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ИЗДАТЕЛЬ
ООО «Эко-Вектор»
Адрес: 191186, г. Санкт-Петербург, Аптекарский переулок, д. 3, литера А, помещение 1Н
E-mail: info@eco-vector.com
WEB: https://eco-vector.com

РЕКЛАМА
Отдел рекламы
Тел.: +7 495 308 83 89
E-mail: adv@eco-vector.com

РЕДАКЦИЯ
Зав. редакцией
Елена Андреевна Филиппова
E-mail: ddjournal@eco-vector.com
Тел: +7 (965) 012 70 72
Адрес: 127051, г. Москва, ул. Петровка, д. 24, стр. 1

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Adv. department
Phone: +7 (495) 308 83 89
E-mail: adv@eco-vector.com

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Executive editor
Elena A. Philippova
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CONTENTS

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Обоснование нового подхода к критериям оценки дозы облучения пациентов при компьютерной томографии

Е.И. Маткевич[1, 2], В.Е. Синицын[2, 3], И.В. Иванов[4, 5]

[1] Государственный научный центр Российской Федерации — Федеральный медицинский биофизический центр имени А.И. Бурназяна, Москва, Российская Федерация
[2] Городская клиническая больница имени И.В. Давыдовского, Москва, Российская Федерация
[3] Московский государственный университет имени М.В. Ломоносова, Москва, Российская Федерация
[4] Первый Московский государственный медицинский университет имени И.М. Сеченова (Сеченовский Университет), Москва, Российская Федерация
[5] Государственный научно-исследовательский испытательный институт военной медицины, Санкт-Петербург, Российская Федерация

АННОТАЦИЯ

Обоснование. В период резкого возрастания количества исследований с применением компьютерной томографии (КТ) повышается актуальность совершенствования методов контроля дозы облучения пациентов в целях непревышения рекомендуемых уровней.

Цель — проанализировать зависимость эффективной дозы при компьютерной томографии различных областей тела от массы пациента и рассчитать стандартную эффективную дозу для пациентов массой 70 кг и 80 кг.

Материалы и методы. Проанализированы протоколы КТ-исследований — однофазных (209 пациентов) и многофазных (114 пациентов). Эффективную дозу рассчитывали в соответствии с нормализованными коэффициентами для каждой области тела (голова, грудная клетка, брюшная полость и малый таз). Значения стандартной эффективной дозы рассчитывали путём аппроксимации данных с использованием линейной функции эффективной дозы относительно массы тела для стандартного пациента массой 70 кг или 80 кг для каждого типа КТ-сканера и сканируемой области тела.

Результаты. Установлено, что при КТ-исследовании эффективная доза увеличивается пропорционально массе тела пациентов. Рассчитаны и сопоставлены значения средней эффективной дозы, медианной эффективной дозы, референтных диагностических уровней (мЗв) со стандартной эффективной дозой (мЗв) при однофазной и многофазной компьютерной томографии. Во всех сравниваемых группах эти показатели были несколько выше, чем стандартная эффективная доза, если критерием была масса 70 кг, и были близки к стандартной эффективной дозе, если критерием была масса 80 кг. Показана возможность использования для расчёта стандартной эффективной дозы не только данных пациентов, отобранных по стандартной массе тела, но и всего массива данных методом аппроксимации. Это может быть использовано для совершенствования руководящих принципов сравнения и стандартизации доз облучения при компьютерной томографии у пациентов по изученным областям тела.

Заключение. В исследовании описана методика оценки и сравнения дозы КТ-излучения на примере двух больниц и двух КТ-сканеров с учётом массы стандартного пациента. Результаты показывают, что расчёт и анализ стандартной эффективной дозы для каждой области тела вместо средней эффективной дозы, медианной эффективной дозы или 75-го квантиля эффективной дозы помогают более корректно сравнивать радиационное облучение в разных медицинских учреждениях и анализировать причины превышения региональных или национальных референтных диагностических уровней. В условиях резкого увеличения числа КТ-исследований в последнее время непревышение при компьютерной томографии референтных диагностических уровней, рассчитанных по критерию стандартной эффективной дозы, призвано снизить отдалённые последствия в виде онкологической патологии среди населения.

Ключевые слова: компьютерная томография; радиационное облучение; эффективная доза, референтные диагностические уровни; масса тела; корреляционный анализ.

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Substantiation of a new approach to the criteria for assessing the radiation dose of patients during computed tomography

Elena I. Matkevich[1, 2], Valentin E. Sinitsyn[2, 3], Ivan V. Ivanov[4, 5]

[1] State Research Center - Burnasyan Federal Medical Biophysical Center of Federal Medical Biological Agency, Moscow, Russian Federation
[2] I.V. Davydovsky City Clinical Hospital, Moscow, Russian Federation
[3] Lomonosov Moscow State University, Moscow, Russian Federation
[4] Sechenov First Moscow State Medical University (Sechenov University), Moscow, Russian Federation
[5] State Scientific-Research Test Institute of Military Medicine, Saint Petersburg, Russian Federation

ABSTRACT

BACKGROUND: In accordance with the requirements of the IAEA basic safety standards and the International Commission on Radiation Protection, comparing the radiation dose for patients undergoing computed tomography (CT) in diagnostic and treatment clinics with national or international DRLs is important for controlling medical radiation doses. The search for ways to improve DRLs calculations determines the relevance of such studies.

AIM: To analyze the dependence of effective doses (EDs) in CT of different body parts on patient's weight and to calculate the standard ED for the patient (70 and 80 kg).

MATERIALS AND METHODS: CT acquisition protocols in 209 patients were single phase (SP) CT, while 114 patients underwent multi-phase (MP) CT. ED was calculated according to the normalized coefficients for each body area. The values of standard ED was calculated by data approximation using linear function of ED relatively body weight for each type CT scanner and body area scanned.

RESULTS: The increase in ED following a CT examination was proportional to the body weight of patients. For SP and MP CT scans, the standard EDs were calculated according to all body areas. The mean ED, median ED, and DRLs (mSv) in these groups was slightly higher than standard ED (mSv) if the criterion was 70 kg and were close to standard ED if the criterion was 80 kg. These values give a basis for improving the guidelines concerning the recommended limits of radiation doses for CT in individual patients according to indications and body parts studied.

CONCLUSIONS: In the study, a methodology for assessing and comparing the dose of CT-radiation at two hospitals in the two CT scanners, considering weight of a standard patient, is described. Our results show that the calculation and analysis of the standard ED of CT-examining areas of the body instead of mean ED and median ED help to compare the radiation exposure in different medical facilities more properly. Given the recent sharp increase in the number of CT studies, not exceeding the standard ED for patients with CT will reduce the long-term consequences in the form of oncological pathology among the population.

Keywords: computed tomography; radiation dose; effective dose; diagnostic reference levels; body weight; correlation of data.

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在计算机断层扫描中估计病人剂量的标准的新方法的论证

Elena I. Matkevich[1, 2], Valentin E. Sinitsyn[2, 3], Ivan V. Ivanov[4, 5]

[1] State Research Center - Burnasyan Federal Medical Biophysical Center of Federal Medical Biological Agency, Moscow, Russian Federation
[2] I.V. Davydovsky City Clinical Hospital, Moscow, Russian Federation
[3] Lomonosov Moscow State University, Moscow, Russian Federation
[4] Sechenov First Moscow State Medical University (Sechenov University), Moscow, Russian Federation
[5] State Scientific-Research Test Institute of Military Medicine, Saint Petersburg, Russian Federation

结构化简评

论证。在计算机断层扫描（CT）检查数量急剧增加的时候，改进监测病人剂量的方法越来越迫切，不要超过推荐水平。

目的是分析身体各部分CT的有效剂量（ED）对病人体重的依赖性，并计算体重70公斤和80公斤的病人的标准ED。

方法。我们分析了CT检查的协议——单相（SP）（209名患者）和多相（MP）（114名患者）。ED是根据身体各部分（头部、胸部、腹部和骨盆）的归一化系数计算的。对于每一种CT扫描仪和扫描的身体面积，使用线性ED函数与体重的关系来计算标准的ED值，标准的ED值是通过近似的数据，对于体重70公斤或80公斤的标准病人。

结果。在CT扫描中发现，ED的增加与病人体重成正比。计算了平均ED、中位ED、DRLs（mSv），并与SP和MP　CT的标准ED值（mSv）进行了比较。在所有比较组中，如果标准是体重70公斤，这些指标略高于标准ED，如果标准是体重80公斤，这些指标接近标准ED。同时表现了，不仅可以使用按标准体重取样的病人的数据，而且可以通过近似法使用整个数据集来计算标准ED。按所研究的身体部分，这可以用于改进比较导则和使患者的CT辐射剂量标准化。

结论。该研究描述了一种评估和比较CT辐射剂量的方法，以两家医院和两台CT扫描仪为例，考虑到一个标准病人的体重。结果显示，不是平均ED、中位ED或75分位ED，而是计算和分析每个身体部分的标准ED，有助于更正确地比较不同医疗机构的辐射量，分析超过区域或国家的参考诊断水平（DRLs）的原因。随着最近CT检查数量的急剧增加，为了减少人口中癌症病理形式的长期后果，应该不超过CT中使用标准ED标准计算的DRLs。

关键词：CT扫描；射线照射；有效剂量；参考诊断水平；身体质量；相关性分析。

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ABBREVIATIONS

CT: computed tomography
CTDIvol: volume computed tomography dose index (mGy)
DLP: dose–length product calculated as a product of dose (mGy) and the length of the body area scanned (cm)
DRLs: diagnostic reference levels
ED: effective dose (mSv)
ICRP: International Commission on Radiological Protection
SSDE: size-specific dose estimate (mGy)

BACKGROUND

Recently, the application of computed tomography (CT) has increased in Russia and elsewhere. In 2020, the average annual medical effective dose per capita in Russia dramatically increased by 30% (0.6 mSv in 2019, 0.81 mSv in 2020) [1], but the CT contribution to the collective medical exposure dose increased from 22.1% in 2010 to 73.5% in 2020 and currently ranks first among all types of X-ray and radiological examinations. In the long term, an increase in the total patient radiation doses should be expected during screening CT scans to diagnose the consequences of COVID-19 and lung and breast cancer as well as repeated CT scans to establish changes in the pathological process, including CT using radiopaque agents.

According to the basic safety standards of the International Atomic Energy Agency [2] and the International Commission on Radiological Protection ICRP) [3–7], to control medical radiation doses, CT radiation doses in diagnostic and medical clinics must be compared with national or international diagnostic reference levels (DRLs). The importance of such studies is driven by the need to find ways to improve DRL calculations.

The purpose of this study was to analyze the relationship between an effective dose (ED) and patient weights in the CT scans of various body areas as well as to calculate standard EDs for patients weighing 70 kg and 80 kg.

MATERIALS AND METHODS

Study Design

A retrospective study was performed using the electronic databases of the single-phase CT (SP-CT) and multiphase CT (MP-CT) of the head, chest, abdomen, and pelvis.

Eligibility Criteria

Inclusion Criteria: patients aged 17 to 95 who were referred to a diagnostic CT scan by their attending healthcare professional.

Exclusion Criteria: patients with missing body weight data.

Study Conditions

This study included the patients of two multi-disciplinary healthcare institutions: the Treatment and Rehabilitation Center of the Ministry of Health of Russia (Site 1) and the I.V. Davydov City Clinical Hospital of the Department of Health of Moscow (Site 2) using standard CT protocols for these body areas.

Study Duration

Electronic data on patient CT radiation exposure for 2015–2018 were analyzed.

Description of Medical Intervention

CT scans were performed using two CT scanners (at Site 1: GE Discovery CT750 HD, 64-slice, GE Healthcare, USA; at Site 2, Toshiba Aquilion Prime, 80-slice, Toshiba, Japan) following the standard scanning protocol [8]: The tube voltage was 100 kV or 120 kV with automatic current modulation, and the slice thickness was 0.5, 0.625, 1.25, and 1.5 mm. The key parameters of CT protocols are presented in Table 1. In this study, all CT scans used the same type of noise reduction algorithms for the corresponding body area.

Based on the CT reports of each patient, the following radiation exposure parameters were entered into the database: CTDIvol (volume-weighted computed tomography dose index, mGy) and DLP (absorbed dose for the entire CT scan, mGy × cm). Individual patient EDs were calculated using the formula [5]:

$$ED\ (mSv) = K_{ED\ DLP} \times DLP, \quad (1)$$

where ED is the effective dose; K is a coefficient; and DLP (dose–length product) is the product of the dose absorbed (mGy) and the length of the body area scanned (cm).

For the calculations, we used the $K_{Ed\ DLP}$ conversion coefficients ($mSv \times mGy^{-1} \times cm^{-1}$) [4]: head, 0.0023; chest, 0.017; abdomen, 0.015; and, pelvis 0.019.

Primary Study Outcome

This study is aimed at evaluating the relationship between the ED in patients undergoing CT scans of various body areas and the patient's body weight as well as at calculating a standard ED for typical patients weighing 70 kg and 80 kg. As a reference, we used the mean ED, median ED, and the 75th quantile of the ED in the same group of patients.

Additional Study Outcomes

The body weight distribution was assessed by group, and mean weight changes were analyzed in our study population.

Subgroup Analysis

Two study groups were formed and compared: the group of Site 1 (GE Discovery CT750 HD, 64-slice) and the group of Site 2 (Toshiba Aquilion Prime, 80-slice). Each group was divided into three subgroups according to CT areas (head, chest, and abdomen and pelvis). In each subgroup, patient radiation doses were calculated for SP-CT and MP-CT.

Ethical Review

For retrospective studies using anonymized datasets, an ethics committee opinion is not required.

Statistical Analysis

The size of the groups was determined by the number of patients who were followed up during the study period and who had data on the radiation dose + weight during CT scans. The analysis included CT scans with good image quality following the European guidelines on Quality Criteria for Computed Tomography [4]. In this context, good image quality was considered as "visually clear reproduction of the structure of organs, tissues, etc., the boundaries between them, as well as lesions and foci."

We specifically measured the body weight of each patient with an accuracy of ±3 kg and calculated mean body weights (M ± m, kg) for all groups. Inter-site differences in means reported for each CT area were calculated using the t-test ($p \leqslant 0.05$). To establish the radiation dose–weight relationship, a regression correlation analysis was performed using STATISTICA software (v. 10.0).

We determined individual patient EDs (in mSv) for Site 1 and Site 2 using formula (1), then calculated the mean ED (mSv) as the arithmetic mean (M) with standard deviations (± m), median, 25th and 75th quantiles of the ED (mSv) (Me [25th, 75th]), and DRLs (mSv; ED_{75th}) for each scan area using the Microsoft Excel 2013 software package.

We calculated the standard ED assuming [4, 7, 9, 10] that this is the mean ED for adult males and females weighing 70 ± 3 kg. For the selected diagnostic radiologic procedure (following the standard protocol with a typical operation mode of the system used), the standard $ED_{70\ kg}$ (mSv) and the standard $ED_{80\ kg}$ (mSv) were calculated by approximating the data for each of the three scan areas (head, chest, and abdomen + pelvis) using linear ED–weight functions by the following regression equation:

$$ED\ (mSv) = a + b \times W\ (rg), \quad (2)$$

where ED is the effective dose (mSv) received by the patient; a and b are regression coefficients; and W is the patient's body weight (kg).

The values of coefficients a and b were calculated using STATISTICA for each scan area (head, chest, and abdomen + pelvis) in Site 1 and Site 2 for SP-CT and MP-CT. Then, the standard $ED_{70\ kg}$ (for a typical patient weighing 70 kg) and the standard $ED_{80\ kg}$ (for a typical patient weighing 80 kg) were calculated using equation (2) for W = 70 kg and W = 80 kg, respectively.

RESULTS

Study Subjects

Statistical analysis included finding 323 CT scans (137 men and 186 women aged 17–93). CT was performed according to standard protocols. A total of 209 SP-CT scans and 114 MP-CT scans were analyzed.

As shown in Table 1, the groups were generally well-balanced by age, sex, and body weight, which varied from 42 to 129 kg.

Primary Study Outcomes

In the first stage of the study, mean radiation exposure parameters (CTDIvol, DLPs, and the ED per CT scan) were determined for the SP-CT and MP-CT of the head, chest, and abdomen and pelvis, respectively (Table 2). The mean patient ED per one SP-CT scan and one MP-CT scan was 1.8–2.0 mSv and 2.4–4.6 mSv for the head, 2.4–5.3 mSv and 7.9–8.4 mSv for the chest, and 7.5–8.2 mSv and 27.4–33.0 mSv for the abdomen + pelvis, respectively.

As shown in Table 1, the mean weight of Site 1 and Site 2 groups differed insignificantly, except for the SP-CT of the abdomen + pelvis (75.5 ± 2.0 kg and 83.1 ± 3.5 kg, respectively) and the MP-CT of the chest (75.5 ± 5.0 kg and 91.6 ± 3.2 kg, respectively).

In the second stage of the study, a correlation analysis was performed to establish the ED–weight relationship. The correlation coefficients were 0.66–0.70 and 0.59–0.68 for SP-CT and MP-CT, respectively. For abdomen + pelvis, the correlation coefficients were 0.37 and 0.59 for SP-CT and MP-CT, respectively. For the head, the correlation coefficients were extremely low: 0.05–0.09 and 0.11–0.18 for SP-CT and MP-CT, respectively.

In the third stage of the study, the median ED (Me [25th, 75th]) and DRLs (ED_{75th}) were calculated (see Table 3). For each scan area, the standard EDs were calculated using a dose–weight regression function for patients weighing 70 kg and 80 kg during SP-CT and MP-CT scans (Figures 1 and 2).

We compared the mean ED, the median ED, and DRLs (ED75th) with standard EDs for these groups (see Table 3). There are no significant differences in the mean ED, median ED, and DRLs (ED_{75th}) compared to the standard ED for the head CT. No correlation with weight was revealed, and these parameters were 1.7–1.9 mSv for Site 1 and 2.1–2.2 mSv for Site 2.

For other scan areas, the weight of patients is important for assessing EDs. If mean weights are similar (e.g., 76.1 ± 4.0 kg and 76.3 ± 2.3 kg for SP-CT scans of the chest at Site 1 and Site 2, respectively), differences in the mean ED, the median ED, DRLs (ED_{75th}), and standard EDs are unidirectional: all ED values at Site 1 were 2.2–3.2-fold higher than those at Site 2.

Table 1. General characteristics of patients and protocol parameters for SP-CT and MP-CT

Parameters	Region of interest	One-phase CT		Multiphase CT	
		Site 1	Site 2	Site 1	Site 2
General characteristics of patients					
Number of patients, *n*	Head	18	32	14	8
	Chest	25	38	11	27
	Abdomen + pelvis	75	21	30	24
	Total	118	91	55	59
Male/female	Head	8/10	9/23	6/8	5/3
	Chest	9/16	17/21	6/5	15/12
	Abdomen + pelvis	33/42	10/11	12/18	7/17
	Total	50/68	36/55	24/31	27/32
Age, M ± m, years	Head	52.1±3.2	66.3±2.5	52.5±3.0	56.8±7.2
	Chest	57.6±2.7	51.9±3.0	58.6±4.7	62.7±3.2
	Abdomen + pelvis	57.5±5.3	65.3±4.8	57.6±2.5	55.5±3.5
Weight, M ± m, kg	Head	79.8±3.2	77.0±2.0	81.2±3.8	86.6±3.5
	Chest	76.1±4.0	76.3±2.3	75.5±5.0	91.6±3.2
	Abdomen + pelvis	75.5±2.0	83.1±3.5	79.7±2.9	80.7±2.7
Key parameters of CT protocols					
Collimation (mm)	Head, chest, abdomen, pelvis	64×0,6	80×0,5	64×0,6	80×0,5
Tube current modulation	Head, chest, abdomen, pelvis	Automatic	Automatic	Automatic	Automatic
Tube voltage (kV)	Head	120	120	120	120
	Chest	120	120	100; 120	120
	Abdomen + pelvis	120	120	100; 120	120
Pitch	Head	0.531	0.625	0.531	0.625
	Chest	1.375	1.388	0.984; 1.375	1.388
	Abdomen + pelvis	1.375	0.813	0.984; 1.375	0.813
Rotation time (sec)	Head	0.8	0.5; 0.75	0.8	0.5; 0.75
	Chest	0.6; 0.7	0.5	0.6; 0.7	0.5
	Abdomen + pelvis	0.7	0.5	0.7	0.5
Slice thickness (mm)	Head	1.25	0.5	1.25	0.5
	Chest	1.25	0.5	0.625; 1.25	0.5
	Abdomen + pelvis	1.25	0.5	0.625; 1.25	0.5

Note. * In the studies conducted, low-dose protocols and special noise reduction algorithms were not used. Filtered BackProjection technology was used. CT: computed tomography.

For the SP-CT scans of abdomen + pelvis, the mean patient weight (83.1 kg) at Site 2 exceeded that at Site 1 (75.5 kg), so the mean ED was slightly higher for Site 2 (8.2 ± 0.7 mSv) than for Site 1 (7.5 ± 1.1 mSv), and DRLs (ED_{75th}) where higher for Site 2 (10.8 mSv) than for Site 1 (8.4 mSv). At the same time, the calculated standard $ED_{70\ kg}$ was lower for Site 2 (5.89 mSv) than for Site 1 (7.19 mSv).

For the MP-CT scans of the chest, the mean patient weight was heavier for Site 2 (91.6 kg) than for Site 1 (75.5 kg), so the mean ED was slightly higher for Site 2 (8.4 ± 0.7 mSv) than for Site 1 (7.9 ± 1.7 mSv). The DRL (ED_{75th}) was slightly higher for Site 2 (11.0 mSv) than for Site 1 (10.0 mSv). At the same time, the calculated standard $ED_{70\ kg}$ was lower for Site 2 (5.28 mSv) than for Site 1 (6.55 mSv).

The DRL (ED_{75th}) depends not only on the weight but also on the abnormal values of the radiation dose of each patient. Therefore, in the group of MP-CT of abdomen + pelvis, the mean patient weights at Site 1 and Site 2 were similar

Table 2. Radiation doses for SP-CT and MP-CT of the head, chest, and abdomen and pelvis at Site 1 and Site 2

Parameters	Region of interest	One-phase CT		Multiphase CT	
		Site 1	Site 2	Site 1	Site 2
ED per CT, M ± m, mSv	Head	1.8±0.1	2.0±0.03	2.4±0.3	4.6±0.3*
	Chest	5.3±0.5	2.4±0.2*	7.9±1.7	8.4±0.7
	Abdomen + pelvis	7.5±1.1	8.2±0.7	33.0±1.8	27.4±2.4
DLP, M ± m, mGy × cm	Head	771.9±38.8	899.2±10.8	1033.3±109.8	1988.7±131.1*
	Chest	309.1±30.6	141.9±10.6*	466.9±97.6	494.3±48.4
	Abdomen + pelvis	449.0±67.3	491.1±51.9	1964.1±108.2	1623.7±144.4
CTDIvol, M ± m, mGy	Head	40.1±1.4	51.5±1.0*	-	-
	Chest	8.3±0.9	3.8±0.3*	-	-
	Abdomen + pelvis	9.4±1.5	13.7±1.1*	-	-
Number of phases per CT, M ± m	Head	1	1	2.1±0.1	2.5±0.2
	Chest	1	1	1.4±0.2	2.0±0
	Abdomen + pelvis	1	1	3.8±0.1	3.8±0.1

Note. * Differences in means for this CT region between Site 1 and Site 2 ($p \leqslant 0.05$). CT: computed tomography; ED: effective dose.

(79.7 ± 2.9 kg and 80.7 ± 2.7 kg, respectively), but in 5 patients at Site 1, the ED values were abnormal and exceeded 45 mSv (see Fig. 2,*e*), so the 75th quantiles of the ED or DRLs (ED_{75th}) were higher at Site 2 (40.1 mSv) than at Site 1 (35.7 mSv). At the same time, the standard $ED_{70\ kg}$ values were 29.99 mSv and 21.63 mSv for Site 1 and Site 2, respectively.

Additional Findings

These data allowed us to determine that the mean weight in both groups approached 80 kg (see Table 1), which is related to the many patients weighing approximately 80 kg in almost all groups. Therefore, the mean ED and DRLs (ED_{75th}) in these groups always exceeded the standard $ED_{70\ kg}$ and were closer to the standard $ED_{80\ kg}$ (see Table 3). We believe that for our population, a reasonable approach is to consider the standard $ED_{80\ kg}$ instead of the standard $ED_{70\ kg}$ as a criterion for assessing the ED since the standard $ED_{80\ kg}$ better reflects the body weight distribution in our population due to recent anthropological changes. At the same time, if the mean weight in both groups approaches the standard weight of 80 kg, the corresponding mean EDs can be used to compare the EDs of different computed tomographs.

