate	34	154	Breast	3	36
Skin	15	30	Skin	16	35
Stomach	−8	−19	Stomach	−10	−18

Table 4: The distribution of highest rate diseases among men (per 100,000 of population)

MNP localization	The share from the total number of diseases (%) among men
Trachea, bronchi, lungs	15.8
Prostate	13.1
Stomach	9.5
Colon	8.0
Other skin neoplasms	6.5
Lymphatic and hematopoietic tissue	6.2
Rectum	6.0

MNP: Magnetic nanoparticle

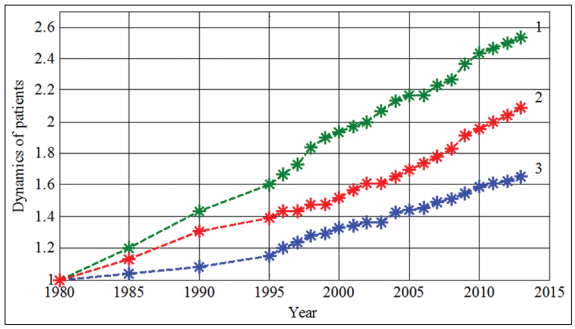

Figure 3: The dynamics of the overall incidence among the women of St. Petersburg and the dynamics of cervix and breast cancer: 1 - Mammary gland, 2 - overall incidence, 3 - cervix

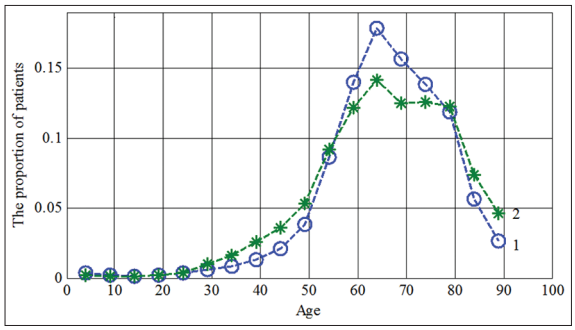

Figure 4: The age structure of morbidity in 2016: 1 - The proportion of men in the appropriate age among all sick men, 2 - the proportion of women in the corresponding age among all sick women.

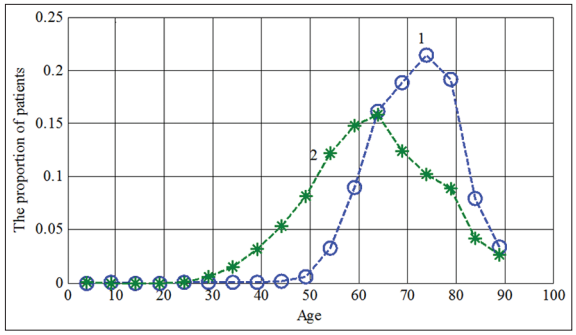

Figure 5: The age structure of men with prostate diseases and women with breast diseases in 2016: 1 - Men, 2 - women

dependence 1 and sick women - the dependence 2. As follows from Figure 4, the maximum number of neoplasms is in the age groups from 60 to 65 years for both men and women. The number of diseases among the women from 25 to 45 years is slightly more than in the same age group of men. In the age group from 60 to 70 years, the number of diseases is greater among men than among women.

Figure 5 shows the age distribution of prostate diseases among men and breast diseases among women. As follows from Figure 5, the women at the age 25 and over have the risk for breast diseases. At the same time, prostate diseases among men begin to progress in the age group over 50 years. At the same time, the total number of breast diseases among women is 2 times more than the number of prostate diseases among men. These diseases are quite common in most countries.[21]

ORGANIZATION OF ONCOLOGICAL AID TO ST. PETERSBURG POPULATION

On the basis of the order of RF Ministry of Health and Social Development (December 3, 2009) N 944n "On the approval of the procedure for medical care provision to oncological patients," the Government of St. Petersburg issued the Order (June 6, 2013) N 223-p "on patient routing for the suspicion or detection of cancer in the framework of primary health care and primary specialized medical care provision." According to the order, a patient routing scheme has been developed for suspected malignant neoplasms.

