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RESEARCH ARTICLE

Algorithm for the formation and functioning of a standard information and analytical system for multidisciplinary medical centers

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Abstract

Objectives. The widespread use of computed tomography (CT) for diagnostic and treatment purposes can lead to excessive cumulative doses of ionizing radiation received by patients in medical institutions. Currently, there are no effective methods of visualization and control of cumulative doses of patients in medical institutions. Thus, there is a need for operational monitoring of the dose load from ionizing radiation. The purpose of this work is to present a developed algorithm for the creation and functioning of an information and analytical system (IAS) for the retrospective accounting, analysis and visualization of cumulative doses of ionizing radiation received by patients undergoing radiation diagnosis and treatment.

Methods. When forming visual output forms for accounting, analyzing and identifying critical values of the dose load of ionizing radiation and the number of CT scans of patients, structured query language (SQL) was used to select the necessary data in order to apply them in summary tables and volumetric diagrams.

Results. An algorithm has been developed for the formation and functioning of IAS based on client-server technology using summary tables and volumetric diagrams in a client application. The algorithm can be used to visualize the analysis and accounting of cumulative doses of ionizing radiation in patients undergoing treatment and medical examination in large multifunctional medical research hospitals, identify the types of CT scans for reducing the number of sessions and limit the growth of cumulative doses of ionizing radiation in patients, as well as to detect errors in data entry by medical professionals into medical information systems and provide timely correction. In addition, an unlimited number of forms can be created for viewing, analyzing, and accounting for data.

Conclusions. The developed methodology for the formation of IAS can be scaled up to other multidisciplinary medical centers for tracking critical values of cumulative doses of ionizing radiation in patients in order to apply the necessary medical solutions in radiation diagnosis.

Keywords: information and analytical systems, client-server technologies, pivot tables, SQL

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НАУЧНАЯ СТАТЬЯ

Алгоритм формирования и функционирования типовой информационно-аналитической системы для многопрофильных медицинских центров

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Резюме

Цели. Широкое применение компьютерной томографии (КТ) в целях диагностики и лечения может приводить к избыточным кумулятивным дозам ионизирующего излучения, получаемым пациентами лечебных учреждений. В медицинских учреждениях на данный момент отсутствуют эффективные методы визуализации и контроля за кумулятивными дозами пациентов. Существует необходимость оперативного контроля за дозовой нагрузкой от ионизирующего излучения. Целью данной работы является разработка алгоритма функционирования информационно-аналитической системы (ИАС) для ретроспективного учета, анализа и визуализации кумулятивных доз ионизирующего излучения, получаемых пациентами, проходящими лучевую диагностику и лечение.

Методы. Используются SQL¹-запросы для выборки необходимых данных с целью применения их в сводных таблицах и объемных диаграммах при формировании выходных наглядных форм учета, анализа и выявления критических величин дозовой нагрузки ионизирующего излучения и количества КТ-исследований пациентов.

Результаты. Разработан алгоритм формирования и функционирования ИАС на основе клиент-серверной технологии с использованием сводных таблиц и объемных диаграмм в клиентском приложении, которая обеспечивает, во-первых, визуализацию анализа и учета кумулятивных доз ионизирующего излучения пациентов, проходящих лечение и диспансеризацию в крупных многофункциональных лечебно-исследовательских стационарах. Во-вторых, данный алгоритм позволяет выявлять виды КТ-исследований, по которым возможно уменьшить число применяемых сеансов с целью ограничения роста кумулятивных доз ионизирующего излучения пациентов. В-третьих, алгоритм дает возможность обнаруживать ошибки ввода данных медицинскими работниками в медицинские информационные системы и вовремя их корректировать. В-четвертых, можно формировать неограниченное число форм для просмотра данных с целью проведения их анализа и учета.

Выводы. Разработанную методику формирования ИАС возможно масштабировать в другие медицинские многопрофильные центры для отслеживания критических величин кумулятивных доз ионизирующего излучения пациентов в целях применения необходимых медицинских решений при лучевой диагностике пациентов.

Ключевые слова: информационно-аналитические системы, клиент-серверные технологии, сводные таблицы, SQL-запросы

¹ Structured query language – язык структурированных запросов.

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INTRODUCTION

Multidisciplinary medical centers and hospitals utilize medical information systems (MIS) to record patient data across various medical procedures and treatment areas. Due to the inability of MIS to retrospectively record and analyze data over long time periods, significant volumes of accumulated information are not fully utilized. The present work presents an algorithm for the development and operation of an information and analytical system (IAS) on the example of computed tomography (CT). The algorithm is used for organizing retrospective recording and analysis of cumulative doses of ionizing radiation received by patients along with the number of CT sessions during radiation diagnostics.

Due to the widespread use of CT, the radiation dose to patients from ionizing radiation has increased significantly, as reflected in numerous publications on this topic. In [1], it is noted that higher doses received from CT in children throughout life lead to an increased estimated risk of death from cancer compared to adults. In [2], it is indicated that intravenous administration of a contrast enhancer during CT for the detection of kidney stones increases the total radiation dose, which must be taken into account when determining the radiation dose to patients. In [3], an increased risk of cancer in children associated with the use of CT for diagnostic purposes is identified due to frequent repeat examinations, as well as the fact that children are more sensitive to the carcinogenic effects of ionizing radiation than adults and a longer life expectancy. In [4], an increased risk of hematological neoplasms in children and adolescents is identified as a result of CT irradiation along with the need for careful justification of CT in this age group. The work [5] provides information on long-term oncological consequences among residents of the city of Ozersk (Chelyabinsk oblast), who were examined using CT for a comprehensive assessment of the effects of low doses associated with diagnostic exposure in a cohort study. In [6], an attempt was made to answer the question of whether patients who were repeatedly examined with a CT scanner for indications related to the diagnosis of oncological pathology are at risk of developing late effects during subsequent years of observation. In [7], the need for centralized recording

of ionizing radiation doses in the electronic medical records of patients undergoing diagnostic and radiation therapy is indicated. The article [8] describes simulation modeling methods used to determine the organs and tissues exposed to the greatest radiation exposure during CT scanning of the chest, abdomen, and head. In [9], an overview of key Russian and foreign studies of the possible adverse effects of medical radiation on human health is presented along with a consideration of existing methods for assessing the possible harm to human health as a result of medical radiological diagnostic procedures. The work [10] indicates that the impact of ionizing radiation during CT scanning is a source of potential risk associated with the development of radiation-induced carcinogenic effects. In [11], methods of using information technology for retrospective analysis of the frequency of detection of neoplasms in patients are described using the example of a large multidisciplinary medical center. In [12], the experience of using computer technologies in visualizing data on the medical examination of patients who underwent CT diagnostics and radiation therapy is presented. The work [13] focuses on the need to develop centralized data warehouses to account for the accumulated dose load of patients in such a way that each person knows their load and can make appropriate decisions on each type of upcoming radiation diagnostics considering the associated risks. In [14], the need for strict personalized accounting of the dose load when using CT is indicated. The article [15] presents the experience of using summary tables and volumetric diagrams for data analysis. In [16] it is asserted that, since the highest doses of medical diagnostic radiation exposure of patients in Russia are caused by CT procedures, radiation risk control becomes especially relevant when using CT.