DISCUSSION

Summary of the Primary Study Outcome

The primary goal of our study was to substantiate the importance of calculating the standard EDs in CT scans for

Table 3. Effective doses (mSv) for SP-CT and MP-CT of the head. chest. and abdomen and pelvis

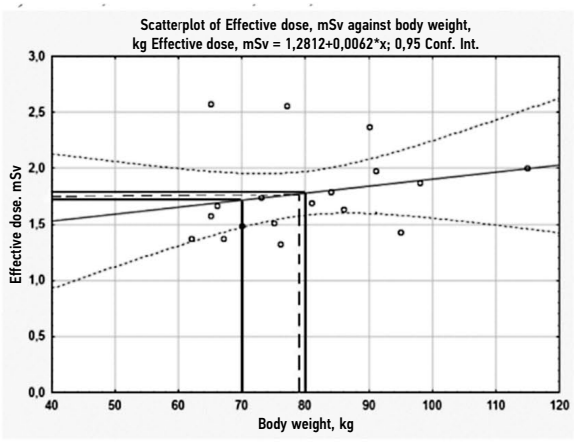
Region of interest	Mean ED		Median ED (Me [25th. 75th])		DRLs ($ED_{75\ th}$)		Standard $ED_{70\ kg*}$		Standard $ED_{80\ kg**}$	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
SP-CT										
Head	1.8±0.1	2.1±0.03	1.7 [1.5; 1.9]	2.1 [2.0; 2.2]	1.9	2.2	1.72	2.06	1.78	2.07
Chest	5.3±0.4	2.4±0.2	4.9 [2.9; 7.6]	1.9 [1.8; 2.4]	7.6	2.4	4.53	2.09	5.71	2.60
Abdomen + pelvis	7.5±1.1	**8.2±0.7**	**6.5 [5.8; 8.4]**	**10.3 [4.4; 10.8]**	**8.4**	**10.8**	**7.19**	**5.89**	7.83	7.63
MP-CT										
Head	2.4±0.3	4.6±0.3	2.2 [2.0; 2.3]	4.6 [4.0; 5.4]	2.3	5.4	1.94	3.61	2.33	3.77
Chest	**7.9±1.7**	**8.4±0.7**	**6.2 [4.4; 10.0]**	**8.9 [5.5; 11.0]**	**10.0**	**11.0**	**6.55**	**5.28**	9.09	6.74
Abdomen + pelvis	33.0±1.8	27.4±2.4	31.4 [27.1; 35.7]	26.6 [17.9; 40.1]	**35.7**	**40.1**	**29.99**	**21.63**	33.11	26.91

Note. * Standard ED70 kg (ED for a typical patient of 70 kg) is calculated using the regression equation: $ED_{70\ kg}$ (mSv) = a + b × W (kg) for W = 70 kg; "a" and "b" are from the equations in Fig. 3. *a–f* (SP-CT) and Fig. 4. *a–f* (MP-CT). ** Standard $ED_{80\ kg}$ (ED for a typical patient of 80 kg) is calculated using the regression equation: $ED_{80\ kg}$ (mSv) = a + b × W (kg) for W = 80 kg; "a" and "b" are from the equations in Fig. 3. *a–f* (SP-CT) and Fig. 4. *a–f* (MP-CT). Differences in mean ED. median ED. and DRLs between Site 1 and Site 2 are highlighted in bold and are oppositely directed with differences in Standard $ED_{70\ kg}$ between these sites. CT: computed tomography; ED: effective dose.

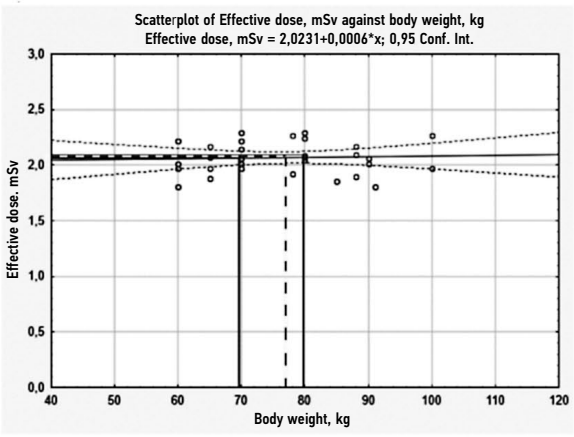
Site 1 (GE Discovery CT750) | **Site 2 (Toshiba Aquilion Prime)**

Head

a) *n*=18, M±m = 79.8±3.2 kg

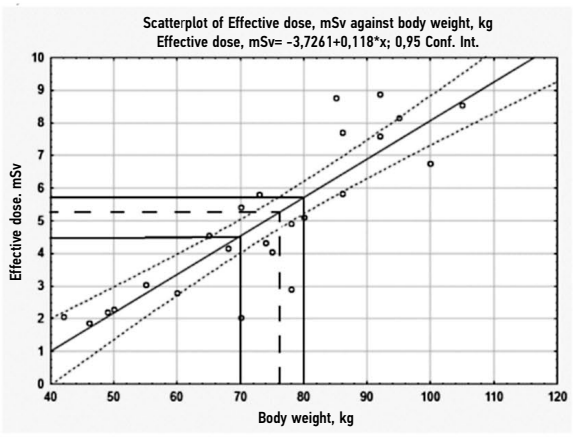


b) *n*=32, M±m = 77.0±2.0 kg

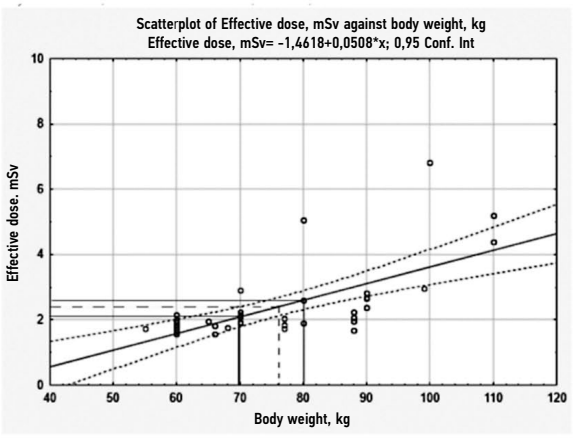


Chest

c) *n*=25, M±m = 76.1±4.0 kg

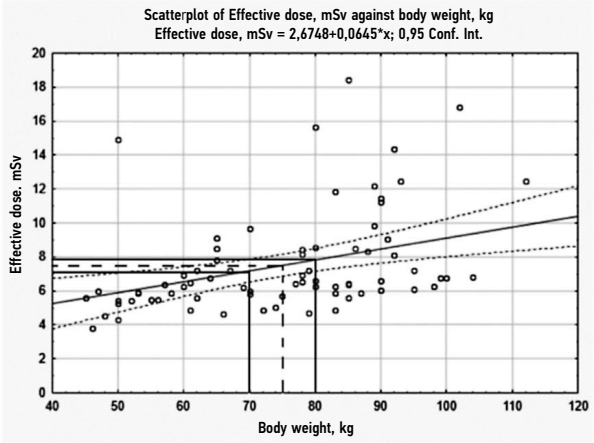


d) *n*=38, M±m = 76.3±2.3 kg



Abdomen + pelvis

e) *n*=75, M±m = 75.5±5.5 kg



f) *n*=21, M±m = 83.10±3.5 kg

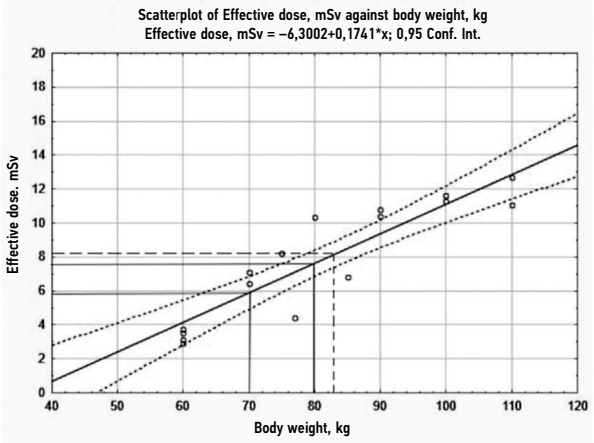


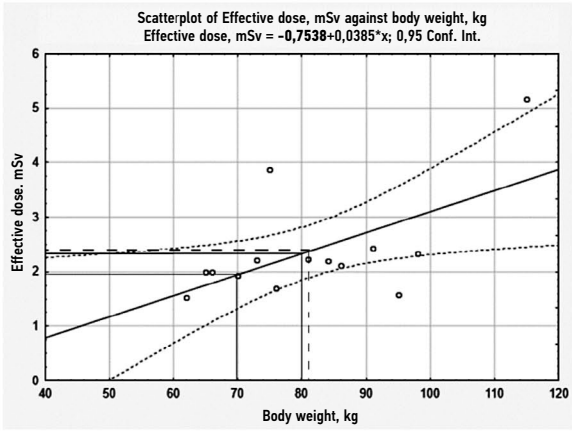
Figure 1. Regression analysis of the ED–weight relationship in SP-CT of the head, chest, and abdomen + pelvis. Y axis: effective dose (mSv); X axis: patient weight (kg).

Legend: A solid line is a regression line with dotted confidence intervals; p = 0.95, solid perpendicular lines for standard $ED_{70\ kg}$ and standard $ED_{80\ kg}$ (mSv), calculated for a patient weighing 70/80 kg; dashed lines for the mean ED (mSv) corresponding to the mean body weight in the group.
CT: computed tomography; ED: effective dose.

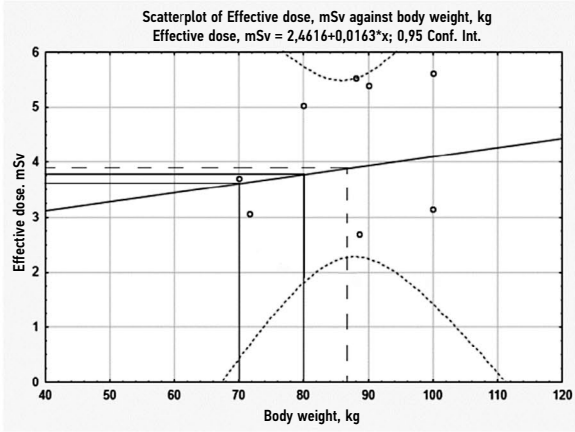
Site 1 (GE Discovery CT750) **Site 2 (Toshiba Aquilion Prime)**

Head

a) *n*=14, M±m = 81.2±3.8 kg

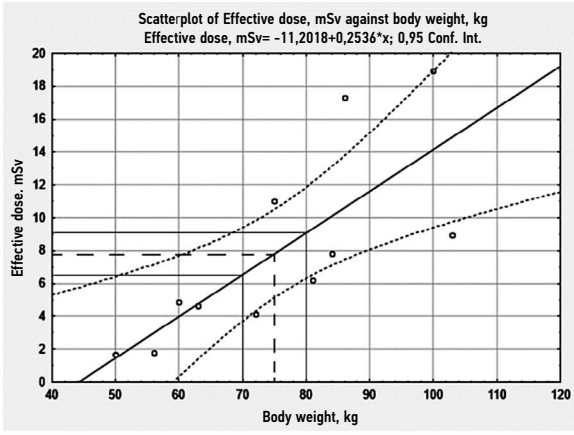


b) *n*=8, M±m = 86.6±3.5 kg

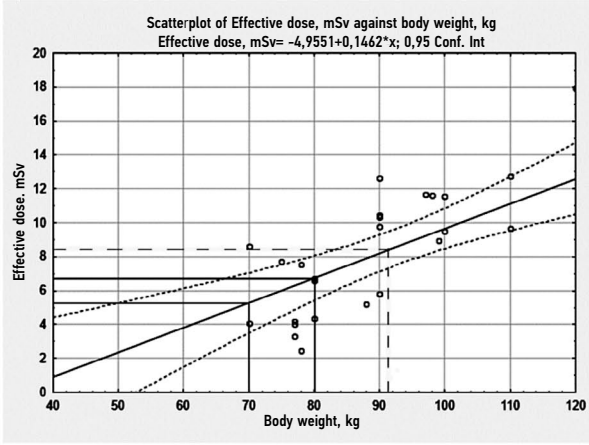


Chest

c) *n*=11, M±m = 75.5±5.0 kg

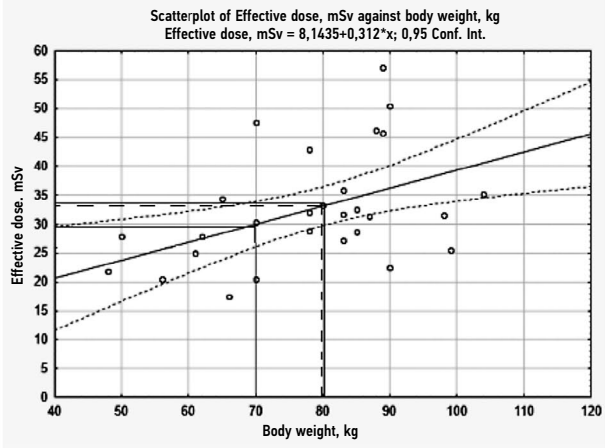


d) *n*=27, M±m = 91.6±3.6 kg



Abdomen + pelvis

e) *n*=30, M±m = 79.7±2.9 kg



f) *n*=24, M±m = 80.7±2.7 kg

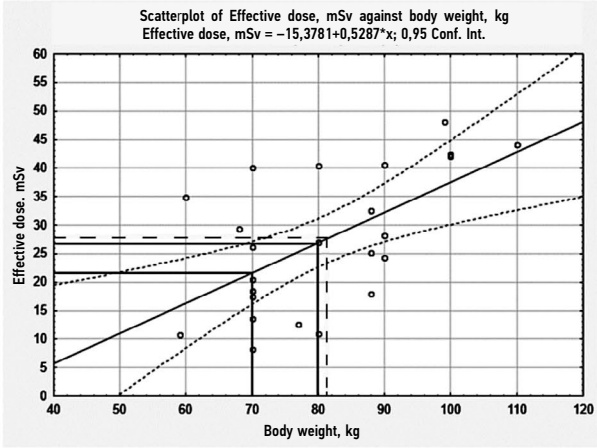


Figure 2. Regression analysis of the ED–weight relationship in MP-CT of the head, chest, and abdomen + pelvis (dotted lines are confidence intervals; p = 0.95). Y axis: effective dose (mSv); X axis: patient weight (kg).

Legend: A solid line is a regression line with dotted confidence intervals; p = 0.95, solid perpendicular lines for standard $ED_{70\ kg}$ and standard $ED_{80\ kg}$ (mSv), calculated for a patient weighing 70/80 kg; dashed lines for the mean ED (mSv) corresponding to the mean body weight in the group.

CT: computed tomography; ED: effective dose.

a more accurate calculation of the patient exposure levels in different medical and diagnostic organizations since the compared groups can differ significantly in body weight. The correlation analysis shows that a higher mean weight is associated with a higher mean radiation dose. DRLs reflect the 75th quantile of radiation doses and are proportional to the mean patient weights of the groups, which prevents using DRLs for a correct comparison of patient exposure doses in these organizations in the case of a significant difference in mean weights between groups.

Our correlation analysis showed that the radiation dose tended to increase proportionally with patient weight during SP-CT and MP-CT scans of the chest (see Figure 1, *c*, *d*; Figure 2, *c*, *d*) and abdomen + pelvis (see Figure 1, *e*, *f*; Figure 2, *e*, *f*). The highest CT dose correlation with patient weight was established for the chest (0.59–0.70) and abdomen + pelvis (0.37–0.59), and the lowest correlation was established for head CT (0.05–0.18) (see Figure 1, *a*, *b*; Figure 2, *a*, *b*). The calculated correlation coefficients were consistent with the relative weight of human body segments [11–14]. The upper body weight, middle body weight, lower body weight, and head weight were 15.9%, 16.3%, 11.2%, and 6.9%, respectively.

The ED–weight relationship is associated with the design features of the sensors and automatic current regulation in the CT scanner tube. This association means that comparing the mean EDs and median EDs obtained in different medical organizations is inappropriate if mean weights significantly differ in the compared patient groups. Therefore, our study shows that for such comparisons, a more appropriate approach is to calculate and compare the standard $ED_{70\ kg}$ or standard $ED_{80\ kg}$ values of the groups.

Discussion of the Primary Study Outcome

Many studies evaluate the problem of assessing the CT radiation dose. As a criterion for optimized patient protection during diagnostic and interventional procedures, a DRL has been established [7]. Since its introduction by the ICRP in 1996, the concept of DRLs has been constantly evolving [2, 6, 7]. The ICRP currently recommends estimating the median radiation dose per treatment for each subject included in a study [7]. National DRLs should be set as the 75th percentile of the median DLP or ED values obtained in a sample of representative centers. However, this guideline neglects possible differences in doses due to the different body weights of patients in the groups compared.

DRLs for the same CT area are known to be subject to great variability, which makes it difficult to compare them correctly. Therefore, in a review study [15], a 2–3-fold difference was reported for DRLs obtained for the same procedure in different studies. However, these differences are related to study design, scanning technology, and the use of different exposure parameters and different dose indices. No consensus has been reached on this issue. One study [16] assessed patient, equipment, and organization factors affecting the CT radiation dose. Patient size (in terms of T-shirt size), site-specific protocols, and multiphase scanning were found to be the most important predictors of dose (R2 8–32%), followed by the equipment manufacturer and iterative reconstruction (R2 0.2–15.0%). Another study [17] showed that CT radiation doses vary widely across countries, but the authors supposed that this variation was related primarily to the local choice of technical CT parameters and was unrelated to the characteristics of the patient, organization, or equipment.

The issue of calculating the standard ED is becoming increasingly important because of the constantly evolving criteria for assessing the radiation dose in various medical organizations. Therefore, international documents [4, 7] indicate that DRLs should be standardized, i.e. they should be given, as much as possible, for a "typical-size patient" for each type of CT scan considering that the "standard dose is the mean dose for adult patients of both sexes weighing 70 ± 3 kg during the selected radiological procedure using a typical mode of operation of the system used with a typical protocol" [4, 8, 10]. The selected mean weight should be near the mean weight in the population considered, and for some countries, an average patient weight of 70 ± 10 kg may be acceptable [7]. However, in practice, medical organizations calculate DRLs using the mean or median values of the radiation dose of the general population, without considering the size and weight of patients.

Only a few authors considered "patient size" for these analyses: For example, A.J. van der Molen et al. [18] provided doses for a "typical-size patient" (height 1.74 m, weight 77 kg, BMI 25.4 kg/m^2 ± 15%) or a patient weighing 70 ± 15 kg [19]. A smaller scatter of data can be assumed, and the comparison of DRLs would be more correct if standard radiation doses for a "typical patient" weighing 70 kg or 80 kg were compared instead of mean or median doses. This calculation method should be used by all medical organizations.

The analysis (Table 4) showed that in different countries, SP-CT ED (mSv) for the studied areas could differ several times, and in different studies, it was 1.5–2.3 mSv for head CT, 4.0–7 .9 mSv for chest CT, 2.4–10.0 mSv for abdomen CT, and 4.1–11.7 mSv for abdomen + pelvis CT. For MP-CT of the studied areas, the ED largely depended on the number of stages of the study and differed to a greater extent: 5.1–9.5 mSv for head CT, 3.6–23.1 mSv for abdomen CT, and 6.3–24.5 for abdomen + pelvis CT. In our study, for a patient of standard weight (70 kg), the calculated standard EDs for SP-CT and MP-CT at Site 1 and Site 2 were comparable to the mean or median EDs for head and chest CT in other studies and slightly exceeded EDs for MP-CT of abdomen + pelvis (see Table 4).

Our data were confirmed by the results of other studies. Therefore, data stratification by two subgroups (non-overweight and overweight) allowed a better optimization of CT doses and the ability to set DRLs based on the BMI category [37].

Table 4. Effective doses for CT of the head, chest, and abdomen and pelvis

ED parameters	ED (mSv) for CT regions[a, b]				Country
	Head	Chest	Abdomen	Abdomen + pelvis	
Median	1.5/-	4.0/5.1	2.4/3.6	4.4/6.3–13.3	Australia [20]
Mean	2.0 (*n*=50) [21]; 1.99 [22]	4.99 (*n*=43) [23]; 9.84 [22]	10.44 (*n*=43) [23]	11.7 [22]	Canada [21–23]
Mean	-	7.9–9.5 (*n*=81) [24]	-	6.15 (*n*=85) [25]	China [24, 25]
Mean	2.1–4.2	2.9–5.2	3.3–7.3	4.1–9.2	Germany [26]
Mean	1.2	5.9	8.2	-	Greece [27]
Mean	-	6.04 (*n*=50)	6.89 (*n*=51)	-	India [23]
Median	2.3 (*n*=26 965)	4.6 (*n*=6542)	-	9.7 (*n*=1692)	Italy [28]
Mean	-	-	7.7/23.1 (*n*=44) [29]	8.0 (*n*=447) [30]	South Korea [29, 30]
Median, only typical patients (1.74 m, 77 kg, BMI 25,4 kg/m^2±15%)	1.5	4.6	8/13.2–19.4	-	The Netherlands [18]
Mean	1.21 (*n*=52)	7.60 (*n*=38)	8.25 (*n*=54)	-	Poland [23]
Median, patient weighing 70±15 kg	-	5.4 (chest. *n*=39)	–/8.1 (appendicitis. *n*=100)	–/24.5 (Abdomen CT for liver and abdominal metastases in colorectal cancer. *n*=40)	Qatar [19]
Standard ED$_{70kg}$	1.7/1.9 (*n*=18/*n*=14)	4.5/6.6 (*n*=25/*n*=11)	-	7.2/30.0 (*n*=75/*n*=30)	Russia, this study, Site 1[c]
Standard ED$_{70kg}$	2.1/3.6 (*n*=32/*n*=8)	2.1/5.3 (*n*=38/*n*=27)	-	5.9/21.6 (*n*=21/*n*=24)	Russia, this study, Site 2[d]
Mean	0.89 (*n*=36)	4.20 (*n*=32)	6.03 (*n*=66)	-	Thailand [23]
Mean (*n*=340)	1.36/1.79	4.34	-	11.6/13.26	UAE [31]
Mean	1.66 (*n*=10) [23]	3.45 (*n*=30) [23]	2.4–6.04/ 8.4–15.33 [32]	6.69 (*n*=25) [23]	UK [23, 32]
Mean	2	7	7.3-8.0/15	10	USA [33, 34]
Mean	2.7	5.8	22.3	-	Ethiopia [35]
Median	2.1	4.4	6.8	-	Turkey [36]

Note. n: number of findings. BMI: body mass index; CT: computed tomography; ED: effective dose.

[a] $K_{DLP\ ED}$ (mSv × mGy^{-1} × cm^{-1}) [4]: head 0.0023, chest 0.017, abdomen 0.015, pelvis 0.019; [b] SP-CT/MP-CT; [c] Site 1, GE Discovery CT750 HD, 64-slice; [d] Site 2, Toshiba Aquilion Prime, 80-slice.

Other authors [38] compared the volumetric CT dose index (CTDIvol), dose–length product (DLP), and size-specific dose estimate (SSDE) for adult chest CT with the 2017 Chinese DRLs. Patients were divided into four groups depending on the water equivalent diameter of the chest (Dw). CTDIvol, DLP, and SSDE were found to increase in proportion to Dw.

The effect of patient size on the CT radiation dose has also been studied [39]. On the basis of the effective diameter estimated from adult body CT scans, each CT scan was classified by T-shirt size as XXS, XS, S, M, L, XL, and XXL. The radiation dose rates were compared for each size and type of CT scan, and the CTDIvol values were established for XXS (~60%), XS (~65%), S (~75%), M (100%), L (~130%), XL (~165%), and XXL (~210%). Thus, younger patients (XXS) received 60% of the dose compared to M patients, and XXL patients required doubling the dose (~210%). The authors considered this new approach, expressing body measurements in terms of T-shirt sizes, to be simple enough as a tool to demonstrate differences in doses between patients of different body types. However, in our opinion, this approach only applies to chest CT. Moreover, the body weight

more accurately reflects the individual characteristics of the patient's body than the T-shirt size.

Study Limitations

One study limitation was the possibility of also using an SSDE concept to consider the patient size when monitoring radiation doses during CT scans. However, the SSDE uses only corrections based on the geometric dimensions of the patient, including linear dimensions determined by measuring the patient or using their images [7]. The SSDE concept is designed to adjust the standard parameters of the CT protocol depending on the CT area size (effective diameter of the scan area) to minimize the absorbed radiation dose (mGy) [40], but it neglects the patient's weight, and it is not intended to assess the ED (mSv) and the risks of long-term radiation consequences.

Therefore, the SSDE is currently not considered a suitable criterion for use as DRLs [7]. This viewpoint is supported by a systematic review [15] of 54 scientific articles, which showed a low prevalence of the SSDE. CTDIvol and/or DLP were the most commonly used criteria for assessing radiation doses (87% of studies), while DLP+SSDE was used only in 1% of studies [15]. Usually, SSDE was used to model the dose during chest CT and document the results of dose reduction strategies for a particular (particularly pediatric) patient [41–43].