Three-level system of care was developed in St. Petersburg:

- Level 1 - The provision of primary health care for population, including primary special health care;
- Level 2 - Interdistrict level for the provision of specialized medical care, mainly in emergency form;
- Level 3 - Urban (regional) level for the provision of specialized medical care, including high-tech one.

This procedure ensures the provision of timely and high-quality medical care to the patients with oncological diseases. If a patient is suspected of a tumor disease, the attending physician will refer the patient to the oncologist of Level 1 facility. If there are the results of the clinical analysis of blood, the general analysis of urine, the radiographs of the chest organs in 2 projections will be within 1 working day, in the absence of the listed tests will be within 2 working days. In the case of a patient's visit to a colon-proctologist, if the colon cancer is suspected, it ensures that the patient is sent to St. Petersburg State Budgetary Healthcare Institution "City Hospital No. 9." The oncologist

Table 5: The distribution of diseases among women with the highest rates (per 100,000 of female population)

MNP localization	The share from the total number of diseases (%) among women
Breast	20.0
Colon	9.8
Other skin neoplasms	8.5
Uterus body	7.3
Stomach	6.1
Lymphatic and hematopoietic tissue	5.6
Rectum	5.3
Ovaries	5.2

MNP: Magnetic nanoparticle

ensures that patients are received at the direction of the attending physician within 3 working days from the date of the referral issuance. The oncologist of the 1st level institution provides the referral to the 2nd level institution to confirm or exclude the tumor diagnosis within the 1st working day. The institutions of the 2nd level provide the reception of patients according to the oncologist referral within 5 working days from the date of the referral issuance. Besides, the institutions of the 2nd level provide the clinical and the diagnostic examination with the establishment of a clinical diagnosis within 14 working days. When the diagnosis of a malignant neoplasm is confirmed, a medical commission consisting of an oncologist, a radiologist, and a chemotherapist is organized for the patient, followed by the determination of treatment tactics and the referral to a specialized treatment. In case of the oncological diagnosis refutation, the patient is sent to the attending physician for further observation.

At each stage of the patient routing scheme with the suspicion of a malignant neoplasm, a routing map is filled using the automated accounting system "The city registry of patient's routing maps with suspected malignant neoplasms." This allows you to keep a careful record of persons with suspected malignant neoplasms as well as to monitor the implementation of the deadlines established by the Ordinance N 223-p (June 6, 2013). The automated accounting system for routing maps in 2016 was implemented only in St. Petersburg.

The structure of the city oncological service includes the federal institutions (42% of all institutions) and city institutions (51%), as well as commercial clinics (7%). The outpatient unit consists of 45 medical institutions, where primary health care and dispensary observation are carried out. 80% of bed capacity of the oncological service accounts for specialized hospitals: The city clinical oncology dispensary - 41%, the St. Petersburg Clinical Scientific and Practical Center for Specialized Types of Medical Care (Oncology) - 27%, the Scientific Research Institute of Oncology named after N.N. Petrov - 20%, and the Russian scientific center for radiology and surgical technology - 12%. The proportion of hospitals for adults in the bed fund of oncological profile makes

Table 6: Hospital bed capacity in 2016

Beds for localized diseases	The loading during the year (%)
Oncological for adults	101
Oncological	99
Head tumors	71
The tumors of bones and soft tissues	63
Palliative	92
Thoracic	140
Oncourological	94

34% and the hospitals for children - 1%. In the bed fund for urban subordination, 55% of beds are made up of oncological beds for adults, 20% are occupied by gynecological and urological beds, and 25% of beds are reserved for other specializations.

According to the distribution of bed loading at the hospitals of the oncological aid system, the standard of 100% is exceeded only by oncological beds within the thoracic profile - 140%. Along with this, an incomplete loading of beds is determined according to the following profiles: Bone cancer, skin and soft tissue cancer, head and neck cancer, and oncologic abdominal. The bed occupancy by specialization in 2017 is reflected in Table 6.