Since, according to the no-threshold radiation risk model, any dose of radiation increases the risk of cancer, it is essential to monitor received doses. Depending on the location of the exposure, the dose may be occupational, medical, natural, etc. Recently, diagnostic imaging using radionuclides to enhance contrast, X-rays, and other methods have become widespread in medicine. For example, radiotherapy (teletherapy and brachytherapy) is widely used to treat cancer. The dose received by a patient from a CT scan per session

varies from 0.3 to 63 mSv depending on the procedure. However, visualization, analysis, and recording of patient doses, particularly those undergoing diagnostic imaging, are not organized to the required standard. Medical information systems (MIS) used in healthcare institutions, such as MEDMIS², Medesk³, ArchiMed+⁴, KMIS⁵, Medialog⁶, and others, are not designed to directly implement these functions, as they operate in online transaction processing (OLTP) mode, which utilizes highly normalized linked tables in the database schema. Visualization, analysis, and accounting of medical data require a different database scenario—online analytical processing (OLAP). This requires uploading data entered into the MIS to other databases, particularly OLAP. Using the example of the Medialog MIS, a system for exporting from the MIS to a database was developed at one of the medical centers of the Federal Medical and Biological Agency of Russia⁷, which implements the above-mentioned functions.

1. ALGORITHM FOR THE FORMATION AND FUNCTIONING OF THE IAS

The algorithm consists of three stages. In the first stage, a data request is generated in the MIS, each record of which corresponds to one CT session of a specific patient with the corresponding attributes (characteristics): patient identifier, type of examination, equipment used, received ionizing radiation dose, examination date, patient date of birth, gender, ICD-10⁸ nosology code, etc. In the second stage, the resulting sample for a specified period is exported from the MIS first to an *Excel* table, from where it is imported into a structured query language (SQL) server database. Figure 1 shows a screenshot of this *Excel* table. The 116269-row imported table in the SQL server database named “Export_CT\$” and covers the period from January 1, 2010, to August 31, 2025. The method has been practically tested using a large multifunctional medical center as an example. A total of 50527 patients were examined, including 27333 women, 23181 men, and 13 patients whose

gender was not specified. The periodically repeated addition of data from the MIS to the SQL server database to Stages 1 and 2 from subsequent time periods keeps it up-to-date.

At the third stage, in order to visualize data on the number of CT scans and the dose received for a given nosology, the *Access* database management system (DBMS) is used as a client application to connect to a SQL server database using an open database connectivity (ODBC) driver. This client-server approach can be used simultaneously by an unlimited number of research clients. In the *Access* application, a query is generated to retrieve data from the SQL server table “Export_CT\$.” The query is executed server-side, which speeds up the execution process, and the result is transferred to the *Access* DBMS application as a table view named “Export_CT_PerDose,” a screenshot of which is shown in Fig. 2.

2. DESCRIPTION OF THE STRUCTURE OF THE SQL QUERY USED IN THE IAS

SQL is a structured query language based on the logic of the relational database model. A relational database model is a logical system consisting of interconnected objects that can be manipulated according to specific rules. The relational database model was founded by mathematician and IBM⁹ employee E.F. Codd, who in the 1960s also created relational algebra, in which he described a number of specific elements and operations on them. This relational algebra forms the theoretical basis of SQL. Introducing the concept of a relation (a flat data table), Codd identified eight relational operations: union, intersection, subtraction, Cartesian product, selection, projection, join, and division.

The structure of an SQL query used in the IAS consists of an outer query and several nested uncorrelated subqueries. It is presented in the table.

The developed technology proposes using uncorrelated subquery processing. A subquery in SQL is defined as a SELECT statement nested within another SELECT statement. With uncorrelated processing, the subquery is executed once, and its result (a list of patients satisfying the specified parameters) is stored in a temporary table, while the outer query retrieves data from the generated list of objects. Execution occurs from the bottom up: the subquery is executed at the bottom level, while a superstructure of other nested subqueries that use the resulting subset of objects is built from below. This enables the use of such SQL structures in various subject areas [17, 18].

² <https://www.medmis.ru> (in Russ.). Accessed May 24, 2026.

³ <https://www.medesk.net/ru> (in Russ.). Accessed May 24, 2026.

⁴ <https://archimed.pro> (in Russ.). Accessed May 24, 2026.

⁵ <https://k-integration.ru/vendors/kompleksnye-medicinskie-informacionnye-sistemy/> (in Russ.). Accessed May 24, 2026.

⁶ <https://www.medialog.ru/> (in Russ.). Accessed May 24, 2026.

⁷ <https://fmba.gov.ru/> (in Russ.). Accessed May 24, 2026.

⁸ The International Classification of Diseases, 10th revision, is a standard document that provides a generally accepted statistical classification of medical diagnoses.

⁹ International Business Machines is one of the world's largest manufacturers and suppliers of hardware and software.

A	B	C	D	E
PATIENTS_ID	RESEARCH_TYPE	NE_LE	GENDER	DOSE
163330	COMPUTED TOMOGRAPHY OF ABDOMINAL ORGANS	22.03.1988	0	15
39046	COMPUTED TOMOGRAPHY OF THE ABDOMINAL CAVITY AND RETROPERITONEAL SPACE	04.12.1974	1	5
56098	COMPUTED TOMOGRAPHY OF THE THORACIC CAVITY ORGANS	13.01.1944	1	3
31622	DENSITOMETRY	29.03.1953	1	
56776	COMPUTED TOMOGRAPHY OF THE PARANASAL SINUSES	20.03.1984	0	0.5
67175	COMPUTED TOMOGRAPHY OF THE THORACIC CAVITY ORGANS	22.10.1960	1	3
168173	COMPUTED TOMOGRAPHY OF THE THORACIC CAVITY ORGANS	13.12.1936	1	3
167682	DENSITOMETRY	03.08.1949	1	
168223	Computed tomography of the lumbosacral spine	28.12.1963	1	2
168706	COMPUTED TOMOGRAPHY OF ABDOMINAL ORGANS	30.04.1932	1	20.2
168668	Computed tomography of the lumbosacral spine	05.10.1946	1	2
22036	DENSITOMETRY	13.09.1952	1	
169293	COMPUTED TOMOGRAPHY OF THE THORACIC CAVITY ORGANS	13.11.1944	0	3
170153	COMPUTED TOMOGRAPHY OF THE BRAIN	23.10.1954	1	3
170439	COMPUTED TOMOGRAPHY OF THE PARANASAL SINUSES	14.09.1957	1	0.5