Another study limitation was using different approaches to calculate standard EDs. In our study, we used a linear approximation method (formula 2) to assess the relationship between the dose and the body weight of patients (linear regression equations). The regression analysis allowed regression coefficients to be established for the dose–weight relationship of each CT area of Site 1 and Site 2. These coefficients were used to calculate the standard $ED_{70\ kg}$ and the standard $ED_{80\ kg}$ for a typical patient weighing 70 kg and 80 kg, respectively (see Table 3).

A nonlinear model (power function) can also be used to describe the relationship between the CT radiation dose and patient size or weight for specific body areas. For example, in a report [23] on abdominal CT, a linear function was used to calculate the relationship between the normalized noise and the body mass index, and a power function was used to calculate the relationship between the normalized noise and the patient's anteroposterior diameter.

However, we believe the linear approximation method to be a more acceptable option for practical radiologists. If each hospital uses its own model for the nonlinear approximation of the ED–weight relationship, the result is different mathematical relationships and an additional nonsystematic error when comparing such standard EDs. Therefore, we consider using the linear regression acceptable for the routine practice of radiologists as a uniform method for this approximation.

Our conclusion is consistent with [23]: "...the best correlation between normalized noise and patient size was obtained using effective patient diameters and a power function." However, in practice, determining anteroposterior and lateral diameters (which are necessary to calculate the effective diameter) can be more logistically complex than weighing the patient. Because of this complexity, the weight of the patient was used [23] because of the simplicity of measuring this parameter compared to measuring the above diameters as well as to use the available acceptable linear correlation, rather than the power function that is more difficult to calculate.

Therefore, the national DRLs are currently set as the 75th percentile of the median patient doses established in a sample of representative centers [7]. If the DRL in a medical organization exceeds the regional level, this is a reason to analyze the CT technique parameters (tube voltage, scan area length, and other parameters of the CT protocol) to find ways to reduce it. However, this excess may be related to not only the technical CT parameters but also the larger mean weight of patients in a medical organization. For a correct comparison of the dose load in groups of patients with significant differences in mean weights, we recommend using the standard $ED_{70\ kg}$ or standard $ED_{80\ kg}$ calculated for the groups compared. Even with significant differences in the mean weights of patients, if the standard ED is higher at Site 1 than at Site 2, it can be safely assumed that this excess is related not to patient weight but to the characteristics of CT scanners and scanning protocols. Thus, to reduce the dose, these parameters should be modified.

Therefore, methods for calculating DRLs are constantly being improved [44–48], and the results obtained are important for establishing the correct DRLs of patient radiation exposure. In the future, the standard ED can be used to calculate DRLs for CT scanners in different regions of the country, but this action would require reporting the patient's body weight in each CT protocol.

Because of the dramatic increase in the number of CT scans, using DRLs not exceeding levels set by standard EDs will reduce the long-term CT consequences, including cancer [49–51]. In public healthcare, measures must be taken to control the radiation dose [44, 45, 52, 53] and meet the goals of cooperation with EUROSAFE international projects.

In practice, the method described can be used to assess the standard ED of each body area and compare the CT EDs using two sites and two CT scanners with the typical patient weight considered. Standard EDs must be calculated an analyzed for each body area (not just the mean ED, the median ED, and the 75th quantile of the ED) to help in more correctly comparing radiation exposure in different medical organizations and more accurately establishing factors for exceeding regional or national DRLs.

CONCLUSION

Effective radiation CT doses are proportional to the body weight of patients.

In groups of patients with a significant difference in mean weights, a comparison between mean and median radiation doses is inappropriate.

The method is designed for comparing patient exposure doses based on the calculated standard effective doses of two CT areas (the chest and abdomen + pelvis).

ADDITIONAL INFORMATION

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AUTHORS' INFO

*** Ivan V. Ivanov,** MD, Dr. Sci. (Med.), Professor;
address: 31, Prospect Budennogo, 105275, Moscow, Russia;
ORCID: https://orcid.org/0000-0001-7729-2724;
eLibrary SPIN: 9888-2780; e-mail: ivanov-iv@yandex.ru

ОБ АВТОРАХ

*** Иванов Иван Васильевич,** д.м.н., профессор;
адрес: Россия, 105275, Москва, Проспект Будённого, д. 31;
ORCID: https://orcid.org/0000-0001-7729-2724;
eLibrary SPIN: 9888-2780; e-mail: ivanov-iv@yandex.ru

* Corresponding author / Автор, ответственный за переписку

Elena I. Matkevich, MD, Cand. Sci. (Med.);
ORCID: http://orcid.org/0000-0001-5917-7706;
eLibrary SPIN: 5546-4830; e-mail: pencil_red@mail.ru

Valentin E. Sinitsyn, MD, Dr. Sci. (Med.), Professor;
ORCID: https://orcid.org/0000-0002-5649-2193;
eLibrary SPIN: 8449-6590; e-mail: vsini@mail.ru

Маткевич Елена Ивановна, к.м.н.;
ORCID: http://orcid.org/0000-0001-5917-7706;
eLibrary SPIN: 5546-4830; e-mail: pencil_red@mail.ru

Синицын Валентин Евгеньевич, д.м.н., профессор;
ORCID: https://orcid.org/0000-0002-5649-2193;
eLibrary SPIN: 8449-6590; e-mail: vsini@mail.ru

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Минимальный стандарт оснащения поликлиник города Москвы ультразвуковыми диагностическими приборами

Н.Н. Ветшева[1], И.В. Солдатов[1], З.А. Лантух[1], С.Г. Киреев[1], А.И. Гуревич[2], А.Н. Мухортова[1]

[1] Научно-практический клинический центр диагностики и телемедицинских технологий, Москва, Российская Федерация
[2] Детская городская клиническая больница имени Н.Ф. Филатова, Москва, Российская Федерация

АННОТАЦИЯ

Обоснование. Разнообразие подвидов ультразвукового оборудования и отсутствие общепринятых классификаций приводит к неэффективному оснащению медицинских организаций, ошибочно подобранному с точки зрения вида прибора, наборов и характеристик датчиков, а также уровню качества исследования. Системный подход к оснащению однотипных медицинских организаций ультразвуковым оборудованием позволит обеспечить доступность и повысить качество первичной медицинской помощи в амбулаторно-поликлинических центрах.

Цель — разработать алгоритм расчёта и рекомендации составления минимального стандарта оснащения амбулаторных медицинских организаций государственной системы здравоохранения для региона на примере г. Москвы.

Материалы и методы. В процессе исследования использовали программные средства статистического и сравнительного анализа, согласно данным системы Управления материальным обеспечением Единой медицинской информационно-аналитической системы (УМО ЕМИАС), формы федерального статистического наблюдения № 30, а также технические данные и обзоры современных ультразвуковых диагностических приборов.

Результаты. Разработанный минимальный стандарт оснащения учитывает такие факторы, как потребность в оказании медицинской помощи отдельно детскому/взрослому населению; соответствие современным диагностическим технологиям; обеспечение территориальной доступности диагностики при условии эффективной эксплуатации работы оборудования.

Заключение. Стандартизация оснащения амбулаторных медицинских организаций ультразвуковыми диагностическими приборами способствует повышению качества проведения диагностики, улучшению доступности оказания необходимых исследований прикреплённому населению, снижению срока ожидания исследований; сокращению дефицита необходимого оборудования; расширению спектра медицинских услуг, оказываемых населению города; минимизации дублирующих исследований на последующих этапах оказания медицинской помощи.

Ключевые слова: стандарт оснащения; ультразвук; поликлиники; ультразвуковые диагностические приборы; медицинское оборудование.

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Minimum standard for equipping Moscow clinics with ultrasound diagnostic devices

Natalia N. Vetsheva[1], Ilya V. Soldatov[1], Zoya A. Lantukh[1], Sergey G. Kireev[1], Anzhelika I. Gurevich[2], Anna N. Mukhortova[1]

[1] Moscow Center for Diagnostics and Telemedicine, Moscow, Russian Federation
[2] Filatov N.F. Children's City Hospital, Moscow, Russian Federation

ABSTRACT

BACKGROUND: A variety of ultrasound equipment and a lack of generally accepted classifications lead to inefficient equipment of medical organizations, incorrectly selected types of device, sets and probes' characteristics, as well as a level of study quality. A systematic approach to equipping similar medical organizations with ultrasound devices will ensure the availability and improve the quality of primary medical care in outpatient centers.

AIM: To develop a calculation algorithm and recommendations for the minimum standard for equipping regional outpatient medical facilities of the state healthcare system based on the Moscow example.

MATERIALS AND METHODS: In conducting the study, we used software for statistical and comparative analysis based on the data of the Material Support Management System of the Unified Medical Information and Analytical System (MSMS UMIAS), Form No.30 of Federal Statistical Observation, as well as a number of assigned population to the outpatient center (hereinafter referred to as the OC), technical data, and reviews of modern ultrasound diagnostic devices.

RESULTS: The developed minimum standard for equipment considers the following factors: 1) need to provide medical care to children and adult populations separately; 2) compliance with modern diagnostic technologies; 3) ensuring the territorial availability of diagnostics under the condition of efficient equipment operation.

CONCLUSIONS: Standardization of equipment of outpatient medical facilities with ultrasound diagnostic devices contributes to improving the quality of diagnostics and the availability of providing required examinations to the assigned population, reducing the waiting time for examinations, reducing the shortage of necessary equipment, expanding the range of medical services provided to the city population, and minimizing duplicate studies at subsequent stages of medical care.

Keywords: equipment and supplies; ultrasonography; ambulatory care facility; medical equipment.

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为莫斯科综合医院配备超声诊断设备的最低标准

Natalia N. Vetsheva[1], Ilya V. Soldatov[1], Zoya A. Lantukh[1], Sergey G. Kireev[1], Anzhelika I. Gurevich[2], Anna N. Mukhortova[1]

[1] Moscow Center for Diagnostics and Telemedicine, Moscow, Russian Federation
[2] Filatov N.F. Children's City Hospital, Moscow, Russian Federation

简评现实意义。超声设备的种类繁多，缺乏通用分类，导致医疗机构的装备效率低下，在设备类型、换能器的设置和特点以及检查质量水平方面的选择都是错误的。为单一类型的医疗机构配备超声设备的系统性方法，将确保门诊综合医院的可及性并提高初级保健的质量。

目的。以莫斯科市为例，开发一种计算算法与推荐来制定该地区公共医疗系统中门诊医疗机构的最低设备标准。

材料与方法。根据统一医疗信息和分析系统材料管理系统（UMO EMIAS）的、联邦统计观察第30号表格的及指定归综合门诊中心（以下简称APC）的人口数的数据，研究中使用了统计和比较分析的软件工具，以及现代超声诊断设备的技术数据和评论。

结果。在已经制定的最低设备标准中，考虑了以下因素：

1） 对儿童和成人分别进行医疗护理的需求；
2） 符合现代诊断技术；
3） 根据设备的有效运行，确保诊断的地域可用性。

结论。为门诊医疗机构配备超声诊断设备的标准化有助于提高诊断质量，增加民众获得必要检查的机会，减少检查的等待时间，减少必要设备的短缺，扩大为城市人口提供的医疗服务范围，尽量减少医疗服务后续阶段的重复检查。

关键词：设备标准；超声波；门诊部；超声诊断设备；医疗设备。

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INTRODUCTION

In the early 2020s, state outpatient care facilities were equipped by the Order of the Ministry of Health and Social Development of the Russian Federation No. 753 dated December 1, 2005,[1] which divides all healthcare facilities by types of subordination and recommends equipping them according to the schedules provided. However, these standards do not fully reflect the current equipment need of healthcare facilities both in terms of the equipment quantity and availability of state-of-art diagnostic technologies. Therefore, determining diagnostic tasks to be solved using specific types of equipment and comparing them with actual market supply are important. To estimate the need for equipment, it is necessary to forecast the equipment utilization for the next 10 years. By the Order of the Department of Health of Moscow No. 751 dated July 31, 2020, for the effective utilization of ultrasound diagnostic devices (UDDs) in a healthcare facility,[2] the annual number of planned examinations should be approximately 9000 per device provided that a device is operated 12 h a day, 5 days a week.

Currently, healthcare facilities may be equipped as follows [1]:

- Procuring new equipment
- Procuring used equipment
- Procuring modernized equipment
- Long-term equipment leasing

After the procurement of new equipment is approved, a term of reference (TOR) shall be prepared as follows:

1. At the planning stage, technical specifications and equipment configuration shall be clinically reasonable.
2. A qualitative (availability) or quantitative characteristic shall be provided for the parameters required, e.g., the minimum and maximum frequency ranges of probes.
3. When preparing the TOR, suppliers must be contacted to obtain equipment characteristics, clarify technical issues, evaluate the relevance of the TOR for the actual medical equipment market, and make competitive purchases with at least three manufacturers.
4. To prepare the TOR, healthcare facilities may use the list of Russian state standards (GOSTs) for compliance with requirements for state procurement and various healthcare standards.

If the TOR is not consistent with the above-mentioned principles, equipment problems may arise, for example, it is impossible to use adult ultrasound probes in pediatric healthcare facilities, and vice versa. The inadequate configuration of probes and programs can also result in the replacement of the entire system because of limitations in expanding the range of healthcare services of the ultrasound diagnostic department [2].

To prevent such errors in large-scale purchases, methodological materials shall be developed, comparing equipment needs by types of facilities and healthcare services provided to set a minimum equipment standard [3].

To introduce a unified systematic approach to resource distribution, a minimum standard for equipping outpatient centers of the Department of Health of Moscow with UDDs has been developed, indicating the quantity and quality of equipment [4].

MATERIALS AND METHODS

Based on the current equipment stock available, equipment utilization and distribution were assessed for outpatient centers of the Department of Health of Moscow, separately in adult and pediatric centers and in branches and head offices. The minimum equipment standard was developed considering the size of the attended population, concentration of clinical specialists in the head office, and number of examinations conducted during the reporting period.

We used the data of the Procurement Management System of the Unified Medical Information and Analysis System (UMIAS or EMIAS) of the Department of Health of Moscow (Federal Statistical Monitoring Form No. 30 for the reporting period) and publicly available technical specifications and reviews of state-of-art UDDs.

Most often, TORs classify devices into multipurpose (260250), hand-held (324320), and special cardiovascular (192070) devices, which are indicated in the Nomenclature of Medical Devices,[3] to cover a wide range of necessary examinations for the attended adult and pediatric population.

RESULTS

Status of UDD stock in outpatient care facilities of the Department of Health of Moscow

According to the Federal Statistical Monitoring Form No. 30 for 2019, 86 outpatient centers (including city outpatient clinics, pediatric city outpatient clinics, diagnostic centers, clinical diagnostic centers, and consultative and diagnostic outpatient clinics) are equipped with more than

[1] Order of the Ministry of Health and Social Development of the Russian Federation dated December 1, 2005, No. 753 "On Equipping Municipal Outpatient and Inpatient Care Facilities with Diagnostic Equipment". Available at: https://docs.cntd.ru/document/901962043. Accessed on September 26, 2022.

[2] Order of the Department of Health of Moscow No. 751 dated July 31, 2020, "On Approval of Target Indicators for Medical Equipment in Healthcare Organizations of the Moscow State Primary Healthcare System". Available at: https://tele-med.ai/media/documents/%D0%B2%D1%85._3884.1-6_mw9IosC.pdf. Accessed on September 26, 2022.

[3] Order of the Ministry of Health of the Russian Federation No. 4n dated June 6, 2012, "On Approval of the Nomenclature of Medical Devices". Available at: https://docs.cntd.ru/document/902353334. Accessed on September 26, 2022.

1,300 UDDs, which are designed to examine the attended population (>10 million) using the territorial program of state guarantees (Table 1).

To classify UDDs by types of care, three types of devices were considered: multipurpose, special cardiovascular, and hand-held devices (Table 2).

In accordance with the Letter of the Primary Healthcare Office of the Department of Health of Moscow No. 41-18-54078/18, for Ultrasound Diagnostics Departments with two-shift working mode, the target efficacy indicator is 40 examinations per day[4]. The average number of examinations per day is 19, and the average number of shifts is 1.6. Changes in available UDD utilization are presented in Table 3.

Considering the head office and all branches, the attended population included 92,000–300,000 and 28,000–73,000 people per adult and pediatric outpatient centers, respectively. According to the Federal Statistical Surveillance Form No. 30 for 2019, more than 4,800,000 and 2,000,000 ultrasound examinations were performed in adult and pediatric outpatient centers, respectively (including more than 2,300,000 and 214,000 cardiovascular ultrasound examinations). There are approximately 663 and 286 wage rates for diagnostic ultrasound technicians in adult and pediatric outpatient centers, respectively (including 604 and 204 HCPs).

DISCUSSION

Minimum equipment standard

According to Reporting Form No. 30 for 2019, adult and pediatric outpatient centers are equipped with more than 1300 UDDs with an attended population of more than 10 million and with more than 7 million examinations performed; therefore, the average annual number of examinations is 6000 per 1 UDD.

For multipurpose UDD utilization for the attended adult population, the above parameter was calculated using the ratio of the attended population to the number of UDDs, multiplied by the ratio of the average attended outpatient population to the total number of examinations, multiplied by the ratio of the number of examinations per 1 UDD per outpatient center to the number of examinations per 1 UDD (excluding cardiovascular examinations). For the attended pediatric population, the minimum equipment standard value is based on the comparison of the number of examinations conducted and the size of attended adult and pediatric populations.

For special cardiovascular UDD utilization for the attended adult population, the above parameter was calculated using the ratio of the average number of cardiovascular examinations per outpatient center to the average number of examinations per one UDD per outpatient center. For

Table 1. Current status of ultrasound diagnostic equipment in outpatient centers*

Parameter	Outpatient centers		
	Adult	Pediatric	Total
Number of equipment (pcs)	964	428	1392
Average service life of UDD (years)	7	8	8
Number of UDDs with service life >10 years (%)	17	21	19
Number of UDDs with service life <3 years (%)	10	2	6

Note. * Based on Federal Statistical Monitoring Form No. 30 for 2019. UDD, ultrasound diagnostic device.

Table 2. Distribution of equipment stock by types of care*

Parameter	Outpatient centers		
	Adult	Pediatric	Total
Number of multipurpose UDDs (pcs)	726	376	1102
Number of special cardiovascular UDDs (pcs)	192	9	201
Number of hand-held UDDs (pcs)	46	43	89

Note. * Based on Federal Statistical Monitoring Form No. 30 for 2019. UDD, ultrasound diagnostic device.

Table 3. Changes in outpatient UDD utilization, 2017–2019*

Type of healthcare facility	2017	2018	2019
Outpatient centers	55	57	59

Note. * Based on the data of Procurement Management System of the Unified Medical Information and Analysis System (UMIAS, EMIAS), 2017–2019.

[4] Letter of the Primary Healthcare Office of the Department of Health of Moscow No. 41-18-54078/18 dated October 22, 2018. Available at: https://tele-med.ai/media/documents/tselevyye_pokazateli_zagruzki_tmt.pdf. Accessed on September 26, 2022.

the attended pediatric population, the minimum equipment standard value is based on the comparison of the number of examinations conducted and the size of the attended adult and pediatric populations.

To improve the efficiency of radiology and imaging departments, the recommendation was to provide at least one hand-held UDD per adult and pediatric outpatient center, both in head and branches, for sedentary patients and medical check-ups and follow-up examinations outside healthcare facilities.

The minimum equipment standard for adult and pediatric primary outpatient centers (Tables 4 and 5; both tables were included in Order No. 1043 dated September 15, 2020[5]) describes the equipment system at a certain time according to the needs at the city level. An increase in the population with the development of districts requires an increase in UDD stocks. If reasonable, if the number of HCPs is sufficient for full equipment utilization, exceeding the minimum equipment standard is allowed.

To increase the efficiency, it is necessary not only to supply UDDs but also to ensure their complete set. For each device type, certain types of examinations are supposed to be performed (Table 6).

To obtain conclusive results of the above-mentioned examinations, in addition to the minimum model for calculating the equipment need of adult and pediatric outpatient centers, the minimum delivery package was developed for UDDs with minimum frequency ranges (Table 7).

Comparison of equipment standards

1. Let's consider equipment for adult and pediatric outpatient centers by the Order of the Ministry of Health and Social Development of the Russian Federation No. 753 dated December 1, 2005,[6] and the minimum equipment standard proposed (Tables 8 and 9).

The need for UDDs in an adult outpatient center was calculated as follows: an adult center was considered a basis, having a head office and three branches located at different addresses remote from each other, and each site has a certain size of an attended population.

The number of UDDs was calculated based on the size of the attended adult population (92,149). According to the minimum equipment standard (Table 4), the head office and branches (<50,000) should be provided with two multipurpose UDDs and one special cardiovascular UDD, and one multipurpose UDD and one special cardiovascular

Table 4. Minimum standard for equipping adult primary outpatient centers with UDDs

Type of ultrasound device	Outpatient center	
	Head office, per 1000 population	Branch office, per 1000 population
Multipurpose UDD	<50 — 1 pc 50–100 — 2 pcs 100–150 — 3 pcs >150 — 4 pcs (but no >4 pcs per office, including 1 expert UDD)	<50 — 1 pc >50 — 2 pcs
Hand-held UDD	1 pc (expert UDD)	1 pc
Special cardiovascular UDD	<100 — 1 pc >100 — 2 pcs	1 pc

Table 5. Minimum standard for equipping pediatric primary outpatient centers with UDDs

Type of ultrasound device	Outpatient center	
	Head office, per 1000 population	Branch office, per 1000 population
Multipurpose pediatric UDD	<30 — 1 pc >30 — 2 pcs	<15 — 1 pc >15 — 2 pcs
Hand-held pediatric UDD	1 pc	1 pc
Special cardiovascular pediatric UDD	<50 — 1 pc >50 — 2 pcs	-

[5] Order of the Department of Health of Moscow No. 1043 dated September 15, 2020, "On Approval of the Model for Calculating the Need for Equipping Healthcare Facilities of the Public Healthcare System of Moscow with Ultrasound Devices". Available at: https://tele-med.ai/media/documents/Приказ_ДЗМ_1043_от_15.09.2020.pdf. Accessed on September 26, 2022.

[6] Order of the Ministry of Health and Social Development of the Russian Federation dated December 1, 2005, No. 753 "On Equipping Municipal Outpatient and Inpatient Care Facilities with Diagnostic Equipment". Available at: https://base.garant.ru/4182310/. Accessed on September 26, 2022.

Table 6. Comparison of examination types by types of UDD

Examination type	Hand-held	Multipurpose	Special*
Neurosonography (for pediatric outpatient centers)	+	+	-
Ultrasonography of superficial organs and structures	+	+	-
Transabdominal ultrasonography of the abdominal cavity, kidneys, retroperitoneal space, and pelvic organs	+	+	-
Ultrasonography of the pleural cavity	+	+	+
Echocardiography	+ (screening level)	+ (screening level)	+ (expert level)
Transcranial vascular ultrasonography	+ (screening level)	+ (screening level)	+ (expert level)
Vascular ultrasonography of the neck and upper and lower extremities	+ (screening level)	+ (screening level)	+ (expert level)
Intracavitary ultrasonography of pelvic organs	-	+	-

Note. * For cardiovascular ultrasonography.

Table 7. Approximate configuration of UDDs with a minimum range of probe frequencies

Type of device	Technical specifications	Outpatient center, head and branch offices	
		Adult	Pediatric
Special cardiovascular UDD	Linear probe, frequency range, MHz	3–10	5–12
	Curvilinear probe, frequency range, MHz	3–5	3–7
	Sector-phased array probe, frequency range, MHz	2–5	2–5
	Sector-phased array probe, frequency range, MHz	-	5–8
Hand-held UDD	Linear probe, frequency range, MHz	5–12	8–14
	Curvilinear probe, frequency range, MHz	3–5	3–7
	Sector-phased array probe, frequency range, MHz	2–4	2–4
	Sector-phased array probe, frequency range, MHz	-	5–8
Multipurpose UDD	Linear probe, frequency range, MHz	5–12	8–14
	Curvilinear probe, frequency range, MHz	2–5	3–7
	Intracavitary microconvex probe, frequency range, MHz	4–9	-
	Sector-phased array probe, frequency range, MHz	-	5–8
	Sector-phased array probe, frequency range, MHz	2–4	2–4

Note. ?????

Table 8. Estimated need for UDDs in an adult outpatient center

Parameters	Adult outpatient center X				
	Head office	Branch office No. 1	Branch office No. 2	Branch office No. 3	Total
Number of attended population	26 451	20 190	26 583	18 925	92 149
Number of UDDs required according to the Order of the Ministry of Health and Social Development of the Russian Federation No. 753 dated December 1, 2005					
Medical UDD	2	2	2	2	8
Hand-held	1	1	1	1	4
Number of UDDs required by the minimum equipment standard					
Multipurpose	2	1	1	1	5
Special	1	1	1	1	4
Hand-held	1	1	1	1	4

Note. UDD, ultrasound diagnostic device.