There are 3.8 doctors per 100,000 population of St. Petersburg in the institutions providing specialized inpatient care and 2.8 doctors per 100,000 inhabitants in outpatient clinics. 42% of all oncologists work in outpatient clinics and 58% in specialized inpatient clinics. At the same time, about 15% of staff remain unoccupied for oncologists. This is probably due to the insufficient material security of specialists or the insufficient number of graduates from medical schools.[22] It is necessary to develop the programs for the rational training of specialists in these areas, and the distribution of material resources is necessary.[23,24]

In 2017, 21,506 patients were registered by the St. Petersburg Cancer Service (2480 per 100,000 population), and 130,279 people were registered, of which 72,278 were registered for >5 years. The annual mortality after diagnosis was about 22%. Help was provided to 80% of patients, 60% of patients received radical medical care, 10% of patients

continued treatment in 2018, 3% of patients refused radical treatment, the radical treatment was prohibited for 14% of patients, and symptomatic treatment was performed for 13% of patients. 24% of patients had a fatal outcome.

When the diagnosis was made, the incidence of the first stage was among 28% of patients from the total number of patients, the second - 25%, the third - 22%, and the fourth - 15%. The main methods of treatment were the following ones: Surgery - 65%, chemical radiation and radiation therapy - 6%, complex method - 27%, and drug therapy - 2%. Despite the development of new technologies for the treatment of tumor diseases, especially in chemotherapy, surgical treatment remains the main treatment method.

The dynamics of all patient number per 100,000 population with newly diagnosed cancer and the dynamics of registered patient number in St. Petersburg almost do not differ from similar characteristics in RF. The growth rate of patient number is constant in the first approximation and makes 6 patients a year per 100,000 inhabitants. Despite the increase of patient number by the oncological service of St. Petersburg, it was possible to achieve success in certain areas of the fight against cancer:

- From 1990 to 2017, the number of deaths among the patients with a newly established diagnosis decreased from 43% to 22%;
- The volume of radical care for the patients with the first-time diagnosis has increased (the growth rate made 40 patients per year with the growth rate of 6 patients per year among 100,000 inhabitants).

The task of various disease incidence reduction and the mortality rate reduction from these diseases is far from simple. The Russian health-care system, starting from the middle of the 19th century, repeatedly solved complex tasks. The tasks of child morbidity and mortality reduction were solved; serious epidemic diseases were practically eliminated. However, over time, new tasks have emerged which require urgent solutions. Mathematical modeling can help to solve problems.[25-28] It is possible to forecast for the near future about the possible number of patients in the region on the basis of statistical data. The mathematical model of incidence growth dynamics among the inhabitants of a region will make it possible to identify the determining factor on which the incidence depends taking into account the main factors influencing it.

SUMMARY

The successes of St. Petersburg oncological service in certain areas of oncological assistance provision to the residents of the city have not stopped the increase of patient number within the majority of neoplasms. The rate of patient number growth in most diseases has remained virtually unchanged over the past 40 years. In general, the oncological assistance provided to the residents so far only holds back the growth of mortality from neoplasms. The attempts to stop the growth of patient number were unsuccessful, despite the significant efforts made in this direction. Apparently, the health-care system is not enough to solve this kind of problem.

CONFLICTD OF INTEREST

The author confirms that the submitted data do not contain conflicts of interest.

ACKNOWLEDGMENTS

This work was supported by the RFBR grant mol_a No. 18-31-00323.