Fig. 1. A screenshot of an Excel spreadsheet. NE_LE—patient birth date; 0—male, 1—female;
DOSE is the dose received by the patient during one CT session in mSv

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
PATIENTS_ID	RESEARCH_TYPE	DATE_CONSULTATION	NameDisease	Disease_Category	NE_LE	Age	AgePeriod	GENDER	DOSE														
548594	MSCT OF THE THORACIC AND ABDOMINAL CAVITIES with intravenous contrast	24.01.2023	Malignant neoplasm of rectosigmoid junction	Neoplasms (C00-D48)	26.12.1963	60	> 50 и <= 60	Male	45.7														
548594	MSCT OF THE THORACIC AND ABDOMINAL CAVITIES with intravenous contrast	11.05.2022	Malignant neoplasm of rectosigmoid junction	Neoplasms (C00-D48)	26.12.1963	59	> 50 и <= 60	Male	19.6														
548594	MSCT OF THE THORACIC AND ABDOMINAL CAVITIES with intravenous contrast	30.11.2022	Malignant neoplasm of rectosigmoid junction	Neoplasms (C00-D48)	26.12.1963	59	> 50 и <= 60	Male	45.7														
548594	MSCT OF THE THORACIC AND ABDOMINAL CAVITIES with intravenous contrast	26.01.2022	Malignant neoplasm of rectosigmoid junction	Neoplasms (C00-D48)	26.12.1963	59	> 50 и <= 60	Male	45.7														
548594	MSCT OF THE THORACIC AND ABDOMINAL CAVITIES with intravenous contrast	14.09.2022	Malignant neoplasm of rectosigmoid junction	Neoplasms (C00-D48)	26.12.1963	59	> 50 и <= 60	Male	21.3														
548594	MSCT OF THE CORONARY ARTERIES	31.01.2022	Malignant neoplasm of rectosigmoid junction	Neoplasms (C00-D48)	26.12.1963	59	> 50 и <= 60	Male	45.7														
548594	MSCT OF THE THORACIC AND ABDOMINAL CAVITIES with intravenous contrast	27.07.2022	Malignant neoplasm of rectosigmoid junction	Neoplasms (C00-D48)	26.12.1963	59	> 50 и <= 60	Male	45.7														
548594	MSCT OF THE THORACIC AND ABDOMINAL CAVITIES with intravenous contrast	15.03.2022	Malignant neoplasm of rectum	Neoplasms (C00-D48)	26.12.1963	59	> 50 и <= 60	Male	45.7														

Fig. 2. Screenshot of the query result "Export_CT_PerDose." MSCT—multislice computed tomography

Table. Structure of an SQL query

	Query fragment	Explanation of the query fragment
1	SELECT * FROM	External query
2	<pre> (SELECT PATIENTS_ID, ISNULL(Export_CT\$. RESEARCH_TYPE, 'Not specified') AS RESEARCH_TYPE, Cast(Export_CT\$.DATE_CONSULTATION as datetime) as DATE_CONSULTATION,..., LABEL, CODE, ISNULL(SA_ICD_10_MIT_2021.WHO_Full_Desc, 'Not specified') AS NameDisease, ..., CASE WHEN SA_ICD_10_MIT_2021.ICD10_Code IN (SELECT SA_ICD_10_MIT_2021.ICD10_Code FROM Export_CT\$ WHERE SA_ICD_10_ MIT_2021.ICD10_Code LIKE 'A%' OR SA_ICD_10_MIT_2021.ICD10_Code LIKE 'B%') THEN 'Certain infectious and parasitic diseases (A00-B99)' WHEN SA_ICD_10_MIT_2021.ICD10_Code IN (SELECT SA_ICD_10_MIT_2021.ICD10_Code FROM Export_CT\$ WHERE SA_ICD_10_ MIT_2021.ICD10_Code LIKE 'C%' OR SA_ICD_10_MIT_2021.ICD10_Code LIKE 'D0%' OR SA_ICD_10_MIT_2021.ICD10_Code LIKE 'D1%' OR SA_ICD_10_MIT_2021.ICD10_ Code LIKE 'D2%' OR SA_ICD_10_MIT_2021.ICD10_Code LIKE 'D3%' OR SA_ICD_10_MIT_2021. ICD10_Code LIKE 'D4%') THEN 'Neoplasms (C00-D48)' WHEN SA_ICD_10_MIT_2021.ICD10_Code IN (SELECT SA_ICD_10_MIT_2021.ICD10_Code FROM Export_KT\$ WHERE SA_ICD_10_ MIT_2021.ICD10_Code LIKE 'D5%' OR SA_ICD_10_MIT_2021.ICD10_Code LIKE 'D6%' OR SA_ICD_10_MIT_2021.ICD10_Code LIKE 'D7%' OR SA_ICD_10_MIT_2021.ICD10_ Code LIKE 'D8%') THEN 'Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism (D50-D89)' WHEN SA_ICD_10_MIT_2021.ICD10_Code IN (... ELSE 'Not specified ' END as Disease_Category..., </pre>	A nested subquery with a selection of attributes, converting data from symbolic to the format required for pivot tables, attaching the category and name of the disease from the ICD-10 directory of diseases
3	<pre> CASE WHEN EQUIPMENT = '0' THEN 'PHILIPS INGNUTY' WHEN EQUIPMENT = '1' THEN 'CANON ONE'... END AS EQUIPMENT_Name, ..., </pre>	The name of the equipment is programmatically assigned
4	<pre> DATEDIFF(yy, Cast(Export_CT\$.NE_LE as datetime), Cast(Export_CT\$.DATE_ CONSULTATION as datetime)) AS Age, CASE WHEN DATEDIFF(yy, Cast(Export_CT\$.NE_LE as datetime), Cast(Export_CT\$. DATE_CONSULTATION as datetime)) <=20 THEN '<= 20' WHEN DATEDIFF(yy, Cast(Export_CT\$.NE_LE as datetime), Cast(Export_CT\$. DATE_CONSULTATION as datetime)) <=30 AND DATEDIFF(yy, Cast(Export_CT\$.NE_LE as datetime), Cast(Export_CT\$.DATE_ CONSULTATION as datetime)) >20 THEN '> 20 and <=30'... ELSE 'Not specified ' END as AgePeriod, ..., </pre>	The “Age” and “AgePeriods” attributes are programmatically defined
5	<pre> CASE WHEN Export_CT\$.GENDER = 0 THEN 'M' WHEN Export_CT\$.GENDER = 1 THEN 'F' ELSE ' Not specified ' END as GENDER2, ..., </pre>	The value of the “GENDER” attribute is programmatically assigned
6	<pre> Try_Convert(float, Replace(IsNull(Export_CT\$.DOSE, 0), ',', '.')) as DOSE_ </pre>	The symbolic value is programmatically converted to a numeric value for the “DOSE_” attribute
7	<pre> FROM Export_CT\$ LEFT OUTER JOIN SA_ICD_10_MIT_2021 ON Export_CT\$.CODE = SA_ICD_10_ MIT_2021.ICD10_Code) W </pre>	The left outer connection of the tables Export_CT\$ and SA_ICD_10_MIT_2021
8	<pre> WHERE W.PATIENTS_ID IN (SELECT PATIENTS_ID FROM (SELECT PATIENTS_ID, SUM(Try_Convert(float, Replace(IsNull(Export_CT\$. DOSE, 0), ',', '.'))) SmDs FROM Export_CT\$ GROUP BY PATIENTS_ID) Q WHERE Q.SmDs >400 AND Q.SmDs <=700) </pre>	A nested uncorrelated subquery that creates a list of patients whose cumulative ionizing radiation dose falls within the specified range from 400 to 700 mSv (inclusively)