Table 9. Estimated need for UDDs in an pediatric outpatient center

Parameters	Pediatric outpatient center Y				
	Head office	Branch office No. 1	Branch office No. 2	Branch office No. 3	Total
Number of attended population	20 640	14 639	10 160	13 889	59 328
Number of UDDs required according to the Order of the Ministry of Health and Social Development of the Russian Federation No. 753 dated December 1, 2005					
Medical UDD	1	1	1	1	4
Number of UDDs required by the minimum equipment standard					
Multipurpose	2	1	1	1	5
Special	2	0	0	0	2
Hand-held	1	1	1	1	4

Note. UDD, ultrasound diagnostic device.

UDD, respectively. Each office should have one hand-held UDD, regardless of the size of the attended population, for low-mobility patients and examinations outside a healthcare facility.

Therefore, by the Order of the Ministry of Health and Social Development of the Russian Federation No. 753 dated 01.12.2005, 12 UDDs of two proposed types are needed to equip an adult outpatient center with one head office and three branches. The current minimum equipment standard recommends equipping such a center with 13 UDDs, which are divided by types and evenly distributed among branches.

The UDD need in a pediatric outpatient center was calculated similarly to the adult outpatient center.

Based on the size of the attended pediatric population (59,328), the number of devices was calculated. According to the minimum equipment standard (Table 5), the head office and branches (<15,000) should be provided with two multipurpose UDDs and two special cardiovascular UDDs, and one multipurpose UDD, respectively. For each office, one hand-held UDD is required, regardless of the size of the attended population.

Therefore, by the Order of the Ministry of Health and Social Development of the Russian Federation No. 753 dated December 1, 2005, for a pediatric outpatient center with one head office and three branches, only four UDDs of the same type are required. The current minimum equipment standard recommends equipping such a center with 11 UDDs, which are divided by types and evenly distributed among branches.

2. Let's consider equipping an adult and a pediatric outpatient center before and after implementing the minimum equipment standard proposed (Tables 10 and 11).

Table 10 shows the equipment for an adult outpatient center. In total, such a center is equipped with 22 stationary UDDs and two hand-held UDDs per attended population

Table 10. Comparison of UDD availability in an adult outpatient center

Parameters	Adult outpatient center A				
	Head office	Branch office No. 1	Branch office No. 2	Branch office No. 3	Total
Number of attended population	36 051	51 162	45 589	33 653	166 455
Number of UDDs available before equipping according to the minimum equipment standard					
Ultrasound imaging system	8	6	4	4	22
Hand-held ultrasound imaging system	1	0	0	1	2
Number of UDDs available after equipping according to the minimum equipment standard					
Multipurpose	2	2	1	1	6
Special	2	1	1	1	5
Hand-held	1	1	1	1	4

Note. UDD, ultrasound diagnostic device.

Table 11. Comparison of UDD availability in a pediatric outpatient center

Parameters	Pediatric outpatient center B				
	Head office	Branch office No. 1	Branch office No. 2	Branch office No. 3	Total
Number of attended population	14 357	17 931	18 346	13 663	64 297
Number of UDDs available before equipping according to the minimum equipment standard					
Ultrasound imaging system	4	3	2	2	11
Hand-held ultrasound imaging system	1	0	0	0	1
Number of UDDs available after equipping according to the minimum equipment standard					
Multipurpose pediatric	2	2	2	1	7
Special pediatric	2	0	0	0	2
Hand-held pediatric	1	1	1	1	4

Note. UDD, ultrasound diagnostic device.

(166,000). The analysis of the equipment utilization efficiency for 2019 shows that the average efficiency of the current UDD stock is 64%, which corresponds to a low level of efficiency. Therefore, the adult outpatient described in the example has some extra UDDs or lacks HCP wage rates to ensure the utilization of stationary UDDs 5 days a week in two shifts, based on the target equipment utilization rate[7]. According to the minimum standard of equipment, this center requires equipping with six multipurpose, five special, and four hand-held UDDs (total of 15 UDDs) and only 11 stationary UDDs, which require a smaller number of HCP wage rates for full and efficient utilization of the equipment.

Table 11 shows the equipment of a pediatric outpatient center. In total, such a center is equipped with 11 stationary UDDs and one hand-held UDD per attended population (64,000). The analysis of the equipment utilization efficiency for 2019 shows that the average efficiency of the current UDD stock is 91%, which corresponds to a high level of efficiency. According to the minimum equipment standard, this center requires seven multipurpose, two special and four hand-held UDDs (total of 13 UDDs).

Therefore, it is necessary to reduce the number of UDDs, re-equip centers, and distribute UDDs by types (Tables 10 and 11) to provide the attended adult and pediatric populations with all the necessary types of ultrasound examinations and increase the efficiency of the new equipment in accordance with international standards[8].

According to this paper, the outpatient ultrasound equipment standard is included in the database that defines the minimum requirements for equipping healthcare facilities with radiology and imaging equipment[9], approved and implemented by the Department of Health of Moscow.

CONCLUSION

The proposed minimum equipment standard for adult and pediatric outpatient centers contributes to improving the quality of diagnostics. The standard allows even distribution of equipment throughout the healthcare facility for better and more affordable primary medical care in the attended population in the corresponding outpatient center.

The standard is simple to apply because it classifies the equipment by types and describes the necessary equipment. Thus, the equipment required by the head office and branches of outpatient centers should be clarified in accordance with this standard to increase the availability of the necessary examinations to the attended population, reduce the waiting time, ensure reasonable equipment planning for a given period, reduce the shortage of necessary equipment (forecasting the future number of examinations),

[7] Explanatory Letter of the Primary Healthcare Office of the Department of Health of Moscow No. 41-18-54078/18 dated October 22, 2018. Available at: https://tele-med.ai/media/documents/tselevyye_pokazateli_zagruzki_tmt.pdf. Accessed on September 26, 2022.

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[9] Database no. 2022621124/19.05.22. S. P. Morozov, I. V. Soldatov, S. G. Kireyev, et al. Data determining the minimum requirements for equipping healthcare facilities with radiology and imaging equipment. Available at: https://www1.fips.ru/registers-doc-view/fips_servlet?DB=DB&DocNumber=2022621124&TypeFile=html. Accessed on September 26, 2022.

and expand the range of medical services provided to the local population. A state-of-art set of devices is necessary to obtain conclusive results of the examination of various organs and systems and minimize duplicate examinations at subsequent stages of the patient's journey.

The analysis of the outpatient center with a total attended population of 10 million people showed the adequacy of the proposed approach to provide high-quality ultrasound diagnostics. To estimate the economic effect, long-term observations are required because of the gradual replacement of equipment. However, the proposed solution does not reduce the availability of this category of examinations.

An algorithm for calculating the minimum equipment standard can be proposed for other regions of the Russian Federation to standardize the re-equipment of outpatient care facilities.

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AUTHORS' INFO

*** Sergei G. Kireev;**
address: Petrovka st. 24 Bld, 1, Moscow, 127051, Russia;
ORCID: https://orcid.org/0000-0002-3324-3733;
eLibrary SPIN: 3611-2336; e-mail: s.kireev@npcmr.ru

Natalia N. Vetsheva, MD, Dr. Sci. (Med.);
ORCID: https://orcid.org/0000-0002-9017-9432;
eLibrary SPIN: 9201-6146; e-mail: vetsheva@npcmr.ru

Ilya V. Soldatov;
ORCID: https://orcid.org/0000-0002-4867-0746;
eLibrary SPIN: 4065-6048; e-mail: i.soldatov@npcmr.ru

Zoya A. Lantukh;
ORCID: https://orcid.org/0000-0001-6623-9610;
eLibrary SPIN: 5486-6496; e-mail: z.lantukh@npcmr.ru

ОБ АВТОРАХ

*** Киреев Сергей Геннадьевич;**
адрес: Россия, 127051, Москва, ул. Петровка, д. 24, стр. 1;
ORCID: https://orcid.org/0000-0002-3324-3733;
eLibrary SPIN: 3611-2336; e-mail: s.kireev@npcmr.ru

Ветшева Наталья Николаевна, д.м.н.;
ORCID: https://orcid.org/0000-0002-9017-9432;
eLibrary SPIN: 9201-6146; e-mail: vetsheva@npcmr.ru

Солдатов Илья Владимирович;
ORCID: https://orcid.org/0000-0002-4867-0746;
eLibrary SPIN: 4065-6048; e-mail: i.soldatov@npcmr.ru

Лантух Зоя Александровна;
ORCID: https://orcid.org/0000-0001-6623-9610;
eLibrary SPIN: 5486-6496; e-mail: z.lantukh@npcmr.ru

* Corresponding author / Автор, ответственный за переписку

Anzhelika I. Gurevich, MD, Dr. Sci. (Med.);
ORCID: https://orcid.org/0000-0001-8187-214X;
eLibrary SPIN: 7641-1319; e-mail: gurevichai@yandex.ru

Anna N. Mukhortova;
ORCID: https://orcid.org/0000-0001-9814-3533;
eLibrary SPIN: 9051-1130; e-mail: a.mukhortova@npcmr.ru

Гуревич Анжелика Иосифовна, д.м.н.;
ORCID: https://orcid.org/0000-0001-8187-214X;
eLibrary SPIN: 7641-1319; e-mail: gurevichai@yandex.ru

Мухортова Анна Николаевна;
ORCID: https://orcid.org/0000-0001-9814-3533;
eLibrary SPIN: 9051-1130; e-mail: a.mukhortova@npcmr.ru

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Возможности и ограничения использования инструментов машинной обработки текстов в лучевой диагностике

Д.Ю. Кокина, В.А. Гомболевский, К.М. Арзамасов, А.Е. Андрейченко, С.П. Морозов

Научно-практический клинический центр диагностики и телемедицинских технологий, Москва, Российская Федерация

АННОТАЦИЯ

Обоснование. В радиологии важную информацию содержат не только медицинские изображения, но и сопровождающие их текстовые описания, создаваемые врачами-рентгенологами. Идентификация протоколов исследований, содержащих определённые данные, и извлечение этих данных может быть полезным в первую очередь для клинических задач, однако, учитывая большой объём таких данных, необходима разработка машинных алгоритмов анализа.

Цель — оценить возможности и ограничения использования инструментов машинной обработки текстов для поиска патологий в протоколах лучевых исследований.

Материалы и методы. Для создания первого прототипа алгоритма автоматического анализа протоколов были выбраны исследования молочных желёз (маммография) и органов грудной клетки (рентгенография, флюорография, компьютерная томография и низкодозная компьютерная томография), выполненные в лечебно-профилактических учреждениях Москвы, которые участвовали в эксперименте по использованию инновационных технологий в области компьютерного зрения для анализа медицинских изображений. Для каждого вида исследований был первоначально составлен словарь ключевых слов, соответствующий наличию или отсутствию целевых патологий. После первичной автоматической разметки протоколов разработанным инструментом производились выборочная оценка и валидация результатов врачом-рентгенологом. Количество протоколов, проанализированных врачом для обучения и валидации алгоритмов, составило 977 для маммографии, 3196 для рентгенографии, 1608 для флюорографии, 4074 для компьютерной и 398 для низкодозной компьютерной томографии органов грудной клетки. Для окончательного тестирования разработанных алгоритмов были дополнительно размечены тестовые датасеты из 1032 исследований для маммографии, 544 для флюорографии/рентгенографии, 5000 для компьютерной и 1082 для низкодозной компьютерной томографии органов грудной клетки.

Результаты. Наилучшие результаты достигнуты в поиске признаков вирусной пневмонии по протоколам компьютерной томографии органов грудной клетки (точность 0,996, чувствительность 0,998, специфичность 0,989) и рака молочной железы по протоколам маммографии (точность 1,0, чувствительность 1,0, специфичность 1,0). При поиске алгоритмом признаков рака лёгкого метрики получились следующими: точность 0,895, чувствительность 0,829, специфичность 0,936, а при поиске патологических изменений органов грудной клетки в протоколах рентгенографии и флюорографии точность составила 0,912, чувствительность — 1,000, специфичность — 0,844.

Заключение. Машинные методы с высокой точностью могут быть использованы с целью автоматической классификации текстов рентгенологических протоколов маммографии и компьютерной томографии органов грудной клетки для поиска вирусной пневмонии. Для поиска признаков рака лёгкого в модальности компьютерной и низкодозной компьютерной томографии, а также патологических изменений в протоколах рентгенографии и флюорографии органов грудной клетки достигнутой точности достаточно для успешного применения в целях автоматизированного сравнения работы врачей и моделей искусственного интеллекта.

Ключевые слова: протоколы рентгенологических исследований; COVID-19-пневмония; рак лёгкого; рак молочной железы; обработка естественного языка.

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Possibilities and limitations of using machine text-processing tools in Russian radiology reports

Daria.Yu. Kokina, Victor A. Gombolevskiy, Kirill M. Arzamasov, Anna E. Andreychenko, Sergey P. Morozov

Research and Practical Clinical Center for Diagnostics and Telemedicine Technologies, Moscow, Russian Federation

ABSTRACT

BACKGROUND: In radiology, important information can be found not only in medical images, but also in the accompanying text descriptions created by radiologists. Identification of study protocols containing certain data and extraction of these data can be useful primarily for clinical problems; however, given the large amount of such data, the development of machine analysis algorithms is necessary.

AIM: To estimate the possibilities and limitations of using a tool for machine processing of radiology reports to search for pathological findings.

MATERIALS AND METHODS: To create an algorithm for automatic analysis of radiology reports, use cases were selected that participated in the experiment on the use of innovative technologies in the computer vision for the analysis of medical images in 2020. Mammography, chest X-ray, chest computed tomography (CT), and LDCT, were among the use cases performed in Moscow. A dictionary of keywords has been compiled. After the automatic marking of the reports by the developed tool, the results were assessed by a radiologist. The number of protocols analyzed by the radiologist for training and validation of the algorithms was 977 for mammography, 4,804 for all chest X-ray scans, 4,074 for chest CT, and 398 for chest LDCT. For the final testing of the developed algorithms, test datasets of 1,032 studies for mammography, 544 for chest X-ray, 5,000 for CT of the chest, and 1,082 studies for the LDCT of the chest were additionally labeled.

RESULTS: The best results were achieved in the search for viral pneumonia in chest CT reports (accuracy 0.996, sensitivity 0.998, and specificity 0.989) and breast cancer in mammography reports (accuracy 1.0, sensitivity 1.0, and specificity 1.0). When searching for signs of lung cancer by the algorithm, the metrics were as follows: accuracy 0.895, sensitivity 0.829, and specificity 0.936, when searching for pathological changes in the chest organs in radiography and fluorography protocols (accuracy 0.912, sensitivity 1.000, and specificity 0.844).

CONCLUSIONS: Machine methods with high accuracy can be used to automatically classify the radiology reports of mammography and chest CT with viral pneumonia. The achieved accuracy is sufficient for successful application to automatically compare the conclusions of physicians and artificial intelligence models when searching for signs of lung cancer in chest CT and LDCT, pathological findings in chest X-ray.

Keywords: radiology reports, COVID-19 pneumonia, lung cancer, breast cancer, natural language processing

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在辐射诊断中使用文本机床的可能性和局限性

Daria.Yu. Kokina, Victor A. Gombolevskiy, Kirill M. Arzamasov, Anna E. Andreychenko, Sergey P. Morozov

Research and Practical Clinical Center for Diagnostics and Telemedicine Technologies, Moscow, Russian Federation

简评

论证。在放射学中，重要信息不仅包括在医学图像中，还包括在放射科医生创建的随附文本描述中。包含某些数据的研究方案的识别和这些数据的提取首先可能对临床问题有用，但是，鉴于大量此类数据，机器分析算法的开发是必要的。

研究目的是评估使用文本处理工具在放射学协议中搜索病理的可能性和局限性。

材料与方法。为了创建自动协议分析算法的第一个原型，选择了参与使用计算机视觉领域的创新技术进行医学图像分析的实验的研究。这些研究包括在莫斯科医疗机构进行的乳房X光检查、胸部X光摄影、胸部X线间接照相、胸部CT和LDCT。对于每种类型的研究，最初都编制了一个关键词词典，对应于目标病理学的存在与否。在使用开发的工具对协议进行初始自动标记之后，放射科医生对结果进行了选择性评估和验证。医生为训练和验证算法而分析的协议数量为977个乳房X线照相术、3196个射线照相术、1608个荧光照相术、4074个胸部CT和398个胸部LDCT。为了对开发的算法进行最终测试，额外标记了1032项乳房 X线照相术研究、544项荧光照相/射线照相术、5000项胸部CT研究和1082项胸部LDCT研究的测试数据集。

结果。最好结果是根据胸部CT协议（精确度0.996，灵敏度0.998，特异性0.989）和乳房X光检查协议（精确度1.0，灵敏度1.0，特异性1.0）分别在寻找病毒性肺炎迹象和寻找乳腺癌迹象的方面取得的。当通过该算法搜索肺癌征兆时，指标如下：精确度0.895，灵敏度0.829，特异性0.936，以及在射线照相和荧光照相术协议中搜索胸部器官的病理变化时为精确度0.912，灵敏度1.000，特异性0.844。

结论。机器方法可用于乳腺X线检查和胸部CT检查文本的自动分类，以寻找病毒性肺炎。在胸部CT和LDCT模式中寻找肺癌征象，在胸部X线摄影和荧光摄影协议中寻找病理变化，所达到的准确性足以成功应用于医生和人工智能模型工作的自动比较。

关键词：X射线协议；COVID-19肺炎；肺癌；乳腺癌；自然语言处理。

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BACKGROUND

Radiology reports contain textual medical information, including a preliminary diagnosis, clinical data, descriptive characteristics of changes in organs and systems examined a radiologic diagnosis or a conclusion, and follow-up recommendations [1, 2]. This information can be used in complex diagnostics and treatment, outcome prediction, and condition monitoring and for organizational, statistical, or research purposes.

Radiology protocols have several features, including various narrative styles, using telegraphic speech, lexical and terminological variations, various word orders, abbreviations, and acronyms [3]. Special mention should be made of a characteristic of any medical information, such as the use of terminology, which is often impossible to be assessed by a person without special education. Russian protocols have also several specific properties, such as less strict syntax and lexical diversity. Radiologists use nonstandard abbreviations, complex grammatical constructions, long and difficult-to-interpret phrases, and various options to denote negation [4]. Lexical variations are typical for radiology in general; however, in Russian radiology, this diversity is even wider (e.g., "shadow" can be described as "shading," "infiltrate," "area of reduced transparency," "area of increased density," "area of reduced airiness," "focus," "compaction," and various other options even for this group of changes alone). On the contrary, in English radiology, such variability is regulated by rules, recommendations, etc. Therefore, radiology reports contain a lot of textual, unstructured, and specialized information, which poses some difficulties when using exclusively automated methods.

Studies have focused on assessing the current use of natural language processing (NLP) tools for structuring and standardizing reports, highlighting the information necessary for clinical specialists, ensuring the automatic replacement of specific terminology, and including the use of patient-friendly language, more understandable vocabulary, or translation of information into other languages [1, 2]. Identifying reports containing certain data to extract can be useful for solving clinical issues [1]. Some studies have proposed ways to identify reports describing the musculoskeletal system with signs of bone fractures, computed tomography (CT) signs of pulmonary embolism, pulmonary nodules, etc. [3, 5, 6].

An algorithm for machine processing of Russian reports must be developed for the use and analysis of large amounts of data to evaluate and describe medical images and prepare conclusions.

The purpose of the study was to evaluate the opportunities and limitations of using text-processing tools to search for various abnormalities in radiology reports.

MATERIALS AND METHODS

Development of a tool for evaluating text in radiology reports

This study was performed as part of a study previously approved by the ethics committee (Extract from Protocol No. 2 of the Independent Ethics Committee of the Moscow Regional Branch of the Russian Society of Roentgenologists and Radiologists [RSRR] dated February 20, 2020, Clinical trials Registration ID: NCT04489992).

The tool for evaluating text radiology protocols was developed as part of the Moscow experiment on the use of innovative computer vision technologies to analyze medical images and compare the results of assessing medical images for abnormalities by artificial intelligence (AI) services and radiologists.

Mammography, chest radiography and fluorography, CT, and low-dose CT (LDCT) reports were evaluated. All findings were obtained from healthcare facilities of the Department of Health of Moscow in 2020. Anonymized radiology reports were used.

The main purpose was to create an automated algorithm for the automatic analysis of radiography reports for abnormal changes of interest. The target abnormality selection and corresponding glossary development were based on the general requirements for AI data (https://mosmed.ai/).

For chest radiography and fluorography, target abnormalities included pleural effusion, pneumothorax, atelectasis, lesion, infiltration/consolidation, dissemination, cavity with degradation or fluid, calcification, and non-integrity of the cortical layer (fracture). For CT and LDCT, target abnormalities included solid and subsolid nodules larger than 100 mm^3. For chest CT, another group of abnormalities included changes that correlated with signs of coronavirus disease 2019 (COVID-19). The classification by severity was used according to the interim guidelines "Prevention, Diagnosis, and Treatment of a New Coronavirus Infection (COVID-19)" of the Ministry of Health of the Russian Federation and guidelines of the State Budgetary Healthcare Institution "Scientific and Practical Clinical Center for Diagnostics and Telemedicine Technologies of the Department of Health of Moscow" and "Radiology Diagnostics of Coronavirus Disease (COVID-19): Organization, Methodology, Interpretation" [7, 8]. Mammography was performed using the breast imaging reporting and data system (BI-RADS) 3–6 system for analyzing and recording results of breast imaging [9].

Software and hardware solutions for pre-labeling text reports

Software and hardware solutions have been developed for pre-labeling text reports for each type of examination based on NLP methods in combination with the expert opinion of radiologists. Pre-labeling algorithms were developed iteratively with several milestones for each modality.

1. A primary set of key features was defined to search for indications of certain abnormalities. Among others, keywords and phrases, size designations and, if necessary, stop words and phrases were considered. The primary set of keywords compiled by a radiologist included the generally accepted and most frequently used terms by radiologists. Stop words included non-target

abnormalities or non-abnormal findings, such as changes in other organs in the scan area and anatomical variations.
2. Those feature sets were translated into machine language using the high-level programming language Python.

In this study, Python 3.8 was used with pandas libraries = 1.1.3, numpy = 1.19.2, re = 2.2.1, and nltk = 3.5. The input program data are text reports in tabular formats (.csv, .xlsx) containing both the examination description and conclusion. The results are presented with the initial data labeled "0" or "1," where "0" means the absence of a symptom/abnormality, and "1" means the presence of a symptom/abnormality.

The module for searching for COVID-19 signs using textual chest CT conclusions is based on NLP methods and a classifier from the family of machine-learning algorithms. The output indicates the presence or absence of COVID-19 signs and CT degree of lung damage.

The module for searching for breast cancer signs in mammography reports with conclusion and description detects breast cancer signs according to the BI-RADS classification, giving the BI-RADS class and binary classification (like the screening scale) as a response. The requirements for mammography result description define the mandatory classification of examinations according to the BI-RADS scale. On the contrary, BI-RADS 1 spelling has numerous variants. HCPs may use different cases, punctuations, and, most importantly, layouts. Thus, text parsing is not always effective, leading to false omissions. For this task, the purpose of NLP is limited to extracting information.

The module for searching for lung cancer signs according to text chest CT/LDCT reports (with description and conclusion) identifies cancer signs using a combination of keywords (keys) and parameters (sizes) and is based on NLP.

The module for searching for various abnormal signs in text description and conclusion for chest radiography and fluorography identifies abnormal signs according to the keyword glossary ("sign RG/FLG": "keyword1," "keyword2," "keyword3"...).

3. Report labeling by the pre-labeling program created in Step 2.
4. Selection of unique diverse reports (by abnormalities) using a formatted sample in Step 3. In this study, we had several opportunities to prove that radiologists use template formulations. Training NLP algorithms using template formulations will allow quick retraining of the model. We shall ensure the widest possible implementation of the proposed algorithm to enrich the training data set with different rare (unique) formulations.
5. Manual verification of machine labeling and estimated accuracy of the pre-labeling algorithm. Machine labeling accuracy was evaluated as the percentage of correctly labeled protocols. Manual verification was conducted many times for each task by radiologists.
6. A list of adjustments was labeled, including additional stop words and phrases, keywords, and other recommendations to improve the quality of the pre-labeling program.
7. Adding verified protocols to the database.

In this step, diverse, unique, and formatted samples were formed while maintaining the class balance. When forming the study samples, the sizes are given below. All examinations were considered for a limited period (January 2019–August 2020). The class balance corresponded to that of the general population. The expected abnormality distribution was as follows: CT for COVID-19, 20% normal, 80% abnormal; mammography, 95% normal, 5% abnormal; fluorography, 95% normal, 5% abnormal; chest radiography, 75% normal, 25% abnormal.

Steps 2–7 were repeated iteratively until the pre-labeling program is 98% accurate. This value was chosen based on the maximum accuracy level of NLP for individual clinical problems found in the analysis of medical literature, which was 97% [10].

In total, during the development of pre-labeling algorithms, the radiologist analyzed 977 reports for mammography, 3196 for radiography, 1608 for fluorography, 4074 for chest CT, and 398 for chest LDCT. The study included all examination reports that were sent to AI services as part of an experiment on the use of innovative computer vision technologies for the analysis of medical images and further implementation in the healthcare system of Moscow (https://mosmed.ai/). Only reports with incomplete description and conclusion were excluded.

