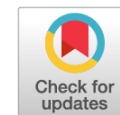# Мобилизация научно-практического потенциала службы лучевой диагностики г. Москвы в пандемию COVID-19

© С.П. Морозов[1], Е.С. Кузьмина[1], Н.В. Ледихова[1], А.В. Владзимирский[1], И.А. Трофименко[1], О.А. Мокиенко[1], Е.В. Панина[1], А.Е. Андрейченко[1], О.В. Омелянская[1], В.А. Гомболевский[1], Н.С. Полищук[1], И.М. Шулькин[1], Р.В. Решетников[1, 2*]

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Уже в начале первой волны пандемии COVID-19 для компьютерной томографической (КТ) диагностики поражения лёгких у пациентов с подозрением на вирусную пневмонию в Москве была сформирована сеть амбулаторных КТ-центров (АКТЦ) с круглосуточным режимом работы. Введение шкалы «КТ 0–4» позволило проводить эффективную маршрутизацию. Для предотвращения распространения инфекции среди пациентов и персонала было введено зонирование АКТЦ с разбиением на «красную», «буферную» и «зелёную» зоны. В рамках мобилизации службы лучевой диагностики создан Московский референс-центр, осуществляющий контроль качества, экспертные дистанционные консультации и организационно-методическое сопровождение. Разработано несколько дистанционных курсов и обучающих вебинаров. Для распознавания признаков COVID-19 и оценки степени тяжести были подключены сервисы искусственного интеллекта. Разработанная стратегия службы лучевой диагностики г. Москвы обеспечила готовность к высокой нагрузке на систему здравоохранения города и позволила минимизировать потери среди медицинского персонала. Специалисты службы внесли существенный вклад в эффективное сдерживание распространения инфекции за счёт доступной, своевременной и качественной диагностики и маршрутизации.

Ключевые слова: КТ; COVID-19; искусственный интеллект.

Mobilizing the academic and practical potential of diagnostic radiology during the COVID-19 pandemic in Moscow

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At the beginning of the first wave of the COVID-19 pandemic, a network of outpatient CT centers (OCTC) for lung pathology diagnostics in patients with suspected viral pneumonia with the round-the-clock operation was formed in Moscow. The introduction of the "CT 0–4" scale allowed for effective routing. To prevent the spread of infection among patients and staff, OCTC zoning was introduced, dividing into "red," "buffer," and "green" zones. As part of the mobilization of the Radiology Service, the Moscow Reference Center was established, aimed at quality control, remote expert consultations, and organizational and methodological support. Several online courses and training webinars have been developed. Artificial Intelligence services were connected to recognize the signs of COVID-19 and assess the severity.

The developed strategy of the Moscow Radiology Service ensured readiness for the high burden on the city health care system and minimized losses among medical personnel. The experts significantly contributed to effective infection control through accessible, timely, and high-quality diagnostics and routing.

Keywords: CT; COVID-19; artificial intelligence.

调动莫斯科辐射诊断服务处在COVID-19大流行中的科学和实际潜力

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在2019冠状病毒第一波大流行开始之际，莫斯科已经建立了一个24小时运转的门诊CT诊断中心，用于对疑似病毒性肺炎患者肺部损伤的计算机断层扫描（CT）诊断。CT0—CT4量表的引入允许高效路由。为防止感染在患者和工作人员之间的传播，门诊CT中心被分为《红色》、《缓冲》和《绿色》区。作为辐射诊断服务动员的一部分，成立了莫斯科基准中心，进行质量控制、专家远程咨询以及组织和方法支助。还编制了几个远程学习课程和网络讨论会。人工智能服务被用于识别COVID-19的迹象和评估疾病的严重程度。莫斯科辐射诊断服务处制定的战略确保为该市医疗系统的高负荷做好准备，并使医务人员的死亡率降至最低。该服务处的专家通过可达性、及时和高质量的诊断和路由，为有效遏制疫情传播作出了重大贡献。