3. RESULTS

The application uses pivot table mode to display the data obtained as a result of executing a generated query. Figure 3 depicts this mode as an empty workspace with a list of pivot table fields. The locations from which pivot table fields can be dragged from the field list are indicated at the edges and in the center of the workspace.

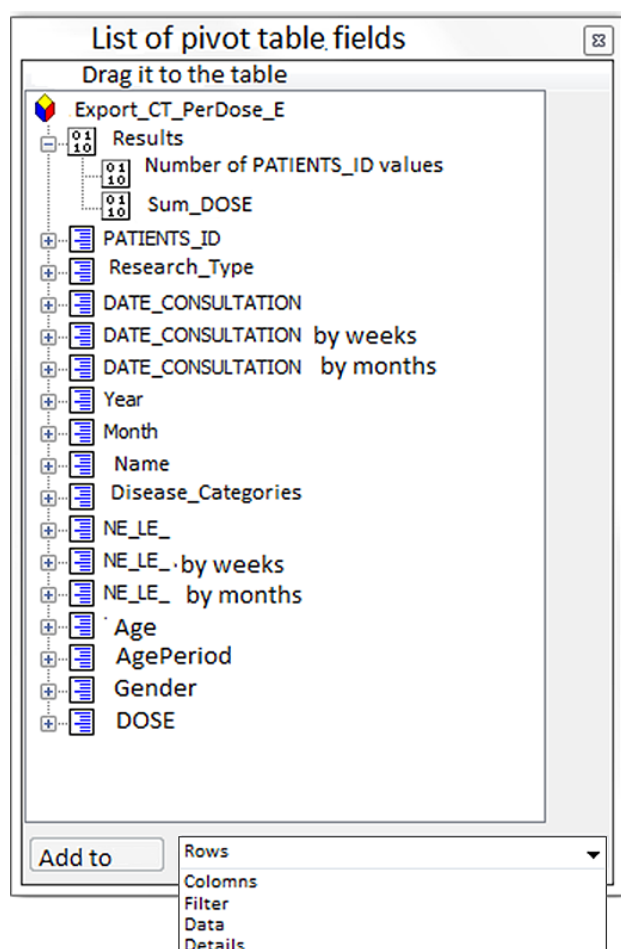


Fig. 3. View of an empty area of a pivot table

By dragging and dropping selected attributes from the field list or adding them to specified locations (rows, columns, filter, data, details), pivot tables can be created in the format required for research. For example, in order to find the patient ID who received specified cumulative doses of ionizing radiation over the past

few years, you would drag the “PATIENTS_ID” attribute from the pivot table field list to the rows area, “DATE_CONSULTATION” to the columns area, and “Sum_DOSE” to the data area. Figure 4 shows the resulting pivot table with the required data. The cumulative dose boundaries are specified in the query text in Section 9 of Table.

If, instead of “Sum_DOSE,” you drag the “Number of PATIENTS_ID values” attribute from the pivot table field list into the data area, you will get a similar pivot table, but the intersection of rows and columns will indicate the number of CT sessions received by patients in a specific time period. By varying the cumulative dose value boundaries in the query text (the last row of item 9 in Table) from 0 to 100 (Fig. 5), from 100 to 400 (Fig. 6), and from 400 to 700 (Fig. 7), and examining the frequency structure of CT sessions by disease category, it is possible to identify differences in the correlations between the number of CT sessions and the cumulative dose value. Thus, the order of disease categories in decreasing order of CT scan sessions for cumulative doses from 0 to 100 mSv differs from the order of disease categories for cumulative doses from 100 to 400 mSv and from 400 to 700 mSv. Neoplasms (C00-D48) ranks first in terms of the number of CT scan sessions in these groups based on cumulative dose load.

In order to view cumulative doses distributed among selected patients by disease category, the disease categories should be placed in Rows, patient IDs in Columns, and the “Sum_DOSE” attribute in Data area. Then the desired patients can be selected from the drop-down list. The resulting pivot table is shown in Fig. 8, while the corresponding 3D diagram appears in Fig. 9. If the “Number of values” attribute is placed in the Data area in this case, the intersection of the columns and rows of the pivot table will yield the corresponding number of CT sessions.

In order to study the distribution of cumulative doses of ionizing radiation by year for specific selected patients, categories can also be expanded by the names of the diseases they comprise. Figure 10 depicts a screenshot of the distribution of cumulative doses of ionizing radiation across all categories by all included diseases for patient ID 99111, who was found to have the highest cumulative dose.