To improve the quality and speed up the automatic labeling of text protocols, machine-learning methods were used to consider the complex semantic structures of sentences in the reports to search for signs of COVID-19 pneumonia according to CT data. In the future, intelligent algorithms should be developed to search for abnormal signs in mammography, CT (for lung cancer), fluorography, and radiography reports.

The module for processing COVID-19 CT reports was designed for three functions: (1) search for conclusions in input data using an already labeled report database, (2) labeling of the remaining reports using a regular expression, and (3) labeling of the remaining reports using k-nearest neighbor (kNN) models. These functions were implemented sequentially. When developing this tool, one of the conditions was performance optimization. Earlier, we mentioned the frequent use of template expressions in reports prepared by radiologists. Thus, most of the COVID-19 CT reports have the same form. In addition, a team of authors initiated manual labeling of chest CT reports with COVID-19 as the target pathology. This simplifies and speeds up the algorithm through the use of a simple logical comparison function, allowing the protocol to be compared with those available in the database. Some reports that are not included in the database of previously labeled examinations remain; hence, a much slower function of text analysis using regular expressions is launched. If there are protocols for which

the regular expression does not find the target pattern, the machine-learning model based on the kNN is launched.

The architecture developed has an optimal combination of speed and accuracy compared with the use of machine-learning alone. Without machine-learning, it was impossible to cover all the reports. The training sample included 4,074 pre-labeled protocols. Such a number of reports was necessary to ensure the required level of accuracy and was obtained in several iterations of model testing and retraining. For the functioning of this module, the Sklearn library (Scikit-learn) was also imported. The trained algorithm was evaluated on a test set and showed high accuracy (99.6%).

RESULTS

A list of keywords and stop words was developed for the selected modalities and abnormalities, considering some special characteristics of reports. Based on Moscow reports, the best results based on the developed glossary were achieved in the search for signs of COVID-19 in pneumonia chest CT reports with an accuracy of 0.996, sensitivity of 0.998, and specificity of 0.989 (true negative [TN]* = 1115; false positive [FP]** = 6; false negative [FN]# = 2; true positive [TP]## = 3,837) and breast cancer mammography with an accuracy of 1.0, sensitivity of 1.0, and specificity of 1.0 (TN = 461; FP = 0; FN = 0; TP = 571). When looking for lung cancer signs in chest CT and LDCT, the following parameters were obtained: accuracy, 0.895; sensitivity, 0.829; specificity, 0.936 (TN = 619; FP = 42; FN = 72; TP = 349). When looking for abnormal changes in chest radiography and fluorography, the above-mentioned parameters were 0.912; 1.000, and 0.844, respectively (TN = 259; FP = 48; FN = 0; TP = 237).

*TN: prediction of negative class as a negative class (number), the true value is 1, and prediction is 1.

**FP: prediction of a negative class as a positive class (number), the true value is 1, and prediction is 0.

#FN: prediction of a positive class as a negative class (number), the true value is 0, and prediction is 1.

##TP: prediction of a positive class as a positive class (number), the true value is 0, and prediction is 0.

DISCUSSION

Mammography glossary

A mammography glossary was the simplest to compile and use because of state-of-art standardized protocols. Mammography reports are the most structured ones. They require BI-RADS and are subject to control because of the high significance of the detected pathology. In most cases, the BI-RADS category is indicated in the conclusion, and changes to set the category are presented in the description. The presence of BI-RADS categories in the glossary ensures achieving a high accuracy of 1.0 in the automated processing of reports. This tool can be used in other regions of the Russian Federation, if required, for example, for reports of a different structure. Moreover, adding key defining words ("tumor" and "c-r") is possible.

Tool limitations may be associated with the absence of the BI-RADS category in the report; such protocols often contain information about the impossibility of assessing the condition of the mammary glands because of inadequate image quality or other reasons. Since such examinations are classified into a separate group, their targeted search is possible, for example, for quality control and selection of patients requiring additional examination. The proposed tool, subject to further improvement, can be used for other purposes, for example, assessment of the compliance of the report with the standard and comparison of the description and conclusion for audit purposes.

Glossary for COVID-19 pneumonia findings by severity

High levels of accuracy were also achieved when using the tool to analyze COVID-19 pneumonia findings by severity, which is also related to the structure of reports and unambiguity of the compiled glossary. The glossary used is based on standard grades: RT0 = no evidence of viral pneumonia; RT1–RT4 = mild-to-critical viral pneumonia; and OTHER = other changes not associated with viral pneumonia. During the pandemic, reports contained information about the absence or presence of viral pneumonia signs, degree of spread associated with the severity, and, in most cases, likelihood of viral pneumonia. Provided that certain parameters are met, the text conclusion and glossary based on the degree of spelling variations are sufficient for the severity assessment. In most cases, the descriptive parts of the reports have common features and common terminology.

Despite the common features of most protocols, slight variations are present in the conclusions, which are associated with various construction options, terminology, spelling, punctuation, lexical features of the HCP language, and personal experience with CT. Sometimes, diagnostic inaccuracies were associated with the CT features of viral pneumonia. If the describing physician believes that changes such as frosted glass, reticular striation, etc., may correspond to other diseases, or there is comorbidity, the protocol and conclusion may contain sentences that are atypical in construction and terminology. In these situations, there may be uncertainty in the tool operation, which allows focusing on such examinations, conducting a targeted audit, identifying inaccuracies in the terminology use, and using it for clinical purposes to identify comorbidities that require special attention and need further monitoring. Different classifications and protocols can be used for describing viral pneumonia in different regions and healthcare facilities.

Glossary for looking up lung cancer signs

Developing keywords and stop words to search for lung cancer signs in chest CT and LDCT reports is difficult;

thus, the algorithm was less accurate. LDCT protocols use the Lung-RADS classification, and its use could simplify searching for suspicious nodes as much as possible [11]. However, when analyzing Moscow findings, the search for Lung-RADS categories does not allow the thorough evaluation of available protocols because not all reports contain such a category in the conclusion. In addition, 8.3% of the reports contain discrepancies between the description and the conclusion [12].

The development of a glossary for searching for signs of various lung nodules and neoplasms is still an urgent task and is associated with several issues and limitations. Despite the use of templates and methodological recommendations for the description, chest CT and LDCT reports have quite a variety of options for structures and sequences. Many radiologists do not use the standard recommended terminology (e.g., 4-mm nodules are denoted by the term "mass"), which leads to the misuse of terms [13].

Based on current recommendations and required terminology, keywords were used to search for suspicious changes, corresponding to solid lung nodules/foci and masses >6 mm (lesions >3 cm) [10–12]. These criteria have several limitations, which can lead to FP or FN algorithm results. Thus, when performing a chest CT, randomly found solid lung nodules are proposed to be evaluated using the Fleischner recommendations. However, their use requires assessing personal and clinical information, risk factors, comorbidities, including neoplasms [14].

The use of the size criterion and main set of keywords made it impossible to completely exclude benign changes. For example, to exclude benign nodes with structural calcification, its distribution, which is often not specified in reports, should be considered. Moreover, calcifications can be described in the cancer structure. Large foci can be described by HCPs as part of the description of other diseases such as tuberculosis, sarcoidosis, and bronchiolitis of various etiologies.

To compare protocol data and results of AI processing, the capabilities of current algorithms are adequate. After further improvement ensuring increased accuracy, this tool can be used in other regions, including for developing another useful tool for different tasks.

The modified tool can be used to create a more accurate algorithm considering necessary risk factors, such as the presence of immunodeficiency, inflammatory processes, clinical information, and referral diagnosis. This improvement may be important when evaluating lung nodules in patients with cancer. Cancer information can be obtained from the description of the report and in electronic medical records. It could also be promising to use the tool for estimating changes in nodule size and comparing findings with recommendations for the management of pulmonary nodules to improve tool functions in accordance with improving computer vision models.

For chest CT, some special limitations are notable, which are associated with a wide and difficult-to-cover list of "stop" words. This is related to the examination characteristics: the scan area includes the abdomen, neck, and other chest organs. For most organs (e.g., thyroid, liver, kidneys, and adrenal glands), such "stop" words include names of such organs. However, anatomical chest structures such as the mediastinum, pericardium, ribs and thoracic vertebrae, soft tissues of the chest wall, and diaphragm cannot be used as independent "stop" words because of cases when lung neoplasms have invasive growth and affect adjacent tissues, which is described by radiologists as a summary ("mass extending into the mediastinum"). Moreover, various independent neoplasms of the listed organs and anatomical structures are often revealed, which leads to many FP algorithm results.

Glossary of keywords for chest radiography and fluorography

The development and use of such a tool for chest radiography and fluorography are challenging. Radiography and fluorography reports have many variations in form, structure, size, and characteristics used, while the terminology varies significantly [15, 16].

In addition to the generally accepted terms for abnormalities, the proposed glossary of keywords for chest radiography and fluorography included specific radiological terms such as "darkening," "focus," and "shadow." This leads to several issues because such terms can be used for non-target abnormalities or anatomical structures ("rib shadow") and additional medical devices ("pacemaker shadow" and "drainage tube shadow").

To define the pathology according to the binary classification (normal/abnormal) considering the listed issues, the high accuracy of radiology examination is required. However, it is necessary to classify abnormalities (e.g., effusion, pneumothorax, atelectasis, and focus), even if radiologists consider it to be findings difficult to classify by groups, which is also associated with the limitations of radiography. In addition, the same keywords are used to refer to completely different radiological findings.

When developing stop words, different variants of normal spellings were considered using various lexical and syntactic variants of negation ("no shadows the in lungs," "no abnormal shadow effects in the lungs," etc.). As new data become available, the glossary shall be constantly updated. Current accuracy indicators for this type of diagnostics allow us to solve the main problem of comparing the results of AI models and HCP findings.

CONCLUSION

With high accuracy achieved, machine-learning methods can be used to automatically classify the texts

of mammography and chest CT reports to search for viral pneumonia signs because of the structured and standardized description of findings.

When searching for lung cancer signs in chest CT and LDCT reports and abnormal changes in chest radiography and fluorography reports, the achieved accuracy is adequate for the successful use of the tool to automatically compare HCP and AI findings in radiology departments. Less accuracy is related to the less strict structure of reports and their diagnostic, lexical, and terminological features.

ADDITIONAL INFORMATION

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AUTHORS' INFO

*** Daria Yu. Kokina;**
address: 24-1 Petrovka str., 127051, Moscow, Russia;
ORCID: https://orcid.org/0000-0002-1141-8395;
eLibrary SPIN: 9883-4656; e-mail: d.kokina@npcmr.ru

Victor A. Gombolevskiy, MD, Cand. Sci. (Med.);
ORCID: https://orcid.org/0000-0003-1816-1315;
eLibrary SPIN: 6810-3279; e-mail: g_victor@mail.ru

Kirill M. Arzamasov, MD, Cand. Sci. (Med.);
ORCID: http://orcid.org/0000-0001-7786-0349;
eLibrary SPIN: 3160-8062; e-mail: k.arzamasov@npcmr.ru

Anna E. Andreychenko, Cand. Sci. (Phys.-Math.);
ORCID: https://orcid.org/0000-0001-6359-0763;
eLibrary SPIN: 6625-4186; e-mail: a.andreychenko@npcmr.ru

Sergey P. Morozov, MD, Dr. Sci. (Med.), Professor;
ORCID: https://orcid.org/0000-0001-6545-6170;
eLibrary SPIN: 8542-1720; e-mail: spmoroz@gmail.com

ОБ АВТОРАХ

*** Кокина Дарья Юрьевна;**
адрес: Россия, 127051, Москва, ул. Петровка, д. 24, стр. 1;
ORCID: https://orcid.org/0000-0002-1141-8395;
eLibrary SPIN: 9883-4656; e-mail: d.kokina@npcmr.ru

Гомболевский Виктор Александрович, к.м.н.;
ORCID: https://orcid.org/0000-0003-1816-1315;
eLibrary SPIN: 6810-3279; e-mail: g_victor@mail.ru

Арзамасов Кирилл Михайлович, к.м.н.;
ORCID: http://orcid.org/0000-0001-7786-0349;
eLibrary SPIN: 3160-8062; e-mail: k.arzamasov@npcmr.ru

Андрейченко Анна Евгеньевна, канд. физ.-мат. наук;
ORCID: https://orcid.org/0000-0001-6359-0763;
eLibrary SPIN: 6625-4186; e-mail: a.andreychenko@npcmr.ru

Морозов Сергей Павлович, д.м.н., профессор;
ORCID: https://orcid.org/0000-0001-6545-6170;
eLibrary SPIN: 8542-1720; e-mail: spmoroz@gmail.com

* Corresponding author / Автор, ответственный за переписку

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Редкая локализация аваскулярного некроза при лечении новой коронавирусной инфекции глюкокортикостероидами

А.П. Гончар[1], И.А. Блохин[1], Ю.Ф. Шумская[1, 2]

[1] Научно-практический клинический центр диагностики и телемедицинских технологий, Москва, Российская Федерация
[2] Первый Московский государственный медицинский университет имени И.М. Сеченова (Сеченовский Университет), Москва, Российская Федерация

АННОТАЦИЯ

Развитие аваскулярного некроза костных структур, индуцированного лечением новой коронавирусной инфекции глюкокортикоидами, является довольно распространённым осложнением терапии, при этом чаще всего встречается поражение головок бедренных костей. Своевременное выявление аваскулярного некроза важно в рамках профилактики развития артритов и других осложнений.

В работе представлен клинический случай пациентки в возрасте 54 лет, госпитализированной по поводу новой коронавирусной инфекции, с жалобами на выраженные боли в обоих коленных суставах через 2 недели от начала болезни. По результатам магнитно-резонансной томографии был выявлен выраженный аваскулярный некроз костей, формирующих коленный сустав, с обеих сторон. Консервативная терапия, включающая приём нестероидных противовоспалительных препаратов и ингибиторов костной резорбции из группы бисфосфонатов, дала выраженный положительный результат. При повторном осмотре через 3 месяца болей нет, сохраняются небольшие ограничения движений в коленных суставах. По данным магнитно-резонансной томографии обоих коленных суставов отмечено значительное уменьшение ранее выявленных изменений.

Побочные эффекты глюкокортикоидов (нарушение толерантности к глюкозе, повышение артериального давления, тахикардия, эрозивно-язвенное поражение желудочно-кишечного тракта, нарушения сна и др.) широко известны, однако остеонекроз костных структур коленных суставов, вызванный приёмом стероидов, редко попадает в поле зрения клиницистов. Приведённый клинический случай подчёркивает комплексный характер патогенеза остеонекроза и демонстрирует широкий спектр осложнений при терапии кортикостероидами.

Ключевые слова: клинический случай; аваскулярный некроз; остеонекроз; коронавирусная инфекция; коленный сустав; магнитно-резонансная томография.

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Rare localization of avascular necrosis during treatment of COVID-19 with glucocorticosteroids

Anna P. Gonchar[1], Ivan A. Blokhin[1], Yuliya F. Shumskaya[1, 2]

[1] Research and Practical Clinical Center for Diagnostics and Telemedicine Technologies, Moscow, Russian Federation
[2] The First Sechenov Moscow State Medical University (Sechenov University), Moscow, Russian Federation

ABSTRACT

The development of bony avascular necrosis induced by glucocorticoid treatment of COVID-19 is a common adverse effect, with femoral head being the most commonly affected. Timely detection of avascular necrosis is important in the prevention of osteoarthrosis and other complications.

We present a clinical case of a 54-year-old patient hospitalized for novel coronavirus infection with complaints of severe pain in both knees 2 weeks after the disease onset. Magnetic resonance imaging revealed pronounced changes in both knees, corresponding to avascular necrosis. The results of conservative therapy, including non-steroidal anti-inflammatory drugs and bisphosphonate bone resorption inhibitors, produced a pronounced positive result. At follow-up examination 3 months later, there was no pain, but the knee joints still had slight restrictions of movement. Magnetic resonance imaging showed a significant decrease in the previously detected changes.

The side effects of glucocorticoids (impaired glucose tolerance, increased blood pressure, tachycardia, gastrointestinal erosive ulcers, sleep disorders, etc.) are widely known, but knee osteonecrosis caused by steroid intake rarely comes to the attention of clinicians. This clinical case emphasizes the complex nature of osteonecrosis pathogenesis and demonstrates a wide range of complications in corticosteroid therapy.

Keywords: case report; avascular necrosis; osteonecrosis; COVID-19; knee joint; magnetic resonance imaging.

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糖皮质激素治疗新型冠状病毒感染罕见局限性缺血性坏死

Anna P. Gonchar[1], Ivan A. Blokhin[1], Yuliya F. Shumskaya[1, 2]

[1] Research and Practical Clinical Center for Diagnostics and Telemedicine Technologies, Moscow, Russian Federation
[2] The First Sechenov Moscow State Medical University (Sechenov University), Moscow, Russian Federation

简评

糖皮质激素治疗新型冠状病毒感染引起的骨结构缺血性坏死是一种相当常见的治疗并发症，其中最常见的是股骨头病变。对于预防关节炎和其他并发症，及时检测缺血性坏死是很重要的。

这项研究展示了一名54岁的患者的临床案例，她因新冠状病毒感染住院，并在发病后两周内抱怨双膝关节疼痛。磁共振成像扫描显示，形成膝关节的骨骼在两侧都有明显的血管性坏死。使用非甾体抗炎药和双磷酸盐骨吸收抑制剂的保守治疗有显著的积极效果。3个月后复查时，没有疼痛，但膝关节的活动仍有轻微限制。两个膝关节的磁共振成像显示，先前确定的变化明显减少。

糖皮质激素的副作用（糖耐量受损、血压升高、心动过速、胃肠道侵蚀性溃疡、睡眠障碍等）广为人知，但由类固醇引起的膝关节骨结构的骨坏死却很少引起临床医生的注意。这个临床病例强调了骨坏死发病机制的复杂性，并展示了皮质类固醇治疗的广泛并发症。

关键词：临床病例；缺血性坏死；骨坏死；冠状病毒感染；膝关节；磁共振成像。

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BACKGROUND

The novel coronavirus infection, discovered in Wuhan, China, in December 2019, has triggered a global pandemic. The use of glucocorticosteroids (GCSs) to treat novel coronavirus infection is pathogenetically justified and widespread [1]. However, even a single dose of GCS can cause the development of avascular necrosis [2]. The literature describes several clinical cases of femoral head avascular necrosis in patients treated with GCS [3, 4]. However, the cases of osteonecrosis in other areas, particularly the knee joints, are mentioned much less frequently [5]. Early diagnosis of this pathology is critical for preventing arthritis and other complications [6].

This paper describes a clinical case of avascular necrosis of the bone structures of both knee joints that developed while treating coronavirus infection with GCS.

CLINICAL CASE

Patient

A 54-year-old woman with complaints of severe cough and fever up to 39.5 °C for 6 days was hospitalized with the novel coronavirus infection. A chest CT revealed lung damage of >30%. The PCR test for SARS-CoV-2 RNA was positive. The medical history was insignificant.

During the hospital stay, the patient received parenteral dexamethasone at a daily dose of 20 mg for 5 days, followed by a 2-day break and subsequent reintroduction of dexamethasone at a daily dose of 12 mg for 5 days. Additionally, the patient received anticoagulant and antisecretory therapy.

On Day 15 of the disease, the patient experienced severe pain and substantial limitation of knee joint movement, which persisted at night. The knee joints were nontender on palpation. On Day 17 of the disease, the patient was discharged because of positive changes. Nonsteroidal anti-inflammatory drugs (NSAIDs) were recommended for treating knee joint pain.

Magnetic resonance imaging (MRI) of both knee joints was performed 1.5 months after hospitalization due to persistent pain and limited movement in the knee joints.

Instrumental findings

MRI of the left knee joint: lesions in the distal parts of the femoral diaphysis and femoral condyles (with involvement of the articular surface) as well as in the patella, inhomogeneously hyperintense on PD-weighted (proton-weighted) images with fat suppression and hypo-/isointense on T1-weighted images (T1WI), with an irregular ("geographic") shape and yellow marrow signal areas visualized in the central parts (Fig. 1). MRI of the right knee joint: similar lesions of the bone marrow of both femoral condyles, with involvement of the distal metaepiphysis and articular surface of the lateral condyle as well as the patella. A perilesional "double line" sign is visualized over a short distance for some lesions (Fig. 2).

The following diagnosis was made on the basis of medical history and identified MRI changes: "Avascular necrosis of the bone structures of both knee joints."

Diagnosis and treatment

On the basis of MRI findings, medical history, and clinical pattern, the patient was diagnosed with avascular necrosis of the femoral and tibial condyles of both knee joints. Thus, the following conservative therapy (physiotherapy) was prescribed: magnet therapy and phonophoresis with NSAID-containing gel, NSAID therapy (tablets) for pain (as needed), vitamin D preparations, and bisphosphonate bone resorption inhibitors.

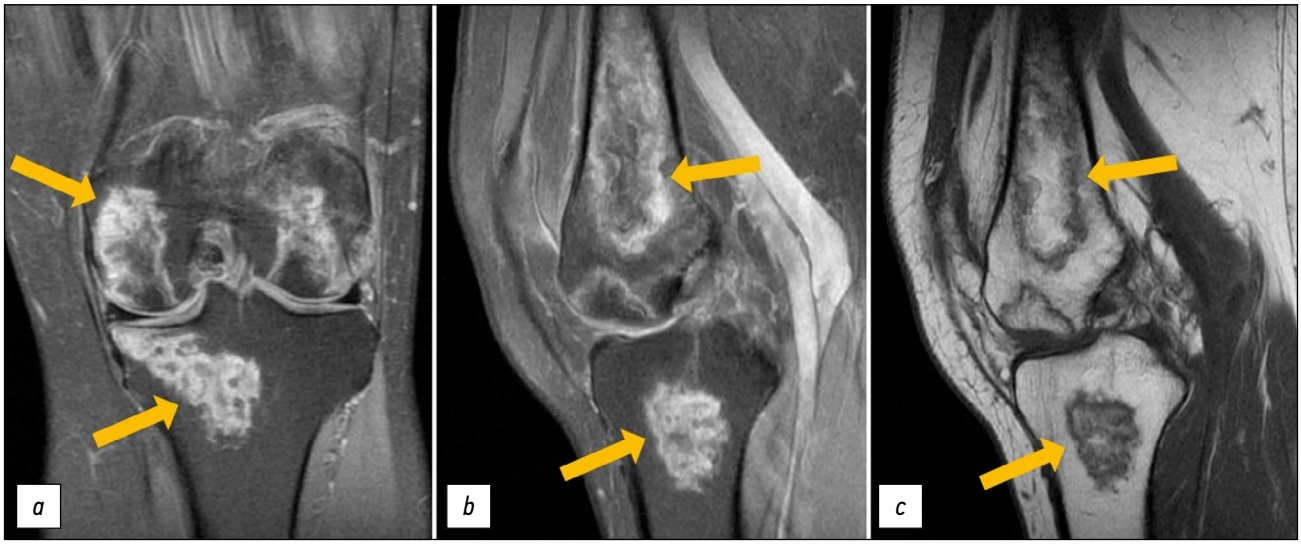

Fig. 1. Primary MRI of the left knee joint: PDWI with fat suppression in the coronal (*a*) and sagittal (*b*) plane and T1WI in the sagittal plane (*c*). The arrows indicate areas of bone marrow edema in the form of a heterogeneous, irregularly shaped ("geographic") MRI signal of femoral and tibial condyles.

The therapy resulted in substantial positive changes after 3 months: The pain had subsided, but some limitations in knee joint movement remained (the patient could not do a deep squat).

A follow-up MRI of both knee joints revealed positive changes: Previously identified lesions had become substantially less severe (Figs. 3 and 4).

DISCUSSION

The prevalence of osteonecrosis in patients with the novel coronavirus infection ranges from 5% to 58% [7]. Damage is more common to the femoral head than to the bone structures of the knee joints and other bones.

Secondary osteonecrosis of knee joint bone structures, particularly avascular necrosis, most commonly affects both femoral condyles, as in the clinical case presented here. Conversely, primary osteonecrosis affects only one of the condyles [8].

Avascular necrosis can develop as a result of GCS treatment, kidney disease, or hematological diseases. Some authors believe that drugs used to treat coronavirus infection, such as lopinavir and ritonavir, can contribute to the development of osteonecrosis [9]. In our case, this pathology most likely developed as a result of GCS treatment for coronavirus infection.