REFERENCES

1. The State of Cancer Care Provided to the Population of Russia in 2008. Moscow: FSI P.A. Herzen Moscow Cancer Research Institute of Russian Medical Technologies; 2009. p. 192. Available from: http://www.oncology.ru/service/statistics. [Last accessed on 2017 Aug 22].
2. The State of Cancer Care Provided to the Population of Russia in 2013. Moscow: FSBI P.A. Herzen Moscow Cancer Research Institute, Ministry of Health of Russia; 2014. p. 235. Available from: http://www.oncology.ru/service/statistics. [Last accessed on 2017 Aug 22].
3. The State of Cancer Care Provided to the Population of Russia in 2017. Moscow: FSBI P.A. Herzen Moscow Cancer Research Institute, Branch Office of FSBI NMRRC, Ministry of Health of Russia; 2015. p. 236. Available from: http://www.oncology.ru/service/statistics. [Last accessed on 2017 Aug 22].
4. Russian Statistical Yearbook. 2003: Stat.sb./SSS. M; 2003. p. 705.
5. Russian Statistical Yearbook. 2014: Stat.sb./SSS. M; 2014. p. 693.
6. Davydov MI, Aksel EM. The incidence of malignant tumors and mortality caused by them in commonwealth of independent states in 2005. Bull Russ Acad Med 2007;11:45-9.
7. Jakab Z, Galea G, Mauer-Stender K, Migliorini L. Cancer in Russia: Reflections from WHO in Europe. Lancet Oncol 2014;15:47.
8. Kolpak EP, Frantsuzova IS, Kuvshinova KV, Senkov RE. Neoplasm morbidity among the population of Russia. Int J Adv Biotechnol Res 2017;8:2315-22.
9. Lewison G, Markusova V. The evaluation of Russian cancer research. Res Eval 2010;19:129-44.
10. Aksel EM, Davydov MI, Ushakova TI. Statistics of lung, stomach and esophageal cancer: Status of oncological care, morbidity and mortality. Bull Russ Acad Med 2001;9:61-5.
11. Ignatyeva VI, Derkach EV, Avxentyeva MV, Omelyanovsky VV. The cost of melanoma and kidney, prostate, and ovarian cancers in Russia. Value Health Reg Issues 2014;4:58-65.
12. Kolpak EP, Abuzyarova RT, Kabrits SA. Leukosis mathematical model. Asian J Pharm 2018;12:S340-5.
13. Kolpak EP, Kabrits SA, Bubalo V. The follicle function and thyroid gland cancer. Biol Med 2015;7:6.
14. Pushkar DY, Govorov AV, Matveev VB. The epidemiology of bladder cancer in Russia. Scand J Urol Nephrol Suppl 2008;218:21-4.
15. Aksel' EM, Mikhaĭlov EA. Morbidity statistics of breast cancer

in Moscow. Oncol Issues 2005;51:656-8.
16. Baccarelli A, Khmelnitskii O, Tretiakova M, Gorbanev S, Lomtev A, Klimkina I, *et al.* Risk of lung cancer from exposure to dusts and fibers in Leningrad province, Russia. Am J Ind Med 2006;49:460-7.
17. Vaktskjold A, Ungurjanu TN, Klestsjinov NM. Cancer incidence in the nenetskij avtonomnyj okrug, arctic Russia. Int J Circumpolar Health 2008;67:433-44.
18. Demidchik YE, Saenko VA, Yamashita S. Childhood thyroid cancer in Belarus, Russia, and Ukraine after Chernobyl and at present. Arq Bras Endocrinol Metabol 2007;51:748-62.
19. Aksel' EM. Statistics of female genital organ malignant tumors. Tumors Female Reprod Syst 2009;1-2:76-80.
20. Zhukova LG. Breast cancer with triple-negative phenotype in the Russian patient population. Clinical and morphologic features. Vopr Onkol 2015;61:189-94.
21. Kolpak EP, Frantsuzova IS. Causes of morbidity and mortality from breast cancer. Eurasian J Anal Chem 2017;12:779-91.
22. Avksentyeva M. Colorectal cancer in Russia. Eur J Health Econ 2010;10 Suppl 1:S91-8.
23. Malafeev OA. Stationary strategies in differential games. USSR Comput Math Math Phys 1977;17:37-46.
24. Zubov AV, Dikusar VV, Zubov NV. Controllability criterion for stationary systems. Dokl Math 2010;81:6-7.
25. Boemo MA, Byrne HM. Mathematical modelling of a hypoxia-regulated oncolytic virus delivered by tumor-associated macrophages. J Theor Biol 2019;461:102-16.
26. Kolobov AV, Kuznetsov MB. Investigation of the effects of angiogenesis on tumor growth using a mathematical model. Biophysics 2015;60:449-56.
27. Kolpak EP, Frantsuzova IS, Alexandrovich KS. Mathematical model of thyroid tumor. Glob J Pure Appl Math 2016;12:55-66.
28. Zhukova IV, Kolpak EP, Yu EB. Mathematical model of growing tumor. Appl Math Sci 2014;8:1455-66.

Source of support: Nil; Conflict of interest: None Declared