Export_CT_PerDose		Year ▾												Overall results	
PATIENTS_ID ▾		2010	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Sum_DOSE	Sum_DOSE	Sum_DOSE
		+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -	+ -
99111					20			40.2	431.2	47.8	79	5.2	623.4		
492869									126	92.1	255.1	103	15.2	591.4	
394588								491	10.6	11.3	48.2	18.3	579.4		
865195												516.9	59.7	576.6	
574199										345.1	174.5		519.6		
917367													515.6		
179363						20	40	113.5	147.6		47.6		144.7	513.4	
502603									319.5	182.4			501.9		
830626												495.5	495.5		
488894									398.6	21.1	38.9	2	460.6		
612961										82.5	371.1		453.6		
146442		224								225.022			449.022		
182157				4				59.6	95.8	29.1	132.3	127.8	448.6		
389560								66.9	350	30			446.9		
715676													443.3		
52627				10	55	41	30	47.2	93.6	18.8	404.4	38.9	436.1		
749577											48.1	29	63.4		
531085									410.8		415.5		415.5		
519626									344.2				410.8		
38717								104	302.9		19.3	44.6	408.1		
Overall results		224		14	75	61	70	922.4	3030.8	860.2	2259.022	1381.2	798.6	9696.222	

Fig. 4. Cumulative doses to patients from 400 to 700 mSv over the years

Disease_Category	Year												Overall results
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
Not specified	2036	2754	3270	2808	2808	4805	3305	3562	3321	2534	28395	28395	
Neoplasms (C00-D48)	2542	2774	2907	2188	2188	2956	2400	2728	2794	2073	23362	23362	
Diseases of the circulatory system (I00-I99)	729	763	782	622	622	1049	975	955	974	650	7499	7499	
Diseases of the digestive system (K00-K93)	424	505	556	367	367	635	611	671	594	375	4738	4738	
Injury, poisoning and certain other consequences of external causes (S00-T98)	321	360	322	136	136	228	208	444	702	640	3361	3361	
Diseases of the respiratory system (J00-J99)	244	283	295	194	194	410	293	221	275	152	2367	2367	
Diseases of the musculoskeletal system and connective tissue (M00-M99)	156	150	233	212	212	464	293	290	290	180	2268	2268	
Diseases of the genitourinary system (N00-N99)	77	71	223	237	237	464	360	280	280	187	2179	2179	
Diseases of the nervous system (G00-G99)	183	184	179	149	149	284	293	343	274	186	2075	2075	
Codes for special purposes (U00-U85)	73	79	53	30	30	133	106	83	92	59	708	708	
Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism (D50-D89)	30	27	26	60	60	119	67	76	88	67	560	560	
Factors influencing health status and contact with health services (Z00-Z99)	25	29	16	12	12	76	65	56	34	40	353	353	
Endocrine, nutritional and metabolic diseases (E00-E90)	84	35	29	47	47	24	20	24	42	18	323	323	
Certain infectious and parasitic diseases (A00-B99)	36	47	19	20	20	29	14	11	24	16	216	216	
Diseases of the ear and mastoid process (H60-H95)	9	10	13	4	4	24	3	8	4	6	81	81	
Congenital malformations, deformations and chromosomal abnormalities (Q00-Q99)	1	1	9	4	4	12	13	18	7	7	65	65	
Diseases of the eye and adnexa (H40-H59)	5	1	2	1	1	29	7	6	7	2	60	60	
Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified (R00-R99)	3	2	2	4	4	5	4	4	2	4	30	30	
Diseases of the skin and subcutaneous tissue (L00-L99)	6978	8075	8946	8124	8124	11773	9038	9780	9808	7189	79711	79711	
Pregnancy, childbirth and the puerperium (O00-O99)													
Overall results													

Fig. 5. Number of CT sessions by disease category for cumulative doses from 0 to 100 mSv

Disease_Category	Years												Overall results
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
Neoplasms (C00-D48)	252	373	669	834	834	2339	1346	1581	1474	1050	9918	9918	
Not specified	101	184	266	275	275	707	402	402	353	330	3020	3020	
Diseases of the digestive system (K00-K93)	43	85	134	191	191	386	236	265	232	161	1733	1733	
Injury, poisoning and certain other consequences of external causes (S00-T98)	17	31	49	92	92	166	169	171	126	92	913	913	
Diseases of the circulatory system (I00-I99)	41	60	43	63	63	126	102	102	64	67	631	631	
Diseases of the respiratory system (J00-J99)	10	9	9	11	11	102	21	31	5	13	211	211	
Diseases of the genitourinary system (N00-N99)	8	4	11	11	11	54	10	28	51	20	197	197	
Diseases of the nervous system (G00-G99)	3	8	5	28	28	62	25	13	22	19	185	185	
Factors influencing health status and contact with health services (Z00-Z99)	2	3	6	6	6	9	13	12	10	6	67	67	
Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism (D50-D89)	2	3	5	15	15	12	8	6	6	6	58	58	
Certain infectious and parasitic diseases (A00-B99)	5	3	4	5	5	18	3	9	7	7	54	54	
Diseases of the musculoskeletal system and connective tissue (M00-M99)													
Endocrine, nutritional and metabolic diseases (E00-E90)	14	3	2	2	2	4	7	5	5	3	43	43	
Congenital malformations, deformations and chromosomal abnormalities (Q00-Q99)	2	1				2	12	12			17	17	
Codes for special purposes (U00-U85)						8	1				9	9	
Diseases of the skin and subcutaneous tissue (L00-L99)								1			4	4	
Diseases of the ear and mastoid process (H60-H95)													
Diseases of the eye and adnexa (H40-H59)													
Overall results	486	780	1214	1541	1541	4026	2353	2615	2389	1792	17196	17196	