GCSs, which play an important role in treating novel coronavirus infection, are an independent risk factor for

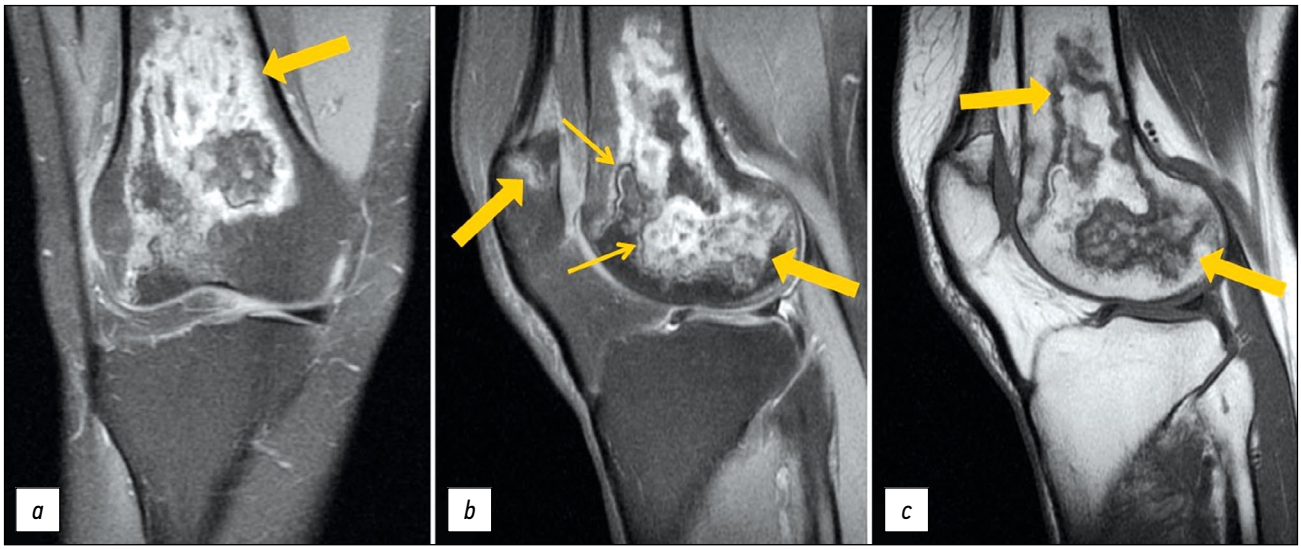

Fig. 2. Primary MRI of the right knee joint: PDWI with fat suppression in the coronal (*a*) and sagittal (*b*) plane and T1WI in the sagittal plane (*c*). Thick arrows indicate areas of bone marrow edema in the form of a heterogeneous, irregularly shaped ("geographic") MRI signal of femoral condyles and patella; thin arrows indicate the "double line" sign in the form of internal hyperintense (granulation tissue) and external hypointense (osteosclerosis) lines on PDWI.

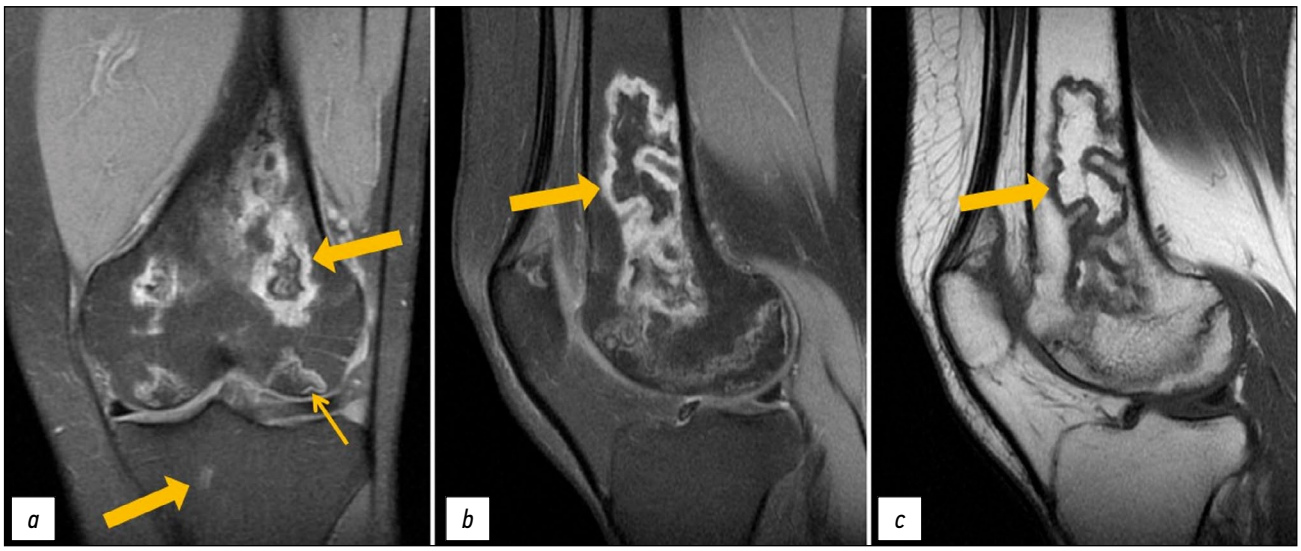

Fig. 3. Follow-up MRI of the left knee joint: PDWI with fat suppression in the coronal (*a*) and sagittal (*b*) plane and T1WI in the sagittal plane (*c*). Thick arrows indicate areas of bone marrow edema in the form of a heterogeneous, irregularly shaped ("geographic") MRI signal of femoral condyles and patella; the thin arrow indicates the "double line" sign in the form of internal hyperintense (granulation tissue) and external hypointense (osteosclerosis) lines on PDWI.

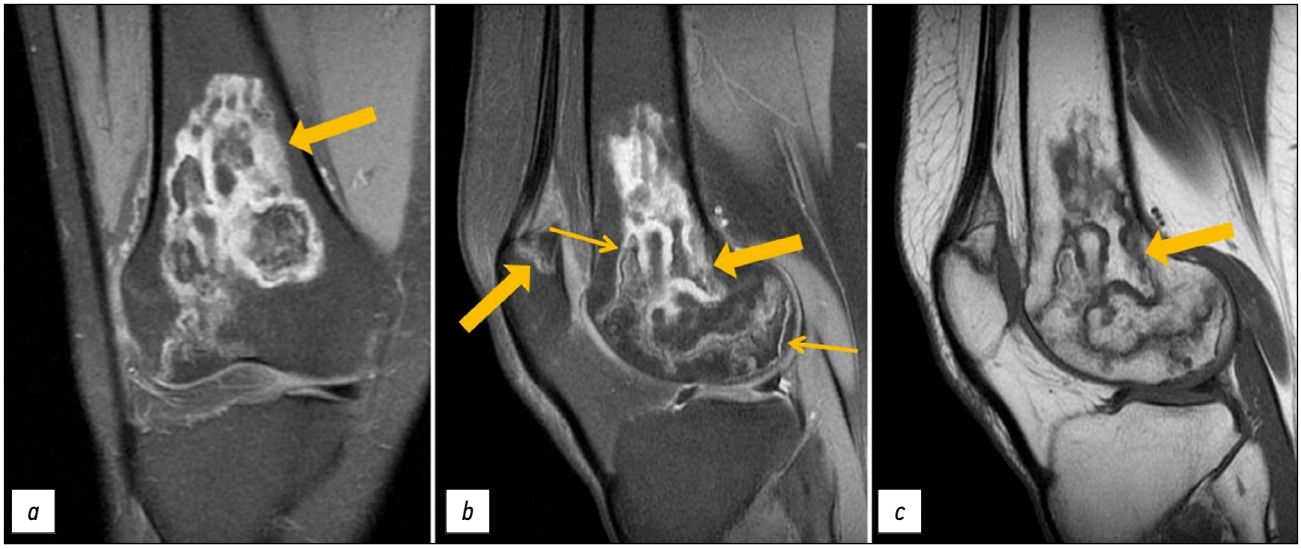

Fig. 4. Follow-up MRI of the right knee joint: PDWI with fat suppression in the coronal (*a*) and sagittal (*b*) plane and T1WI in the sagittal plane (*c*). Thick arrows indicate areas of bone marrow edema in the form of a heterogeneous, irregularly shaped ("geographic") MRI signal of femoral condyles and patella; thin arrows indicate the "double line" sign in the form of internal hyperintense (granulation tissue) and external hypointense (osteosclerosis) lines on PDWI.

developing avascular necrosis. At the same time, the pathogenesis of osteonecrosis in these patients is unclear: In addition to GCS therapy, independent causes may include vascular thrombosis, adipocyte hypertrophy, fat embolism, hypercoagulopathy, endothelial destruction, and leukocyte aggregation [7, 10]. However, we could not find clinical cases of osteonecrosis due to the above factors in the literature [7, 9].

No agreement has been made on the duration of corticosteroid therapy or the dosage that increases the risk of osteonecrosis. Nonetheless, numerous studies suggest that controlling the cumulative dose of GCS is important in developing this pathology [11]. Thus, osteonecrosis of the bone structures of the knee joint was found to develop with a cumulative dose of prednisolone ranging from 1.012 to 6.562 g, [12, 13] whereas in other clinical cases, the cumulative dose of prednisolone was in the range of 0.9–1.413 g, with an average value of 1.156 g [14]. In our case, dexamethasone was used at a dose of 20 mg/day, followed by a decrease to 12 mg/day.

Agarwala et al. [14] describe a case of avascular necrosis in a 20-year-old woman after using methylprednisolone for 15 days. The patient experienced pain in the knees on Day 25 of the disease, with lesions of both condyles and the patella according to MRI. The same authors describe a case of a 16-year-old boy who developed pain in both hip joints and the right knee joint 4 months after the novel coronavirus infection when treated with methylprednisolone and dexamethasone for 19 days. In our clinical case, dexamethasone was used for 10 days with a 2-day break. The first complaints of knee pain occurred on Day 15 of the disease (Day 9 of GCS therapy), similar to the case of the abovementioned female patient, although our patient's age differed considerably.

Another clinical case refers to avascular necrosis of the right knee joint in a 78-year-old woman with a history of bilateral gonarthrosis, more pronounced on the left, as well as concomitant cardiovascular diseases and obesity [15]. The treatment included antibacterial drugs, hydroxychloroquine, antiviral drugs (lopinavir, ritonavir), and oxygen therapy. Two weeks after discharge, the patient reported that the pain in the right knee joint had worsened. During this period, the patient also received GCS therapy for 9 days for bronchospasm. Seven days later, the patient developed local edema of the right knee joint. MRI revealed osteonecrosis of the right femoral medial condyle. GCS therapy cannot be considered the sole cause of avascular necrosis in this case; the presence of concomitant diseases is also a risk factor for developing osteonecrosis. However, the brevity between coronavirus infection and developing avascular necrosis suggests an effect of GCS therapy. In our clinical case, the patient had no other risk factors for developing avascular necrosis other than taking GCS; however, as in the example above, arthralgia developed rather quickly during GCS therapy.

Conversely, the study by Sulewski et al. [16] indicates insufficient evidence of the direct effect of GCSs on the development of osteonecrosis. This study analyzed 10 patients with confirmed coronavirus infection and signs of avascular necrosis. The mean age of the patients was 61 years. Although only four out of ten patients received GCSs, all of them developed avascular necrosis on Day 14 of the disease, on average. Li et al. [17] obtained similar data in a meta-analysis, confirming the theory of multifactorial pathogenesis of avascular necrosis in patients with the novel coronavirus infection. A deficiency of angiotensin-converting enzyme 2, which can cause bone destruction as well as vascular thromboses, as in the case of osteonecrosis

development on GCS therapy, is a possible factor in the development of avascular necrosis in such patients. Thus, no clear consensus exists regarding the etiology and mechanism of avascular necrosis development in patients with novel coronavirus infection.

In our clinical case and cases presented by foreign authors, the treatment of avascular necrosis is primarily conservative, with the main goals of relieving pain, slowing the progression of osteonecrosis, and preventing fractures and arthritis. At the same time, no generally accepted treatment scheme is available [18]. In turn, some researchers confirm that combination therapy with bisphosphonates is effective for treating osteonecrosis, including in the early stages, as our clinical case demonstrates [19, 20].

Thus, early identification of patients at high risk of developing avascular necrosis because of the novel coronavirus infection is critical in preventing arthritis and other complications.

CONCLUSION

We present a clinical case of MRI-detected bilateral avascular necrosis of the bone structures of the knee joint during treatment of COVID-19 with GCSs. GCS therapy has well-known side effects, such as impaired glucose tolerance, increased blood pressure, tachycardia, erosive and ulcerative lesions of the gastrointestinal tract, and sleep disturbances. However, avascular necrosis of the bone structures of the knee joints caused by GCS therapy is rarely brought to the attention of clinicians. Our case not only highlights the complexities of the pathogenesis of osteonecrosis but also demonstrates the wide range of complications associated with GCS therapy.

ADDITIONAL INFORMATION

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AUTHORS' INFO

*** Anna P. Gonchar;**
address: 24-1 Petrovka street, 127051 Moscow, Russia;
ORCID: https://orcid.org/0000-0001-5161-6540;
eLibrary SPIN: 3513-9531; e-mail: a.gonchar@npcmr.ru

Ivan A. Blokhin;
ORCID: https://orcid.org/0000-0002-2681-9378;
eLibrary SPIN: 3306-1387; e-mail: i.blokhin@npcmr.ru

Yuliya F. Shumskaya;
ORCID: https://orcid.org/0000-0002-8521-4045;
eLibrary SPIN: 3164-5518; e-mail: yu.shumskaia@npcmr.ru

ОБ АВТОРАХ

*** Гончар Анна Павловна;**
адрес: Россия, 127051, Москва, ул. Петровка, д. 24, стр. 1;
ORCID: https://orcid.org/0000-0001-5161-6540;
eLibrary SPIN: 3513-9531; e-mail: a.gonchar@npcmr.ru

Блохин Иван Андреевич;
ORCID: https://orcid.org/0000-0002-2681-9378;
eLibrary SPIN: 3306-1387; e-mail: i.blokhin@npcmr.ru

Шумская Юлия Федоровна;
ORCID: https://orcid.org/0000-0002-8521-4045;
eLibrary SPIN: 3164-5518; e-mail: yu.shumskaia@npcmr.ru

* Corresponding author / Автор, ответственный за переписку

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Скрытое течение болезни Крона: роль томографических методов в диагностике

Ю.Ф. Шумская[1, 2], Т.С. Нефедова[1], Д.А. Ахмедзянова[1], И.А. Блохин[2], М.Г. Мнацаканян[1]

[1] Первый Московский государственный медицинский университет имени И.М. Сеченова (Сеченовский Университет), Москва, Российская Федерация

[2] Научно-практический клинический центр диагностики и телемедицинских технологий, Москва, Российская Федерация

АННОТАЦИЯ

Болезнь Крона с локализацией процесса в верхних отделах желудочно-кишечного тракта, терминальном отделе подвздошной кишки или в толстой кишке диагностируется на основании визуализации области поражения при помощи эндоскопических методов исследования и гистологического исследования биоптатов. В случаях поражения тонкой кишки, когда методы эндоскопии малоинформативны, а применение видеокапсульной эндоскопии имеет ряд противопоказаний, для постановки диагноза целесообразно использовать лучевые методы диагностики, такие как мультиспиральная компьютерная томография и/или магнитно-резонансная энтерография.

Приводим описание клинического случая пациента со стёртыми клиническими проявлениями болезни Крона с поражением тонкой и прямой кишки, диагноз которому удалось верифицировать благодаря применению томографических лучевых методов исследования. Мужчина в возрасте 44 лет с жалобами на невыраженные боли в животе, диспепсию. В анализах — косвенные признаки мальабсорбции, повышение фекального кальпротектина; при эндоскопическом обследовании с гистологической верификацией — картина проктита. После выполнения энтерографии с помощью компьютерной и магнитно-резонансной томографии удалось диагностировать массивное поражение тонкой кишки, являющееся субстратом симптоматики.

Приведённый клинический случай демонстрирует атипичную клиническую картину болезни Крона с поражением петель тощей, подвздошной и отделов прямой кишки. В отсутствии характерных жалоб у пациента, а также вследствие недостаточно информативных результатов эндоскопического и морфологического исследования такие методы визуализации, как компьютерная и магнитно-резонансная томография, сыграли решающую роль в постановке диагноза.

Ключевые слова: болезнь Крона; МР-энтерография; КТ-энтерография; клинический случай.

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Latent course of Crohn's disease: the role of tomographic imaging in diagnosis

Yuliya F. Shumskaya[1, 2], Tamara S. Nefedova[1], Dina A. Akhmedzyanova[1], Ivan A. Blokhin[2], Marina G. Mnatsakanyan[1]

[1] The First Sechenov Moscow State Medical University (Sechenov University), Moscow, Russian Federation
[2] Research and Practical Clinical Center for Diagnostics and Telemedicine Technologies, Moscow, Russian Federation

ABSTRACT

Crohn's disease with localization in the upper gastrointestinal tract, terminal ileum, or colon is diagnosed based on visualization of the lesion area using endoscopic methods and histological examination. In cases of damage to the small intestine, when endoscopy methods are not informative enough and the use of videocapsular endoscopy has a number of contraindications, it is advised to use radiation diagnostic methods, such as multispiral computed tomography and/or magnetic resonance enterography, to make a diagnosis.

We present a clinical case of ambiguous clinical manifestations of Crohn's disease with small intestine and rectal involvement. Tomographic imaging was used to confirm the diagnosis. A 44-year-old patient presented with complaints of non-pronounced abdominal pain, dyspepsia. The lab panel showed indirect signs of malabsorption, an increase in fecal calprotectin. An endoscopic examination with histological verification revealed a picture of proctitis. After performing computed tomography and/or magnetic resonance enterography multiple lesions of the small intestine were revealed. This clinical case demonstrates an atypical clinical picture of Crohn's disease with jejunal, iliac, and rectal lesions.

The patient had no characteristic complaints; the results of endoscopic and morphological studies were not informative. Imaging by means of computed and magnetic resonance tomography has played a crucial role in the diagnosis and successful treatment.

Keywords: Crohn's disease; MRI-enterography; CT-enterography; clinical case.

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克罗恩病的潜伏过程：断层扫描方法在诊断中的作用

Yuliya F. Shumskaya[1, 2], Tamara S. Nefedova[1], Dina A. Akhmedzyanova[1], Ivan A. Blokhin[2], Marina G. Mnatsakanyan[1]

[1] The First Sechenov Moscow State Medical University (Sechenov University), Moscow, Russian Federation
[2] Research and Practical Clinical Center for Diagnostics and Telemedicine Technologies, Moscow, Russian Federation

简评

上消化道、回肠末端或结肠局部的克罗恩病是通过内镜检查和活检标本的组织学检查观察病变而诊断的。在小肠受累的情况下，内镜检查的价值不大，视频胶囊内镜检查有一些禁忌症，建议使用放射学技术，如多螺旋计算机断层扫描和/或磁共振肠成像来进行诊断。

这里描述的是一位临床表现轻微的克罗恩病患者，其小肠和直肠受累，通过使用影像放射学技术验证了其诊断。一名44岁的男子，有轻微腹痛和消化不良。检查显示，有吸收不良的间接迹象，粪便钙蛋白增加；内镜检查与组织学验证显示，有直肠炎的模式。经过计算机断层扫描和磁共振成像肠道造影，可以诊断出小肠的巨大病变，这是症状的基底。

这个临床病例显示了克罗恩病的非典型临床表现，包括空肠、回肠和直肠受累。由于患者没有特征性的主诉，并且由于内窥镜和形态学检查的结果信息量不足，CT和MRI等影像技术在诊断中起到了决定性的作用。

关键词：克罗恩病；磁共振小肠造影；CT小肠造影；临床病例。

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BACKGROUND

Because of its systemic nature, Crohn's disease can affect not only the gastrointestinal tract but also the musculoskeletal or respiratory system, organs of vision, and skin [1-4]. Thus, Crohn's disease frequently draws the attention of doctors from various specialties. The possible polymorphism of complaints, particularly at the time of disease onset, with extraintestinal symptoms or rare complaints in the latent stages make the diagnosis of this disease extremely difficult [5, 6] and prevents the timely prescription of adequate therapy.

In classic cases, Crohn's disease is diagnosed through endoscopic visualization of the affected area, which is only possible when the disease is localized in the upper gastrointestinal tract, terminal ileum, or colon. However, when the small intestine is affected, endoscopic methods become uninformative, whereas video capsule endoscopy has contraindications, making it difficult to use in clinical practice [7]. Thus, radiation diagnostic methods, such as multislice computed tomography (MSCT) and/or magnetic resonance (MR) enterography, should be used for diagnosis [8, 9].

We present the case of a patient with Crohn's disease with inapparent clinical manifestations and damage to the small intestine and rectum whose diagnosis was confirmed using radiation diagnostic methods.

CLINICAL CASE

Patient

Patient D., 44 years old, was admitted to the gastroenterology department with complaints of umbilical discomfort, bloating, and fullness in the epigastrium and umbilical region that appears 30–60 minutes after a meal. In 2017, the patient noticed a feeling of heaviness in the abdomen, gaseous eructation, and episodes of heartburn after consuming food, and lost 15 kg in 2 years with no dietary changes. The patient underwent outpatient examination, which revealed no gastrointestinal pathology. Abdominal ultrasound revealed no abnormalities; oesophagogastroduodenoscopy showed superficial gastritis not associated with *Helicobacter pylori* infection (negative rapid urease test); and colonoscopy showed no organic pathology. The condition was classified as the sphincter of Oddi functional disorder and the patient was treated with rabeprazole and hymecromone but without any significant effect. Episodic abdominal pain (once in every several months) persisted. The patient was hospitalized for examination for the aforementioned complaints.

The patient's condition at the time of admission was satisfactory. Their physique was asthenic, with a body mass index of 20.02 kg/m^2. Body temperature on admission was 36.5°C; the skin was pale; and the abdomen was visually symmetrical and tender on palpation in the umbilical, right mesogastric, and right iliac regions. The bowel movements were normal without pathological admixtures.

Laboratory and instrumental findings

According to laboratory findings during hospitalization, hemoglobin level decreased from 137.2 to 123 g/L (normal range: 132–180 g/L), serum iron level decreased to 10.4 μmol/L (normal range: 12.5–32.2 μmol/L), total protein level decreased to 63 g/L (normal range: 66–83 g/L), fecal occult blood test was positive, and fecal calprotectin level was elevated to 389 μg/g (normal value: up to 50 μg/g). All other parameters in complete blood count, blood chemistry, coagulogram, urinalysis, and stool test remained within the normal range.

Oesophagogastroduodenoscopy revealed no signs of upper gastrointestinal damage.

Colonoscopy revealed endoscopic signs of proctitis: swelling of the rectal mucosa, multiple hemorrhages, and a smoothened vascular pattern. A biopsy was performed.

Histological findings revealed the following: preserved architectonics of the rectal mucosa, dense uniform lymphoplasmacytic infiltration in the deep mucosa with an abundance of eosinophilic leukocytes, and hyperplastic lymphoid follicles with proliferative centers in several fragments.

These findings did not indicate a uniform pattern. Given the indirect signs of malabsorption syndrome (low hemoglobin, serum iron, and total protein), the small intestine was examined.

Abdominal MSCT with intravenous contrast was performed after the oral administration of 1 L of macrogol solution. The jejunum and ileum walls were locally thickened with inactive contrast agent accumulation. Approximately 5 cm of the wall of the distal jejunum transitioning into the ileum was markedly thickened up to 17 mm, with more active contrast agent accumulation, including in the mucosa (Fig. 1). Regional adipose tissue was infiltrated with the formation of liquid zones along the midline between the loops in the small pelvis; and regional lymph nodes as large as 9 mm showed active accumulation of the contrast agent.

To determine the extent and volume of the lesion, MR enterography was performed after administering 1.2 L of mannitol solution orally. Four local areas of uneven wall thickening were noted in the small intestine: thickening of up to 8 mm over 25 mm with narrowing of the lumen to 5 mm, thickening of up to 12 mm over ~90 mm with narrowing of the lumen to 3 mm, thickening of up to 10 mm over 160 mm with narrowing of the lumen to 3 mm, and thickening of up to 9 mm over ~32 mm with narrowing of the lumen to 3 mm (Figs. 2 and 3). These areas of the small intestine actively accumulated the contrast agent and showed signs of limited diffusion on diffusion-weighted imaging. Because the lesions resembled those seen in intestinal tuberculosis, an immunodiagnosis of tuberculosis infection (interferon gamma release assays, T-SPOT.TB, with a negative result) and chest MSCT (with no pathology) were performed.

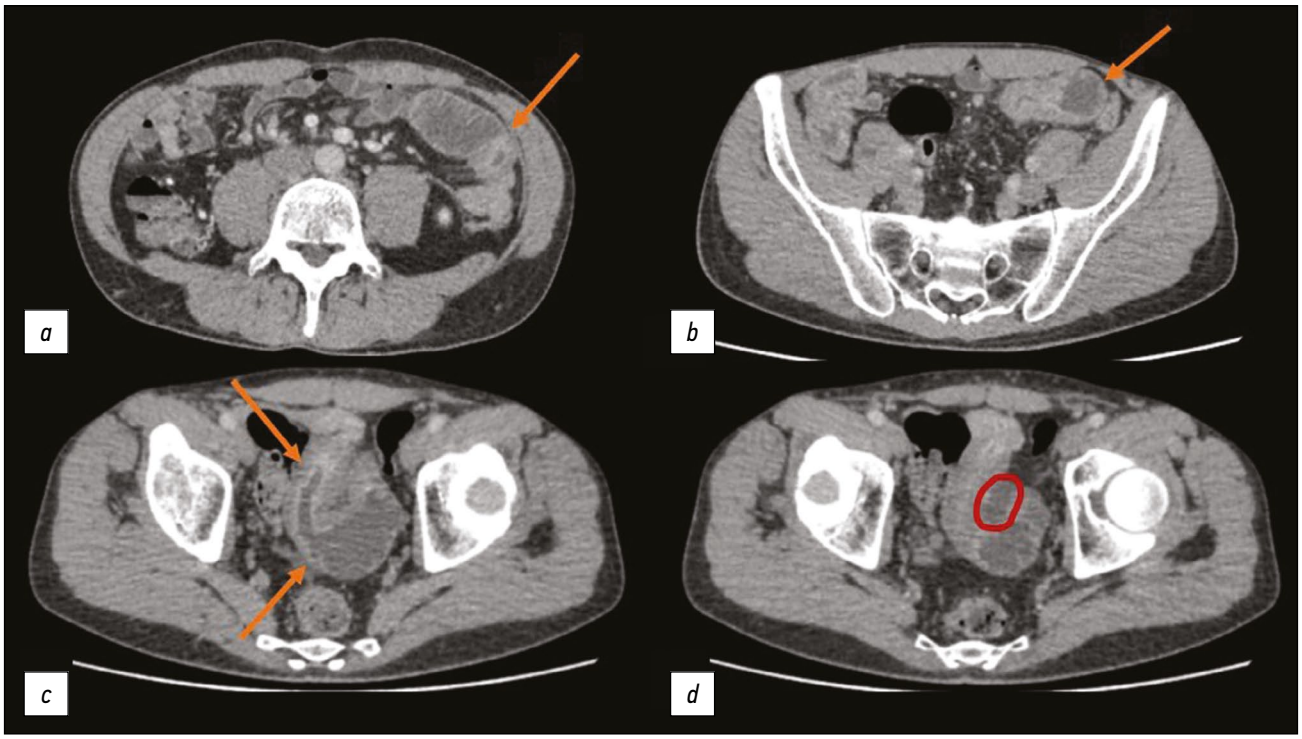

Fig. 1. Abdominal multislice computed tomography with intravenous contrast, axial plane: *a*) substantial narrowing of the intestinal lumen and thickening of the wall with active contrast agent accumulation (arrow); *b*) dilated loop of the small intestine with an unevenly thickened wall (arrow); *c*) dilation and narrowing of the intestinal lumen is visible; additionally, of interest is the intestinal mucosa, which actively accumulates the contrast agent (arrows); *d*) the area of fluid accumulation between the loops in the small pelvis is marked red.

Diagnosis and treatment

Considering the "kangaroo jumping" type of gastrointestinal lesion discovered during the examination along with the findings of colonoscopy and histological examinations, the patient was diagnosed with Crohn's disease with strictures and lesions of the small intestine and rectum.

To relive the condition, prednisolone was intravenously administered at a dose of 120 mg/day, with a gradual decrease

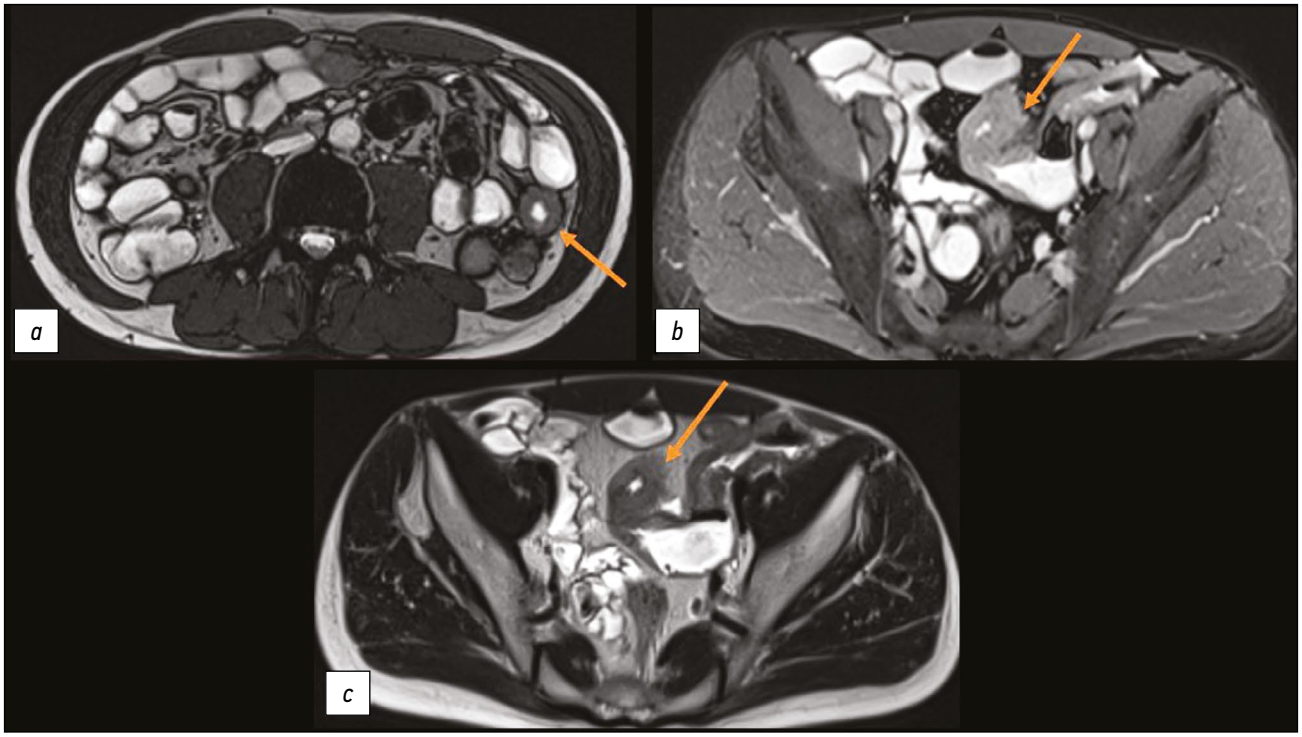

Fig. 2. Magnetic resonance enterography, axial plane: the arrows show thickened areas of the small intestine.

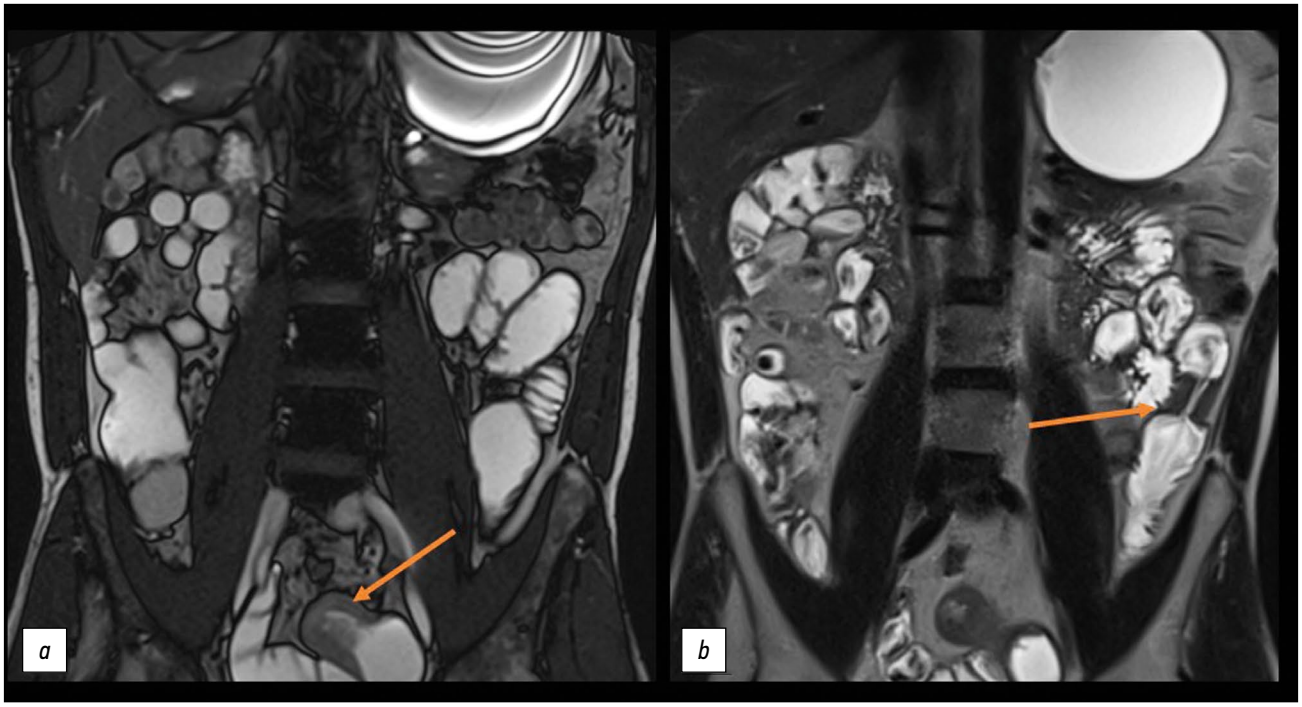

Fig. 3. Magnetic resonance enterography, coronal plane: the arrows show areas of thickening of the long sections of the small intestine walls.

in the dose and a switch to oral methylprednisolone at a dose of 8 mg/day. In addition, the patient received mesalazine rectally at a dose of 2 g/day. To maintain remission, a genetically engineered biological drug (infliximab) and azathioprine were chosen because of the atypical localization of the process, the extent of the lesion, and the high activity of the disease.

During treatment, the patient's condition improved; there were no complaints of abdominal pain and dyspepsia. At a follow-up examination after 3 months, the level of fecal calprotectin was within the normal range, and blood chemistry showed no signs of malabsorption. The patient had gained approximately 5 kg of weight.

DISCUSSION

The clinical case presented here shows an unusual clinical picture of Crohn's disease, exhibiting damage to the jejunum, ileum, and rectum. In the absence of specific complaints and with insufficient endoscopic and morphological findings, tomographic radiation diagnostics played a critical role in establishing the diagnosis.

According to the clinical guidelines for the diagnosis and treatment of Crohn's disease, MSCT and MR enterography are only used to rule out small intestine strictures before performing video capsule endoscopy [10]. However, published foreign literature demonstrates the inherent value of radiation tomography methods for diagnosing Crohn's disease, including a consensus on their use [11].

Chavoshi et al. [12] conducted a systematic review and found that the sensitivity and specificity of MR enterography in detecting lesions of the small intestine in Crohn's disease were 80%–88% and 81%–91%, respectively, which are sufficient to make MR enterography a popular method for diagnosing pathologies associated with Crohn's disease in the small intestine.

According to Park et al. [13] the data obtained using abdominal MSCT were significantly correlated with the Crohn's disease activity index and C-reactive protein level ($p < 0.05$). AUC was 0.85 when performing ROC analysis on MSCT data to predict disease activity. Sensitivity and negative predictive values were 95% and 94%, respectively, with a cutoff value of 0.8.

Publications in the Russian literature describe the diagnostic value of tomography. For example, Dubrova and Stashuk [14] emphasized the importance of using these methods in conjunction with endoscopic methods in the diagnosis of Crohn's disease. Kurilo et al. [15] demonstrated the exceptional importance of MSCT enterography in a series of clinical cases, obtaining data on the localization and extent of pathological changes, process activity, and presence of extraintestinal complications. These data allowed determining the tactics for managing patients with complicated Crohn's disease (such as with perforation of the ileum in one case and decompensated stenosis of the descending colon in another).

Our clinical case also demonstrates the importance of using tomographic radiation methods for the diagnosis of Crohn's disease with small intestine lesions to determine the activity and extent of the lesion. The information obtained via enterography was crucial for diagnosing the disease and deciding the treatment tactics.

CONCLUSION

Crohn's disease does not always present with pronounced clinical symptoms. Routine examinations, including endoscopies, are often insufficient to diagnose small bowel disease. Tomographic methods (CT and MR enterography) are highly informative and accurate and allow the visualization of the small intestine when assessing the volume and activity of the lesion.

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AUTHORS' INFO

*** Yuliya F. Shumskaya;**
address: 24-1 Petrovka str., 127051, Moscow, Russia;
ORCID: https://orcid.org/0000-0002-8521-4045;
eLibrary SPIN: 3164-5518; e-mail: yu.shumskaia@npcmr.ru

Tamara S. Nefedova;
ORCID: https://orcid.org/0000-0002-6718-8701;
eLibrary SPIN: 3097-4977; e-mail: prosto.toma.22@gmail.com

Dina A. Akhmedzyanova;
ORCID: https://orcid.org/0000-0001-7705-9754;
eLibrary SPIN: 6983-5991; e-mail: dina_akhm@mail.ru

Ivan A. Blokhin;
ORCID: https://orcid.org/0000-0002-2681-9378;
eLibrary SPIN: 3306-1387; e-mail: i.blokhin@npcmr.ru

Marina G. Mnatsakanyan, MD, Dr. Sci. (Med.);
ORCID: https://orcid.org/0000-0001-9337-7453;
eLibrary SPIN: 2015-1822; e-mail: mnatsakanyan08@mail.ru

ОБ АВТОРАХ

*** Шумская Юлия Федоровна;**
адрес: Россия, 127051, Москва, ул. Петровка, д. 24, стр. 1;
ORCID: https://orcid.org/0000-0002-8521-4045;
eLibrary SPIN: 3164-5518; e-mail: yu.shumskaia@npcmr.ru

Нефедова Тамара Сергеевна;
ORCID: https://orcid.org/0000-0002-6718-8701;
eLibrary SPIN: 3097-4977; e-mail: prosto.toma.22@gmail.com

Ахмедзянова Дина Альфредовна;
ORCID: https://orcid.org/0000-0001-7705-9754;
eLibrary SPIN: 6983-5991; e-mail: dina_akhm@mail.ru

Блохин Иван Андреевич;
ORCID: https://orcid.org/0000-0002-2681-9378;
eLibrary SPIN: 3306-1387; e-mail: i.blokhin@npcmr.ru

Мнацаканян Марина Генриковна, д.м.н.;
ORCID: https://orcid.org/0000-0001-9337-7453;
eLibrary SPIN: 2015-1822; e-mail: mnatsakanyan08@mail.ru

* Corresponding author / Автор, ответственный за переписку

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Как создать современный медицинский центр в текущих условиях?

П.О. Румянцев[1], Д.А. Черкасов[2]

[1] Группа компаний «Мой медицинский центр», Санкт-Петербург, Российская Федерация
[2] Агентство консалтинга и коммуникаций в науке и здравоохранении HASCCA, Москва, Российская Федерация

АННОТАЦИЯ

Современная многопрофильная клиника представляет не только медицинский, но и инженерно-технический и нередко биотехнический объект. Технологическая сложность объекта зависит от планируемых (био)медицинских профилей и функционала, потребности в масштабируемости и модернизируемости, а также множества других факторов.

При взгляде со стороны, создание современного профильного или многопрофильного медицинского центра от идеи до запуска в эксплуатацию не выглядит запредельно сложным, а его этапы (предпроектные изыскания, медико-техническое задание, эскизный проект, стадии проектирования, строительства, оснащения и выхода на запланированную производственную мощность) видятся понятными и достижимыми. Однако наш собственный опыт непосредственного участия и анализа реализации различных профильных медицинских центров в нашей стране свидетельствует о наличии массы ложных предубеждений, ошибок, устаревших принципов и прочих проблем на практике.

В статье мы анализируем, объясняем и систематизируем типичные заблуждения и пороки при создании онкологического центра, однако те же проблемы возникают при создании любого многопрофильного медицинского центра. Мы полагаем, что наш опыт окажется полезным для ознакомления не только проектировщикам, технологам и архитекторам, но и врачам, организаторам здравоохранения, как, впрочем, и всем специалистам, привлекаемым к созданию медицинских центров современного уровня.

Ключевые слова: проектирование; медико-техническое задание; медицинский центр; онкологический центр.

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How to create a modern medical center in the current conditions?

Pavel O. Rumiantsev, Dmitry A. Cherkasov

[1] My Medical Center Group of Companies, Saint Petersburg, Russian Federation
[2] Healthcare and Science Consulting Communications Agency HASCCA, Moscow, Russian Federation

ABSTRACT

A modern multidisciplinary clinic is not only a medical facility, but also an engineering and often biotechnical facility. The technological complexity of the object depends on the planned (bio) medical profiles and functionality, the need for scalability and upgradability, as well as many other factors.

When viewed from the outside, the creation, from an idea to commissioning, of a modern specialized or multidisciplinary medical center does not look prohibitively complicated, and its stages (pre-project surveys, medical and technical specifications, draft design, design stages, construction, equipping, and entering the planned production power) are seen as understandable and achievable. However, our own experience of direct participation and analysis of the implementation of various specialized medical centers in our country indicates the presence of a lot of false prejudices, mistakes, outdated principles, and other problems in practice.

In the article, we analyze, explain, and systematize typical misconceptions and vices when creating an oncology center, but the same problems arise when creating any multidisciplinary medical center. We believe that our experience will be useful for familiarization not only to designers, technologists and architects, but also to doctors, healthcare organizers, as well as to all specialists involved in the creation of modern medical centers.

Keywords: engineering; medico-technical enquiry; medical center; oncology center.

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在当前条件下如何建立现代医疗中心？

Pavel O. Rumiantsev, Dmitry A. Cherkasov

[1] My Medical Center Group of Companies, Saint Petersburg, Russian Federation
[2] Healthcare and Science Consulting Communications Agency HASCCA, Moscow, Russian Federation

简评

一个现代的、多学科的诊所不仅是一个医疗机构，也是一个工程设施，而且往往是生物技术设施。该设施的技术复杂性取决于计划中的（生物）医疗概况和功能，对可扩展性和可升级性的需求，以及一系列其他因素。

从外面看，建立一个现代的专科或多学科医疗中心看起来并不十分复杂，其阶段（项目前的研究、医疗和技术任务、概念设计、设计、施工、设备和达到计划的生产能力）似乎很清楚，可以实现。然而，我们自己直接参与和分析我国各种专科医疗中心的实施的经验表明，在实践中存在大量错误的先入为主的观念、错误、过时的原则和其他问题。

在这篇文章中，我们分析、解释并系统化了建立肿瘤中心的典型误区和缺陷，但在建立任何多学科医疗中心时都会出现同样的问题。我们相信，我们的经验不仅对规划师、技术专家和建筑师有用，而且对医生、医疗保健组织者，乃至所有参与创建最先进的医疗中心的专业人士也有用。

关键词：设计；医疗和技术任务；医疗中心；肿瘤中心。

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INTRODUCTION

A mountain cannot turn, but a road can.
A Chinese proverb

Over the last 10 years, we have seen numerous healthcare facilities and helped establish at least a dozen of them (most often cancer centers). We would like to share our observations and practical experience in this article.

Now is not the time to expect spare parts to arrive overnight or a service engineer to fly to your location at the drop of a hat. Of course, it appeared somewhat utopian even in the best of times. However, the power of persuasion or exaggeration, future contract promises, or other forms of manipulation could make things easier.

In our practice, it felt like going on a long hike or climbing a mountain every time it became clear that equipping a cancer center step by step would be impossible. Thus, requests for facility modernization and phased launch should be considered during the initial investigation and design phase.

At present, the integrated approach to establishing healthcare facilities at all stages, from design to commissioning, is widely recognized and growing in importance.

The long-accepted conventional approach to medical engineering in our country is becoming unrealistic in terms of achieving the desired result. Moreover, to say that this approach is completely impractical is not an exaggeration. This is supported by our observations and the fact that many medical centers in our country are unfinished, were launched late, or failed to meet performance targets. This is true for cancer centers that require the most advanced and complex technologies. In this context, a cancer center can be viewed as an example of any modern medical center. Oncology employs the most advanced technologies available, including structural and functional imaging, surgery, pathology, radiation therapy, nuclear medicine, and genetics.

Of course, a distinctive exterior and interior design will always catch the eye. However, only the most advanced technologies and their expert application can win and maintain a medical center's reputation. A mismatch between form and content, which will become increasingly obvious over time, will inevitably lead to disappointment for both the medical community and patients.

A MODERN CANCER CENTER: WINNING AND MAINTAINING REPUTATION

Things not to do

The chain of mishaps begins with a medical and/or technical design specification, which occurs frequently during the design or even construction phase. Following that, the most common "design" scenario usually includes the following steps:

1. The design specification barely corresponds to the layout of the future hospital, let alone its purpose. A design specification is typically just a copy-and-paste job based on a previous "similar" project. Furthermore, there is no guarantee that the project in question was not created by simply copying data from an even older specification.
2. This is followed by a two-stage design with mostly ambiguous and vague descriptions. Again, this design is frequently inherited from previous "successful" projects to reduce questions and comments from authorities during multiple expert evaluations.
3. The general contractor then gives the finishing touches to this "Frankenstein's monster"; facade and interior designers can also contribute.
4. The resulting structure necessitates numerous modifications; thus, additional holes are drilled, utility lines that were not included in the design are installed, openings are mured up, and so on.
5. Finally, a manufacturer installs the equipment in the brand-new building and departs with the satisfaction of a job well done.
6. Several months later, the hospital's facilities manager requests additional supplies, elimination of several functions, and mandatory personnel briefings and training. However, some doctors in this position are well aware that such requests and complaints can negatively affect their careers.
7. After 10–15 months of costly visits by the manufacturer's service engineers and additional supplies of equipment that are now at least 1.5–2 times more expensive, the work finally begins. The work is frequently interrupted by a failing connector or valve when moisture gets into a device, resulting in its damage. However, this happens more often during the installation and commissioning of utility systems and medical equipment. Even more frequently, especially recently, there has been a need to replace "equivalent" equipment with that from friendly countries. Moreover, replacement is sometimes required because of medical technology updates that occur during the construction phase. In these cases, you must do without this or that piece of equipment, and you are lucky if these restrictions are only temporary and do not apply to basic medical technologies.

Almost all of the processes listed above are unrelated. In practice, they have no continuity or interconnection. Each contractor is in charge of a specific area of work and is not responsible for the functionality, reliability, or performance of a complex medical engineering system. The more multicomponent and multifunctional the healthcare facility, the higher the risks, and today's reality is even harsher.

What is today's reality?

At the time of this writing, six packages of sanctions had been introduced, with more possibly on the way. Some people

continue to believe that this has had and will have no effect on medicine. This is mostly correct in theory. However, in practice, this effect is significant and will most likely become even greater over time. Let us explain why we think this way.

In our practice, we had to work in parallel with several manufacturers (vendors), each of whom had an approach to dealing with the sanctions. Every week, the situation changes dramatically. As a result, here are our main conclusions:

1. Manufacturers are unaware of our country's current regulatory framework and make no effort to learn more about it.
2. The export policy of each country is determined by its commissions and structures.
3. Most manufacturers understand the gravity of the measures and the risk of criminal prosecution.
4. It is a mistake to believe that manufacturers will gladly take risks in exchange for the profits offered by the Russian market. Typically, sales in Russia account for only 5%–15% of the total international revenue. Thus, halting all activity in the region is simpler for some manufacturers.
5. "But they have a manager in Russia, and the representative assured me that everything would be fine." Managers in representative offices rely on a local market and will go to great lengths to support it. Local managers are frequently unaware of the internal political nuances of companies, which is done for the company's security.
6. Some manufacturers simply take a negative stance toward the Russian market. This is entirely their choice and is not governed by any EU or US laws. We can still argue about obligations in international courts; however, we cannot force them to sign a contract.
7. Co-product manufacturers can also take a radical stance. We have already had to deal with this issue in the context of heavy medical equipment. You may be unaware, for example, that some pieces of equipment are made by such "radical" manufacturers. However, they have the authority to compel a large manufacturer not to use its components or spare parts, citing sanctions and other local laws. As a result, manufacturers are at odds with one another; it is as if the left leg wants to walk but the right leg does not.
8. "Chinese manufacturers can make almost anything." It is mostly true… until it is not. "Anything" refers primarily to consumer goods. Industry-specific solutions that are in high demand in healthcare have been developed for many years by small high-tech companies. In many cases, these solutions have no counterparts anywhere in the world. China does not seek to replicate them because of small batch sizes, patents, and technical nuances. Furthermore, achieving a high level of quality, safety, and customer confidence takes many years, if not decades. Service is not even worth mentioning: proper support necessitates a sizable fleet of equipment in the country.
9. Uniqueness and serial numbers. This function was introduced to ensure quality and safety. Each spare part, similarly to equipment, has a unique identification number and, in some cases, a built-in chip. When ordering such parts, the final product's ID (ultimate product) must be specified. Accordingly, the manufacturer can verify that the maintenance was done correctly and on time. It also allows for the prevention of rogue schemes during the order stage (e.g., it is hardly necessary to replace brake pads five times a month).
10. Human factor. A modern product consists of a unique solution and the expertise of a specialist. The latter is a kind of "fifth element": without it, nothing works. This is another impediment, even in terms of logistics. Moreover, a specialist must be willing to travel to the customer's location; it is not just about the customer's importance and respect.