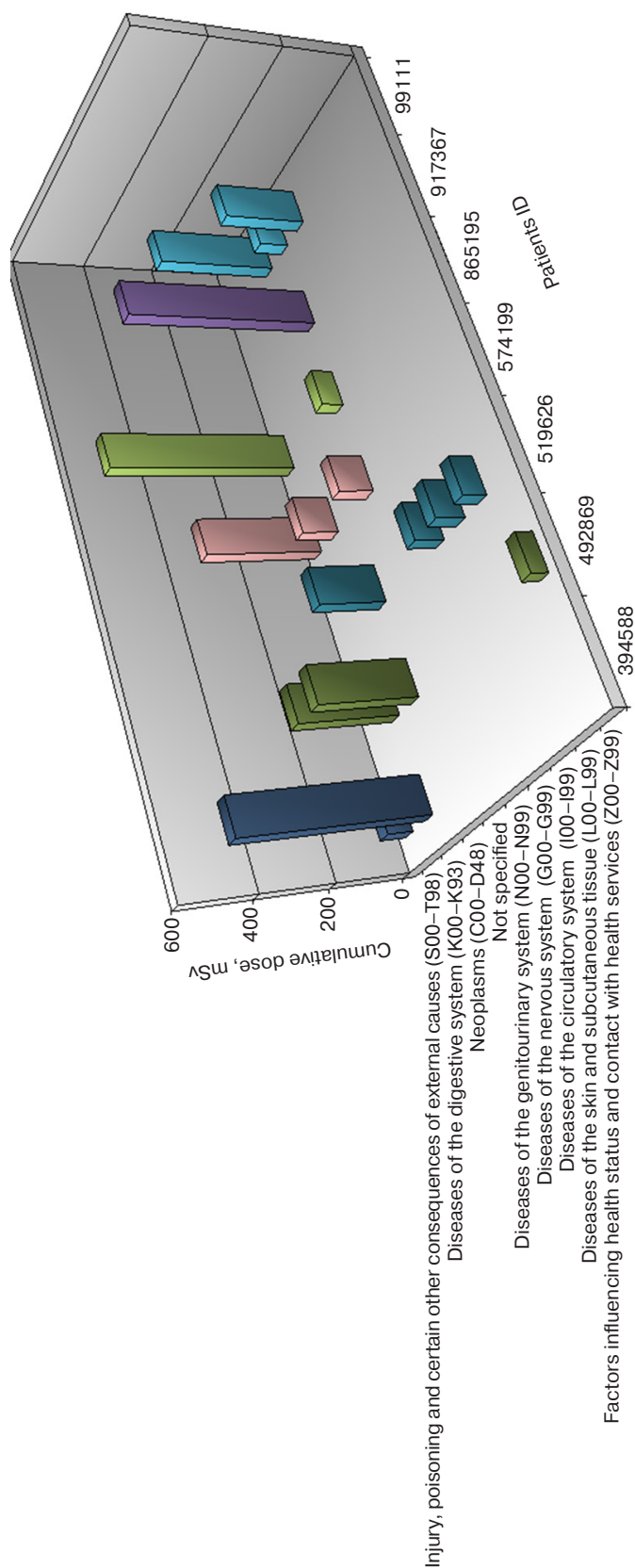
Fig. 6. Number of CT sessions by disease category for cumulative doses from 100 to 400 mSv

Disease_Category	Years											
	Drag the filter fields here											
	2017	2018	2019	2020	2021	2022	2023	2024	2025	Overall results		
	+	+	+	+	+	+	+	+	+	+	+	+
	-	-	-	-	-	-	-	-	-	-	-	-
	Number of values	Number of values	Number of values	Number of values	Number of values	Number of values	Number of values	Number of values	Number of values	Number of values	Number of values	Number of values
Neoplasms (C00-D48)	2		5		8	50	17	54	44	15	139	195
Not specified	4		7		7	31	10	28	11	37	139	195
Diseases of the digestive system (K00-K93)	1		1		11	22	4	18	12	70	70	70
Injury, poisoning and certain other consequences of external causes (S00-T98)					1	25	14	3	15	6	64	64
Diseases of the circulatory system (I00-I99)						27	2	3	1	33	33	33
Diseases of the respiratory system (J00-J99)						12				12	12	12
Diseases of the genitourinary system (N00-N99)	1					6		1		8	8	8
Diseases of the skin and subcutaneous tissue (L00-L99)						1		3	2	6	6	6
Diseases of the nervous system (G00-G99)						4		1		5	5	5
Factors influencing health status and contact with health services (Z00-Z99)								2		2	2	2
Overall results	8	8	10	27	178	47	113	85	58	534	534	534

Fig. 7. Number of CT sessions by disease category for cumulative doses from 400 to 700 mSv

Disease_Category	PATIENTS_ID											
	Drag the filter fields here											
	99111	492869	394588	865195	574199	917367	519626	Overall results				
	+	+	+	+	+	+	+	+	+	+	+	+
	-	-	-	-	-	-	-	-	-	-	-	-
	Sum_DOSE	Sum_DOSE	Sum_DOSE	Sum_DOSE	Sum_DOSE	Sum_DOSE	Sum_DOSE	Sum_DOSE	Sum_DOSE	Sum_DOSE	Sum_DOSE	Sum_DOSE
Neoplasms (C00-D48)	322.2	270.3								184.4	776.9	776.9
Not specified	80.2				59.7	95.6	515.6			751.1	751.1	751.1
Injury, poisoning and certain other consequences of external causes (S00-T98)				70.2	516.9	323	910.1			910.1	910.1	910.1
Diseases of the digestive system (K00-K93)		274.4	509.2		101		884.6			884.6	884.6	884.6
Diseases of the genitourinary system (N00-N99)	221						221			221	221	221
Diseases of the skin and subcutaneous tissue (L00-L99)							63.9			63.9	63.9	63.9
Diseases of the nervous system (G00-G99)							80.2			80.2	80.2	80.2
Diseases of the circulatory system (I00-I99)							79.6			79.6	79.6	79.6
Factors influencing health status and contact with health services (Z00-Z99)		46.7					46.7			46.7	46.7	46.7
Overall results	623.4	591.4	579.4	576.6	519.6	515.6	408.1			3814.1	3814.1	3814.1

Fig. 8. Cumulative doses to patients by disease category in the range from 400 to 700 mSv



Export_CT_PerDose																	
Disease_Category▼		PATIENTS_ID ▼															
All	99111																
		Years ▼		2017		2020		2021		2022		2023		2024		Overall results	
		+ -		+ -		+ -		+ -		+ -		+ -		+ -		+ -	
NamedDisease		Sum_DOSE		Sum_DOSE		Sum_DOSE		Sum_DOSE		Sum_DOSE		Sum_DOSE		Sum_DOSE		Sum_DOSE	
Malignant neoplasm, overlapping lesion of retroperitoneum and peritoneum		226														226	
Rupture of bladder, nontraumatic		180.2				40.2		15								180.2	
Not specified		25														80.2	
Malignant neoplasms of independent (primary) multiple sites												58.2		5,2		63.4	
Malignant neoplasm, retroperitoneum								32,8								32,8	
Hydronephrosis with ureteral stricture, not elsewhere classified												20.8				20.8	
Acute tubulo-interstitial nephritis		20														20	
Overall results		20		40.2		431.2		47.8		79		5,2				623.4	

CONCLUSIONS

The proposed client-server technology using pivot tables and volumetric charts in the client application enables:

1. Visual analysis and accounting of cumulative doses of patients undergoing treatment and medical examination in large multifunctional treatment and research hospitals.
2. Identification of CT scans for which the number of sessions could be reduced to limit the increase in cumulative patient doses. For example, the maximum number of CT sessions identified for one patient over the entire observation period was 83.
3. Detection of data entry errors by medical workers in the MIS and their timely correction. For example,

the “Not specified” value in the tables above means that no data was entered in that column.

4. Creation of various pivot tables for data analysis. For example, all the data presented in the report was obtained using just one query, “Export_CT_PerDose.”