Taking these 10 factors into account (and we believe that these are far from exhaustive), a simple one- or two-move combination will clearly never work. It might be possible in other fields, but not in medical engineering, which is becoming increasingly reliant on multimodality and technology transfer.

Thus, in the current situation, integrity and continuity are critical when establishing a modern medical facility. Moreover, not to be overlooked is the creative collaboration of all those involved: doctors, biologists, chemists, physicists, engineers, process managers, architects, and designers. This is by no means an exhaustive list.

What exactly do we mean by an integrated approach?

A contractor or general contractor must be in charge of all processes, from concept formulation, design, procurement, and construction, to the technology's launch and maintenance for at least 2–3 years.

But first things first. A good concept, or pre-design specification, saves money on medical center construction while lowering operating costs. Ideally, this should be done in accordance with evidence-based architecture principles, with the participation of an expert group and the development of competitive solutions within this expert group.

1. A project based on the building information modeling (BIM) technique can coordinate ideas, budgets, construction, and timelines.
2. Procurement planning. This includes the development of priority criteria for equipment selection, such as upgradability, compatibility, replaceability, adaptability, maintainability, and fault tolerance.
3. A unified, minimally specific, maximally simple, and flexible technology transfer structure, universal units, open architecture, alternatives for consumables, etc.
4. Modern construction includes, among other things, the installation, assembly, and adjustment of biomedical equipment. The days of only needing sockets and well-painted walls to install equipment are long gone.

Construction readiness stages 1, 2, 3, and so on are the stages of facility readiness that correspond to the stages of technology launch. They should be an integral part of the launch process, with unified management and coordination, rather than a circular firing squad.

5. Quality system development and validation should be provided for at all stages, from design to operation.
6. Unified project management and BIM-compliant support. The so-called designer's supervision is obviously insufficient.
7. A unified launch and operation management team. Most processes require 2–3 years of adjustment.
8. Centralized control of information about the facility and its processes is another requirement for high-quality project management.
9. Establishing HR management processes and laying the groundwork for proper communication and growth.

As a result, regardless of the negative external factors, the project can achieve the required level of communication and be launched.

Correcting errors during construction is becoming increasingly difficult. Constructing and launching a modern healthcare facility is reminiscent of an airplane in flight or a group of climbers on an ascent. There is no way to go to the store for a spare part or start over. Engineering consulting, process audits, and scenario planning and preparation (i.e., simulating different scenarios on paper and on screen rather than in concrete) are becoming more important than ever.

What is the doctor's role in creating a new cancer center?

In our opinion, doctors must take the lead and be the most active and engaged participants in the process. After all, the involvement of healthcare professionals determines the innovativeness and creativity of the project. Who, if not a doctor, should be interested in self-fulfillment and skill development within a new medical center? Who else, besides a doctor, will determine the appropriate range of medical technologies and services, as well as the future trends in their advancement?

To be fair, none of us were taught to create new medical centers or their components during our college years. It never occurred to us in college or in our scientific and practical work that it was the responsibility of a doctor. Complaining and criticizing are always easier than improving or creating something new. What good is it to be able to write a medical and then a technical design specification? It is not just that we were not taught to do it; it was never even discussed. It was probably assumed that the job would be done by "specially trained people" or that no special knowledge or training would be required at all. Of course, "what man has done, man can do." However, any job requires skill, and establishing a complex medical engineering facility also requires specialized knowledge, experience, and rapid learning. This is a collaborative effort in which expertise, sharing of best practices and communication skills are essential.

In modern medicine, the level of technology integration (such as medical, engineering, biotechnological, and information) is extremely high and will only increase. Unfortunately, it can only be learned firsthand. Even the most highly qualified doctors and health administrators are frequently unable to comprehend the full scope and complexity of integration. Typically, the doctors involved simply go with general requirements and preferences based on their specialty and its specifics. They sincerely believe that these requirements are as straightforward as they can be and that issues such as standards, building codes, and prohibitions are the responsibility of specially trained people. Consequently, the doctors involved are disappointed at least twice: once when they have to spend time explaining what they want, and again when they accept work that is anything but what they wanted. However, the most difficult aspect is not conveying the idea but making it a reality with the best possible outcome under the given circumstances. Lots of effort, diligence, patience, perseverance, ingenuity, and sociability are needed. Even the most capable doctor may not be appropriate for such a role, where passion and a visionary approach are essential.

In general, engaging a doctor in such a mission is not the best idea if they are content with what they have, are unpretentious and rational, and do not aspire to master modern technologies or compete with the best. Such a mindset is simply unfit for the role of general designer, a visionary of a new generation of medicine, and everyone will be disappointed.

What should we focus on and strive for?

To begin with, because the future center will primarily serve Russian patients, provisions for implementing existing domestic guidelines are required. If the cancer center intends to enter the global medical market (medical tourism and participation in international clinical trials), compliance with international standards (GCP, GMP, JCI, etc.) is also recommended. Finally, providing modernization without incurring capital-intensive costs will be strategically important to increase efficiency and introduce innovations. Replacing heavy medical equipment is extremely expensive; thus, selecting a device that ensures high performance, compatibility with other equipment, upgradability, and fault tolerance is critical. Because up-to-dateness, dependability, and operational stability are highly valued in the medical industry, the redundancy (duplication) of production lines, channels, and bottlenecks should be planned from the start.

Why do Russian patients prefer to be treated abroad when they can be treated for free at home?

Several factors are involved. Let us concentrate on the obvious differences.

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First, patients are not kept in the dark in foreign clinics; they receive clear explanations of what tests and procedures will be performed, what they are for, and what the outcome will be. Doctors and support staff are always available and ready to help patients. Doctors are open to differing viewpoints and treat one another with dignity, and the patient's interests and preferences are always prioritized. Second, patients are always at the forefront of Western medicine: they are the primary customers and managers of their health, including diagnosis and treatment. Patients' preferences are respected, but more importantly, doctors listen to them and explain everything without rushing them to make a decision. Following such a positive experience, the patient will strive to repeat it and strongly advise others to do the same.

Third, clinics value their reputation in the foreign competitive practice of evidence-based medicine and are constantly improving in technology and personnel. It is hardly surprising that leading clinics care more about existing patients receiving the best medical care and being satisfied, referring the clinic to others, and leaving "likes" than prospective patients choosing them. They frequently accept difficult clinical cases with enthusiasm, even when other clinics have failed, because such cases allow them to creatively improve their skills and thus their reputation. If the treatment is successful, it will be these patients with difficult-to-treat cases who will publicize the clinic in the media and on social networks, serving as a "golden pool" for the clinic's popularity to grow. Furthermore, clinics are sometimes willing to treat such patients for free.

Our country provides government-funded healthcare through the distribution (quotation) of resources in the healthcare network. This program does not encourage competition among individual healthcare facilities or groups of clinics to improve medical and economic efficiency. According to the logic of the system's supporters, competition is replaced by planned volume distribution and uniform standards and tariffs for healthcare services. However, demanding patients are willing to pay or pay extra not only for health restoration but also for the most effective and high-quality medical and diagnostic care on the market. In many countries, medical care can be co-financed by the patient or another source (charity, employer, etc.). By contrast, in our country, a single-channel system for healthcare financing is strictly enshrined in law. Perhaps this was done to promote social equality. However, in practice, the accessibility, efficiency, and quality of healthcare vary, and such an approach does not contribute to market mechanisms for improving it.

Another important aspect of patient trust in Western medicine is adherence to appropriate quality standards and evidence-based improvements in medical and economic efficiency. Rather than simply distributing and setting aside resources, regulatory authorities seek to encourage multicenter studies and improve diagnostic and treatment approaches. The highly competitive, open-market environment of global medical tourism compels medical centers and groups of clinics to constantly improve the efficiency and quality of healthcare services. They are primarily concerned with improving the efficacy and safety of new algorithms/technologies/drugs, as evidenced by extensive and long-term clinical data. Guidelines are now updated and implemented in clinical practice by leading clinics in weeks (2–3 months at most) rather than years, as was previously the case.

Furthermore, today's efficacy and safety criteria include not only the novelty of the method or algorithm but also the reproducibility of results in other clinics under similar conditions. Forward-thinking clinics are actively involved in multicenter studies and the development of multidisciplinary data banks and clinical and epidemiological registers. Evidence-based medical practice puts everything in its proper place in the end, with state regulators (Food and Drug Administration and European Medicines Agency) and expert medical communities playing an active role.

Patients' trust in leading clinics, earned through purposeful and dedicated work, is perhaps the most important factor in why they choose them for health restoration. Health is the most valuable asset, and its preservation is worth all the money in the world. As a result, modern medicine attracts interest and investment in areas beyond its practical applications, which are only the tip of the iceberg and would have "melted" long ago if extensive fundamental and translational research had not been conducted. Any modern multidisciplinary medical center is a biomedical cluster that combines the following three key factors of continuous development that are inextricably linked:

1) Production (such as medical services, development of medical radioisotopes, radiopharmaceuticals, and genetic tests).

2) Research (such as pathology, transcriptomics, biobanking, collaborative research, data and biomaterial banks, and evidence-based data analysis).

3) Education (such as transfer of knowledge, experience, technologies, innovations, and artificial intelligence development).

How reliant are we on imported equipment, reagents, drugs, and techniques?

Briefly, reliance is extremely high: it has been increasing for decades and will continue to increase in the future. This is a global trend associated with the global market's competitive development. To some extent, our country has established production in medicine and pharmaceutics; however, this list is short and does not cover the need for high-tech medical equipment. There are no worthy domestic alternatives to leading manufacturers' modern solutions in endoscopic equipment, radiotherapy irradiation devices, brachytherapy, single-photon emission computed tomography, positron emission tomography, and so on. The situation with drugs is slightly better; however, the stability of the quality targeted anticancer drugs is a source of concern, as are the efficacies

and toxicity of domestic generic biosimilars in relation to original drugs.

In turn, reliance on imported production equipment and ingredients is one of the most significant barriers to increasing high-quality import substitution in the field of biomedicine, not to mention the existing regulatory framework, which is out of date and frequently contradictory. The regulatory environment must improve to promote, rather than stifle, the development of the industry.

Each segment has numerous problems and contradictions that are organically interconnected, making resolution increasingly difficult. The primary reason is that no one wants to be the change they want to see in the world. There is also a lack of motivation and result-oriented teamwork skills.

Thus, we must change our mindset and learn new skills. Otherwise, dreams will remain just that, dreams.

Do we really need international experience? Can't we get by on our own?

No, we cannot because the goal is not to write another program but to demonstrate success in developing competitive and innovative products for modern biomedicine.

What is the point of reinventing the wheel? It may make sense in other fields, but it is simply impossible in medicine. It will almost certainly be time-consuming and possibly fruitless, and patients do not have the luxury of waiting. This makes even less sense given the willingness of foreign colleagues to share knowledge and experience, at least for the time being. The global scientific, practical medical, and biotechnological communities are open to all physicians and researchers. Our mission is to preserve and extend people's lives through the advancement of life sciences.

One could argue that limited access to technology provides an additional incentive for creativity. This is undeniably correct. However, medicine is very conservative, and new technologies are few and limited to specific countries. Any innovation, such as a new surgical technique necessitates independent evidence-based validation in other medical institutions. In the global medical community, which strictly adheres to the principles of evidence, impartiality, and ethics, such validation occurs much more quickly. Even if all individual innovations are successful, can they compensate for the knowledge, experience, and technology transfer gaps? Certainly not. Furthermore, innovations necessitate advancements in equipment and consumables, service, and modernization, and any country is heavily reliant on the global market in this regard. Progress is not on the horizon, no matter how you look at it.

CONCLUSION

Of course, we need global experience in biomedicine, just as our experience may be valuable to the world. It is no good to learn only from our mistakes and fall further and further behind. However, the worst part is wasting time that could have been put to better use. While the opportunity exists, learning from and obtaining innovative solutions from global industry leaders is critical, first and foremost, for the benefit of our patients and the future of our successors. Creativity and flexibility are essential skills to master, especially in today's force majeure and competitive environment.

Nothing is impossible, and we must be the change we wish to see in the world. These words of wisdom, along with the epigraph to this article, best capture the essence of our thoughts on the topic.

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AUTHORS' INFO

*** Pavel O. Rumiantsev,** MD, Dr. Sci. (Med);
address: 8, Malaya Konyushennaya,
Saints Peterburg, 191186, Russia;
ORCID: https://orcid.org/0000-0002-7721-634X;
eLibrary SPIN: 7085-7976; e-mail: pavelrum@gmail.com

Dmitry A. Cherkasov;
ORCID: https://orcid.org/0000-0001-6750-3997;
e-mail: dr.cherkasov@gmail.com

ОБ АВТОРАХ

*** Румянцев Павел Олегович,** д.м.н.;
адрес: Россия, 191186, Санкт-Петербург,
Малая Конюшенная, д. 8;
ORCID: https://orcid.org/0000-0002-7721-634X;
eLibrary SPIN: 7085-7976; e-mail: pavelrum@gmail.com

Черкасов Дмитрий Алексеевич;
ORCID: https://orcid.org/0000-0001-6750-3997;
e-mail: dr.cherkasov@gmail.com

* Corresponding author / Автор, ответственный за переписку

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Инновационная стратегическая сессия в научной деятельности Центра диагностики и телемедицины

И.А. Виноградова, Л.А. Низовцова, О.В. Омелянская

Научно-практический клинический центр диагностики и телемедицинских технологий, Москва, Российская Федерация

АННОТАЦИЯ

Иногда для того чтобы создавать что-то новое, нужно выходить за рамки возможного и привычного. Человеческий потенциал безграничен, а мир технологических возможностей открывает новые горизонты и помогает достичь даже самой сложной цели.

Настоящему учёному необходимо умение выходить за рамки правил, ограничивающих образ его мыслей. То, что мы знаем, гораздо сильнее препятствует нашему научному прогрессу, чем то, чего мы не знаем. Очистить разум от предвзятости довольно трудно, практически невозможно. Как и невозможно вытащить себя из «колеи» правил без помощи какой-нибудь идеи со стороны.

Последняя неделя июля в ГБУЗ «Научно-практический клинический центр диагностики и телемедицинских технологий Департамента здравоохранения Москвы» была ознаменована ярким, неординарным событием — «Неделей науки», которая показала сотрудникам важность научных открытий как для отдельно взятого человека, так и для общества в целом, и, по сути, явилась площадкой для обсуждения опережающих технологий, вызовов и решений. Четыре дня учёные Центра презентовали и защищали свои доклады, а их коллеги задавали вопросы по применению и воплощению инициатив.

Ключевые слова: искусственный интеллект; нейровизуализация; организация здравоохранения; научные проекты.

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Innovative strategic session in the scientific activity of the Center for Diagnostics and Telemedicine

Irina A. Vinogradova, Lyudmila A. Nizovtsova, Olga V. Omelyanskaya

Research and Practical Clinical Center for Diagnostics and Telemedicine Technologies, Moscow, Russian Federation

ABSTRACT

Sometimes, you need to go beyond the possible and ordinary in order to create something new. Human potential is limitless, and the world of technological possibilities opens up new horizons and helps to achieve the most difficult goals.

A real scientist should think out of the box and go beyond the rules. Sticking with what we know today and being not open to new knowledge hinders our scientific progress. It is quite difficult, if not impossible, to get rid of bias. Similar to how it is almost beyond our possibilities to pull yourself out of the "rut" of the rules without a help.

However, we tried to do impossible possible at our "Science Week." The last week of July at the Research and Practical Clinical Center for Diagnostics and Telemedicine Technologies of the Moscow Healthcare Department was highlighted by this outstanding extraordinary event. During this week, the importance of scientific discoveries for both an individual and whole society was demonstrated. In fact, it was a platform for discussing advanced technologies, challenges, and solutions. For 4 days, the scientists of the Center presented their reports and defended their ideas. Their colleagues took part in the discussion and asked questions about the application and implementation of their initiatives.

Keywords: artificial intelligence; neuroimaging; healthcare management; scientific projects.

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诊断和远程医疗中心科学活动中的创新战略会议

Irina A. Vinogradova, Lyudmila A. Nizovtsova, Olga V. Omelyanskaya

Research and Practical Clinical Center for Diagnostics and Telemedicine Technologies, Moscow, Russian Federation

简评

有时为了创造新东西，你必须超越可能和通常的东西。人类的潜力是无限的，一个充满技术可能性的世界开辟了新天地，有助于实现最具挑战性的目标。

一个真正的科学家需要有能力超越限制其思考方式的规则。我们知道的东西比我们不知道的东西更能成为我们科学进步的障碍。清除头脑中的偏见是相当困难的，几乎不可能。正如没有一些外部想法的帮助，就不可能让自己走出规则的“困境”。

7月的最后一周，在莫斯科医疗保健部门的诊断和远程医疗技术科学与实践临床中心举办了一场精彩非凡的活动——《科学周》，向员工展示了科学发现对个人和整个社会的重要性，事实上，是讨论先进技术、挑战和解决方案的平台。在为期四天的时间里，该中心的科学家们展示并捍卫了他们的报告，他们的同事们就提出了关于如何应用和实施倡议的问题。

关键词：人工智能；神经影像学；医疗机构；科学项目。

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INTRODUCTION

On July 25–28, 2022, the Research and Practical Clinical Centre for Diagnostics and Telemedicine Technologies of the Moscow Department of Health hosted Science Week, the largest scientific event arranged by the Centre and attended by approximately 100 employees from practically all departments and divisions. Due to the wide range of participants, Science Week has become a unique scientific event that can be considered a platform for discussing important interdisciplinary problems of science and technology as well as the first step in promoting research and project activities among young people and a place to demonstrate the achievements of research departments of the Centre.

The Directorate of Science presented more than 40 reports that described original solutions going beyond the existing paradigms and suggested responses to great challenges including social risks and threats.

Science Week plays an important role as a space for broad communication, allowing colleagues to suggest new research topics and areas, share initiatives, increase networking, and cooperate for working on projects. Researchers reported wishing to prove themself in related areas, new collaborations were born, and participants showed keen interest in each other's ideas.

During preparation for Science Week, Yuriy A. Vasilyev, Candidate of Medical Sciences, Director of State Budgetary Healthcare Institution of the Research and Practical Clinical Centre for Diagnostics and Telemedicine Technologies, asked participants to focus on visionary scientific work, which means to come up with something unusual and interesting. "There should be no limits for science. Even the most unordinary ideas should have a chance to be implemented if they seem valuable," he said.

RESEARCH PROJECTS AND DISCUSSION

Most projects were covered by two main areas, namely, research and practical projects aimed at facilitating the study participation or treatment process for patients, and healthcare management projects aimed at simplifying the work of healthcare professionals including nursing staff. There were various ideas including fundamental proposals going beyond existing approaches and methods. Each presentation ended with an online vote with all participants evaluating the viability of each project presented, followed by active discussion and a Q&A session.

The Developing an R&D Centre project presented by Daria Sharova, the Head of Innovative Technologies was voted the leading project. Her presentation outlined the global goal of the project which is to ensure a universally high level of medical device development in Russia by creating an R&D Centre based on the Centre for Diagnostics and Telemedicine.

The presentation by Roman Reshetnikov, the Head of Medical Research, also attracted great interest. Its topic was "Psychoradiology: Detection of Mental Disorders Using Radiation Diagnostics." The project is dedicated to the urgent problem of population screening for mental disorders, which are among the top five diseases or disorders leading to

The Steering Committee headed by Yuriy A. Vasilyev, Candidate of Medical Sciences, Director of the Research and Practical Clinical Centre for Diagnostics and Telemedicine Technologies.

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Science Week is well underway. Day 3.

disability. To solve this problem, it was proposed to create a trusted diagnostic tool using objective and evidence-based neuroimaging biomarkers. Among other features, this tool allows the clinician to provide timely and personalized psychological counseling for those patients who need it. When discussing the project, some opportunities were revealed for cooperation with other relevant scientific and medical organizations.

Denis Leonov, the Senior Research Fellow of Medical Research, presented the "Affordable Teaching Phantoms for Medical Universities" start-up project, which was also considered very interesting. The project aims to increase the effectiveness of teaching medical students by introducing a line of phantoms into the educational process. Phantoms can imitate the setting of diagnostic ultrasound of various human organs, including cerebrovascular ultrasound. Phantoms provide closer conditions to real-world clinical practice and there is wide scope for the method. Commercial medical ultrasound phantoms are very specific as they simulate specific clinical scenarios. As a result, they are too expensive to be used in a multidisciplinary research and teaching process [1]. When fulfilling a government order, a unique technique has been developed to arrange affordable serial production of phantoms for a specific clinical task. There are two proposed options, namely, large-scale production which is more affordable and manufacturing single phantoms to order. Considering the market volume in Russia, the volume of such production can be approximately 2000 pieces per year.

Anastasiya Smorchkova, a Junior Researcher at Innovative Technologies, presented a project "Screening for Cerebral Artery Aneurysms and Evaluating Their Significance in Younger Patients." A ruptured cerebral aneurysm is one of the most common causes of nontraumatic intracerebral hemorrhage (approximately 13 cases per 100,000 per year). At the same time, in the period from aneurysm rupture to treatment, the mortality rate is 10%–15% [2]. According to clinical guidelines [3], noninvasive screening can be recommended for every person over 30 years of age, regardless of risk factors. The definitive factors of rupture risk are the perpendicular aneurysm height and the size ratio of the aneurysm and the adjacent vessel. These parameters can be evaluated by neuroimaging methods. As a solution, the authors proposed developing a morphometric artificial intelligence algorithm for detecting and measuring salient sizes and estimating the

Phantoms can be used for ultrasound imaging of blood vessels through the skull bones.

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The conference ended with a lively discussion.

aneurysm rupture probability. Therefore, this project may contribute to the increased detection of hidden (unruptured) cerebral aneurysms and potentially reduce mortality and disability in younger patients. During the discussion, the high social significance of the project was noted, as it is aimed at preventing the mortality of people of working age.

A series of reports presented by Ivan Blokhin, acting Head of the Research Sector in Radiation Diagnostics, was followed by a lively discussion. He described necessary changes in management in radiology departments suggesting solutions for interacting with patients as well as for optimizing and increasing the efficiency of radiologists. The Information Materials for Correct Patient Preparation for an Investigation project proposed to develop digital and paper information materials for patients preparing for the most common types of X-rays, CT, and MRI to reduce the number of delayed examinations due to poor patient preparation and the number of duplicate examinations due to poor image quality. The Working Memory of a Medical Organisation presentation proposed to analyze the time intervals for radiation diagnostics in various medical organizations. This analysis allows the optimization of operating and logistics processes in outpatient medical organizations by tracking patients at each stage of the diagnostic process using code bracelets and identifying pitfalls in routine outpatient practice.

All presentations are included in the Bank of Research Projects of the Centre for Diagnostics and Telemedicine.

In addition, the discussion highlighted the most promising areas that need to be included in a 3-year research plan of the Centre for Diagnostics and Telemedicine.

CONCLUSION

One of the outcomes of this event lies in developing an environment for the open long-term planning of research activities.

Scientists noticed how important it is to get a critical review because this helped them to see the weaknesses and potential problems of their projects. In addition, employees shared ideas and ways of doing similar work, so now they can try to optimize and improve their own projects.

At the end of Science Week, Yuriy Vasilyev, the Director of the Centre for Diagnostics and Telemedicine, expressed his hope that this event will become a regular one and will attract a growing number of participants every year.

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AUTHORS' INFO

*** Irina A. Vinogradova,** Cand. Sci. (Tech.);
address: 24 Petrovka str., 127051, Moscow, Russia;
ORCID: https://orcid.org/0000-0001-6465-4132;
eLibrary SPIN: 6493-1970; e-mail: i.vinogradova@npcmr.ru

Lyudmila A. Nizovtsova, MD, Dr. Sci. (Med), Professor;
ORCID: https://orcid.org/0000-0002-9614-4505;
eLibrary SPIN: 9957-8107; e-mail: lanizo@yandex.ru

Olga V. Omelyanskaya;
ORCID: https://orcid.org/0000-0002-0245-4431;
eLibrary SPIN: 8948-6152; e-mail: o.omelyanskaya@npcmr.ru

ОБ АВТОРАХ

*** Виноградова Ирина Александровна,** к.т.н.;
адрес: Россия, 127051, Москва, ул. Петровка, д. 24;
ORCID: https://orcid.org/0000-0001-6465-4132;
eLibrary SPIN: 6493-1970; e-mail: i.vinogradova@npcmr.ru

Низовцова Людмила Арсеньевна, д.м.н., профессор;
ORCID: https://orcid.org/0000-0002-9614-4505;
eLibrary SPIN: 9957-8107; e-mail: lanizo@yandex.ru

Омелянская Ольга Васильевна;
ORCID: https://orcid.org/0000-0002-0245-4431;
eLibrary SPIN: 8948-6152; e-mail: o.omelyanskaya@npcmr.ru

* Corresponding author / Автор, ответственный за переписку