Thus, pivot tables and volumetric diagrams are shown to be a visual and effective tool for analyzing and studying the processes of disease progression across time and age series, for example, to determine the effectiveness of certain treatment procedures and the impact of the use of drugs on the results of treatment carried out in multidisciplinary clinical hospitals.

Authors' contributions

V.A. Kadymov—general guidelines for writing the article.

S.M. Dumansky—introduction, sections 1 and 2.

E.V. Vasiliev—section 3 and conclusion.

REFERENCES

1. Brenner D., Elliston C., Hall E., Berdon W. Estimated risks of radiation-induced fatal cancer from pediatric CT. *Am. J. Roentgenology*. 2001;176(2):289–296. <https://doi.org/10.2214/ajr.176.2.1760289>
2. Denton E.R., Mackenzie A., Greenwell T., Popert R., Rankin S.C. Unenhanced helical CT for renal colic – is the radiation dose justifiable? *Clin Radiol*. 1999;54(7):444–447. [https://doi.org/10.1016/S0009-9260\(99\)90829-2](https://doi.org/10.1016/S0009-9260(99)90829-2)
3. Kleinerman R.A. Cancer Risks Following Diagnostic and Therapeutic Radiation Exposure in Children. *Pediatr. Radiol*. 2006;36(Suppl.2):121–125. <https://doi.org/10.1007/s00247-006-0191-5>
4. Bosch de Basea M., Thierry-Chef I., Harbron R., et al. Risk of hematological malignancies from CT radiation exposure in children, adolescents and young adults. *Nat. Med*. 2023;29(12):3111–3119. <https://doi.org/10.1038/s41591-023-02620-0>
5. Osipov M.V., Shkarednykh V.Yu., Loginov V.S., Melnikov V.V., Druzhinina P.S., Sokolnikov M.E. Retrospective analysis of cancer morbidity among patients after computed tomography. *Radiatsionnaya Gygiena = Radiation Hygiene*. 2021;14(3): 80–90 (in Russ.). <https://doi.org/10.21514/1998-426X-2021-14-3-80-90>
6. Osipov M.V., Vazhenin A.V., Domozhirova A.S., Chernova O.N., Aksenova I.A. Computed tomography as a risk factor in cancer patients with professional radiation exposure. *Rossiiskii ehlektronnyi zhurnal luchevoi diagnostiki = Russian Electronic Journal of Radiology*. 2019;9(1):142–147 (in Russ.). <https://elibrary.ru/lzhdgh>
7. Bullard T.B., Falk J.L., Smith M.S., et al. Cumulative Radiation Exposure from Medical Imaging in Two Hospital Systems – Implications for Medical Record Portability. *Emergency Med*. 2014;4(211):5.
8. Kashcheev V.V., Pryakhin E.A., Menyailo A.N. A method for assessing the radiation risk of medical exposure after computed tomography scan of children and adolescents based on data from scanning protocols. *Radiatsiya i risk = Radiation and Risk*. 2023;32(3):5–13 (in Russ.). <https://doi.org/10.21870/0131-3878-2023-32-3-5-13>
9. Kashcheev V.V., Pryakhin E.A. Medical diagnostic imaging: radiation safety issues. Review. *Radiatsiya i risk = Radiation and Risk*. 2018;27(4):49–64 (in Russ.). <https://doi.org/10.21870/0131-3878-2018-27-4-49-64>
10. Osipov M.V. Computed tomography as a risk factor of cancer among the population of the nuclear city of Ozyorsk. *Radiatsiya i risk = Radiation and Risk*. 2023;32(3):109–121 (in Russ.). <https://doi.org/10.21870/0131-3878-2023-32-3-109-121>
11. Dumansky S.M., Vasiliev E.V., Kalinina M.V. The use of information technologies for a retrospective analysis of the frequency of neoplasm detection in patients using the example of a multidisciplinary medical center. In: *The 8th International Forum of Oncology and Radiotherapy “For Life – FOR LIFE”*: Collection of abstracts. Moscow: 2025. ISBN 978-5-00274-009-3. P. 90–91 (in Russ.). Available from URL: <https://drive.google.com/file/d/1hxnTQgBquJ0gBBoOyrXaMumUqJqWYmb6/view>. Accessed May 24, 2026.
12. Vasiliev E.V., Dumansky S.M., Kalinina M.V. On the need for personal centralized accounting and analysis of patients' dose load when using computed tomography. In: *Ilyinsky Readings 2025*: Collection of Materials of the International Scientific and Practical Forum of Young Scientists and Specialists. Moscow: 2025. P. 90–92 (in Russ.). <https://www.elibrary.ru/phvfoi>. Available from URL: <https://ilyinform.ru/materials>. Accessed May 24, 2026.
13. Dumansky S.M., Vasiliev E.V., Baranov L.I., Kalinina M.V. Visualization, analysis and accounting of the dose load of patients undergoing radiation diagnostics. In: *Medical and Ecological Effects of Ionizing Radiation*: Proceedings of the 8th International Scientific Conference, dedicated to the 25th anniversary of the Seversk Biophysical Research Center. Tomsk: 2025. P. 33–34 (in Russ.).

14. Dumansky S.M., Vasiliev E.V., Kalinina M.V. Computed tomography – contribution to cumulative medical dose Chronic radiation exposure: medical and biological effects of small doses: In: *Proceedings of the 8th International Scientific and Practical Conference*. September 23–25, 2025. Chelyabinsk: 2025. P. 88–89 (in Russ.).
15. Dumansky S.M., Vasiliev E.V., Kalinina M.V. Analysis of the prevalence of malignant neoplasms in the context of professions of current and former employees of energy enterprises according to medical examinations conducted in the medical unit system. In: *Proceedings of the 7th International Forum of Oncology and Radiotherapy*. September 16–20, 2024. Moscow: World Trade Center. P. 186–187 (in Russ.). Available from URL: <https://drive.google.com/file/d/1-8szW3yzzOdJ4Ex1ZnnydXkrX3-hmf40/view>. Accessed May 24, 2026.
16. Kashcheev V.V., Pryakhin E.A., Menyailo A.N., Ivanov V.K., Ivanov S.A., Kaprin A.D. Application of the new ICRP 2022 recommendations in calculating radiation risks of patients after computed tomography. *Radiatsiya i risk = Radiation and Risk*. 2025;34(2):39–49 (in Russ.). <https://doi.org/10.21870/0131-3878-2025-34-2-39-49>
17. Ben-Gan Itzik. *Microsoft SQL Server 2012. T-SQL Fundamentals*: transl. from Engl. Moscow: Eksmo; 2015, 400 p. (In Russ.). ISBN 978-5-699-73617-1
[Ben-Gan Itzik. *Microsoft SQL Server 2012 T-SQL Fundamentals*. Microsoft Press Series. Microsoft; 2012, 412 p.]
18. Nielsen P. *Microsoft SQL Server 2005. User's Bible*: transl. from Engl. Moscow: Vil'yams; 2008, 1232 p. (In Russ.). ISBN 978-5-84591-314-2
[Nielsen P. *SQL Server 2005. Bible*. Wiley & Sons; 2006, 1344 p.]

СПИСОК ЛИТЕРАТУРЫ

1. Brenner D., Elliston C., Hall E., Berdon W. Estimated risks of radiation-induced fatal cancer from pediatric CT. *Am. J. Roentgenology*. 2001;176(2):289–296. <https://doi.org/10.2214/ajr.176.2.1760289>
2. Denton E.R., Mackenzie A., Greenwell T., Popert R., Rankin S.C. Unenhanced helical CT for renal colic – is the radiation dose justifiable? *Clin Radiol*. 1999;54(7):444–447. [https://doi.org/10.1016/S0009-9260\(99\)90829-2](https://doi.org/10.1016/S0009-9260(99)90829-2)
3. Kleinerman R.A. Cancer Risks Following Diagnostic and Therapeutic Radiation Exposure in Children. *Pediatr. Radiol*. 2006;36(Suppl.2):121–125. <https://doi.org/10.1007/s00247-006-0191-5>
4. Bosch de Basea M., Thierry-Chef I., Harbron R., et al. Risk of hematological malignancies from CT radiation exposure in children, adolescents and young adults. *Nat. Med*. 2023;29(12):3111–3119. <https://doi.org/10.1038/s41591-023-02620-0>
5. Осипов М.В., Шкаредных В.Ю., Логинов В.С., Мельников В.В., Дружинина П.С., Сокольников М.Э. Ретроспективный анализ онкологической заболеваемости пациентов после проведения компьютерной томографии. *Радиационная гигиена*. 2021;14(3):80–90. <https://doi.org/10.21514/1998-426X-2021-14-3-80-90>
6. Осипов М.В., Важенин А.В., Доможирова А.С., Чернова О.Н., Аксенова И.А. Компьютерная томография как фактор риска у онкологических пациентов при наличии профессионального облучения. *Российский электронный журнал лучевой диагностики*. 2019;9(1):142–147. <https://elibrary.ru/lzhdgh>
7. Bullard T.B., Falk J.L., Smith M.S., et al. Cumulative Radiation Exposure from Medical Imaging in Two Hospital Systems – Implications for Medical Record Portability. *Emergency Med*. 2014;4(211):5.
8. Кашеев В.В., Пряхин Е.А., Меньяло А.Н. Метод оценки радиационного риска медицинского облучения при прохождении компьютерной томографии детей и подростков на основе данных протоколов сканирования. *Радиация и риск*. 2023;32(3):5–13. <https://doi.org/10.21870/0131-3878-2023-32-3-5-13>
9. Кашеев В.В., Пряхин Е.А. Медицинское диагностическое облучение: проблема радиационной безопасности. Обзор. *Радиация и риск*. 2018;27(4):49–64. <https://doi.org/10.21870/0131-3878-2018-27-4-49-64>
10. Осипов М.В. Компьютерная томография как фактор риска злокачественных новообразований среди населения города атомной промышленности Озёрск. *Радиация и риск*. 2023;32(3):109–121. <https://doi.org/10.21870/0131-3878-2023-32-3-109-121>
11. Думанский С.М., Васильев Е.В., Калинина М.В. Использование информационных технологий для ретроспективного анализа частоты выявления новообразований у пациентов на примере многопрофильного медицинского центра. В сб.: *VIII Международный Форум онкологии и радиотерапии «Ради жизни – FOR LIFE»*: Сборник тезисов. Москва. 15–19 сентября 2025 г. ISBN 978-5-00274-009-3. С. 90–91. URL: <https://drive.google.com/file/d/1hxnTQgBquJ0gBB0YrXaMumUqJqWYmb6/view>. Дата обращения 24.05.2026.
12. Васильев Е.В., Думанский С.М., Калинина М.В. О необходимости персонального централизованного учета и анализа дозовой нагрузки пациентов при использовании компьютерной томографии. В сб.: *«Ильинские чтения 2025»*: Сборник материалов международного научно-практического форума молодых ученых и специалистов. Москва: 2025. С. 90–92. <https://www.elibrary.ru/phvfoi>, URL: <https://ilyinform.ru/materials>. Дата обращения 24.05.2026.
13. Думанский С.М., Васильев Е.В., Баранов Л.И., Калинина М.В. Визуализация, анализ и учет дозовой нагрузки пациентов, проходящих лучевую диагностику. В сб.: *Медицинские и экологические эффекты ионизирующего излучения*: материалы VIII Международной научно-практической конференции, посвященной 25-летию образования Северского биофизического научного центра. 09–11 сентября 2025 г., Томск: 2025. С. 33–34.
14. Думанский С.М., Васильев Е.В., Калинина М.В. Компьютерная томография – вклад в кумулятивную медицинскую дозу. В сб.: *Хроническое радиационное воздействие: медико-биологические эффекты малых доз*: материалы VIII Международной научно-практической конференции. 23–25 сентября 2025 г. Челябинск: 2025. С. 88–89.

15. Думанский С.М., Васильев Е.В., Калинина М.В. Анализ распространенности злокачественных новообразований в разрезе профессий действующих и бывших работников энергетических предприятий по данным диспансеризаций, проводимых в системе медсанчастей. В сб.: *VII Международный форум онкологии и радиотерапии*. 16–20 сентября 2024 г. Москва: Центр международной торговли. С. 186–187. URL: <https://drive.google.com/file/d/1-8szW3yzzOdJ4Ex1ZnnydXkrX3-hmf40/view>. Дата обращения 24.05.2026.
16. Кашеев В.В., Пряхин Е.А., Меньяло А.Н., Иванов В.К., Иванов С.А., Каприн А.Д. Применение новых рекомендаций МКРЗ 2022 г. при расчете радиационных рисков пациентов после компьютерной томографии. *Радиация и риск*. 2025;34(2):39–49. <https://doi.org/10.21870/0131-3878-2025-34-2-39-49>
17. Бен-Ган И. *Microsoft SQL Server 2012. Основы T-SQL*: пер. с англ. М.: Эксмо; 2015, 400 с. ISBN 978-5-699-73617-1
18. Нильсен П. *Microsoft SQL Server 2005. Библия пользователя*: пер. с англ. М.: Вильямс; 2008, 1232 с. ISBN 978-5-84591-314-2

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