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Moscow — a large and busy metropolis with an extensive network of airports—will always remain at the center of any outbreak of an infectious disease. It is not surprising that 26% of all reported coronavirus disease (COVID-19) cases in Russia is accounted for Moscow [1], which secured its position among the cities with the highest rates of COVID-19 cases[1]. However, Moscow's first-hand experience in managing the outbreak is, in its own way, distinctive. During the first wave, the peak incidence of 53 cases per 100,000 people was registered on May 7, 2020 [1], although the strict lockdown was announced only on March 29, 2020[2]. To put this into perspective, in large cities of Spain, Germany, Italy, and USA, the period between the introduction of lockdown measures and the surge in COVID-19 cases was 12 ± 3 days[3] [2–4]. Such a slowdown can largely be associated with the agents of Moscow Health Care Department who developed and implemented national action plans, where the primary care sector played the pivotal role.

The key goals of the health care system during any pandemic are to limit disease spread and reduce case fatality rates. For this reason, only patients with objectively severe condition are hospitalized, whereas patients with asymptomatic COVID-19 who are capable of managing their illness at home are quarantined. Failure to do so could overload the national health care system, which could negatively affect the quality of health services and propagate adverse treatment outcomes.

Diagnostic tests that detect viral RNA based on reverse-transcription polymerase chain reaction (RT-PCR) are considered as reference standards for the diagnosis of COVID-19. However, this method has low sensitivity [5], the testing process is slow, the RT-PCR testing for severe acute respiratory syndrome coronavirus 2 has high false-negative rate [6], and the availability and quality of reagents are critical for successful testing. For example, the shortage in viral RNA isolation kits became a major problem of laboratories worldwide[4]. Moreover, although RT-PCR testing helps determine disease severity by measuring the viral load [7], the diagnosis is established exclusively by the presence of either positive or negative test results. This disadvantage adds to the overall lack of clinical information.

One of the most common COVID-19 symptoms is viral pneumonia [8]. Computed tomography (CT) of the chest, though not known as a conventional modality in the diagnosis of acute respiratory virus infections, is very sensitive in examining for the presence of consolidations in the lungs—a typical sign of COVID-19. In light of this, the Moscow Radiology Department developed and introduced a strategy (Fig. 1) that revolved around the concept of a "clinically confirmed COVID-19 case".

This concept offers the criteria for COVID-19 diagnosis, which include a combination of symptoms typical for acute respiratory infection and presence of distinct patterns in the lungs. To measure the consolidation area, the clinicians developed an empirical visual scale "CT 0–4," which consists of five grades [9]. Here, CT-0 is assigned to patients who do not manifest pneumonia symptoms, while the remaining grades differ from one another by the size of the consolidation, each being 25% bigger than the previous. As the pandemic passes, chest CT has become a major component of COVID-19 diagnostics.

The introduction of the "CT 0–4" scale contributed to improving the triage process: while patients presenting with CT-0, CT-1, and CT-2 grades are managed at home with the assistance of telemedicine technologies, those with severe condition required immediate hospitalization. This strategy helped optimize the burden on municipal hospitals and completely yielded good results. According to our estimates, less than 5% of patients with CT-0 and CT-1 to CT-2 were hospitalized as their condition worsened [10].

A chain of outpatient CT centers (OCTC) was established in municipal polyclinics to streamline the screening, routing, and real-time monitoring of patients with COVID-19. All 48 CT scanners in OCTCs were connected into a common digital network powered by ERIS EMIAS. This solution allowed radiologists to carry out distant reading of imaging results and therefore massively reduced the risk of getting infected, the importance of which can barely be overestimated.

During the pandemic, the activities of all Moscow Health Care Department screening programs have been suspended, so radiographers and surgical nurses were re-assigned to OCTCs. To prevent the spread of infection among patients and healthcare workers, the OCTC facilities were segregated into "red," "buffer," and "green" zones. The red zone contains scanning equipment, cleaned with disinfectants after each patient. All medical personnel assigned to

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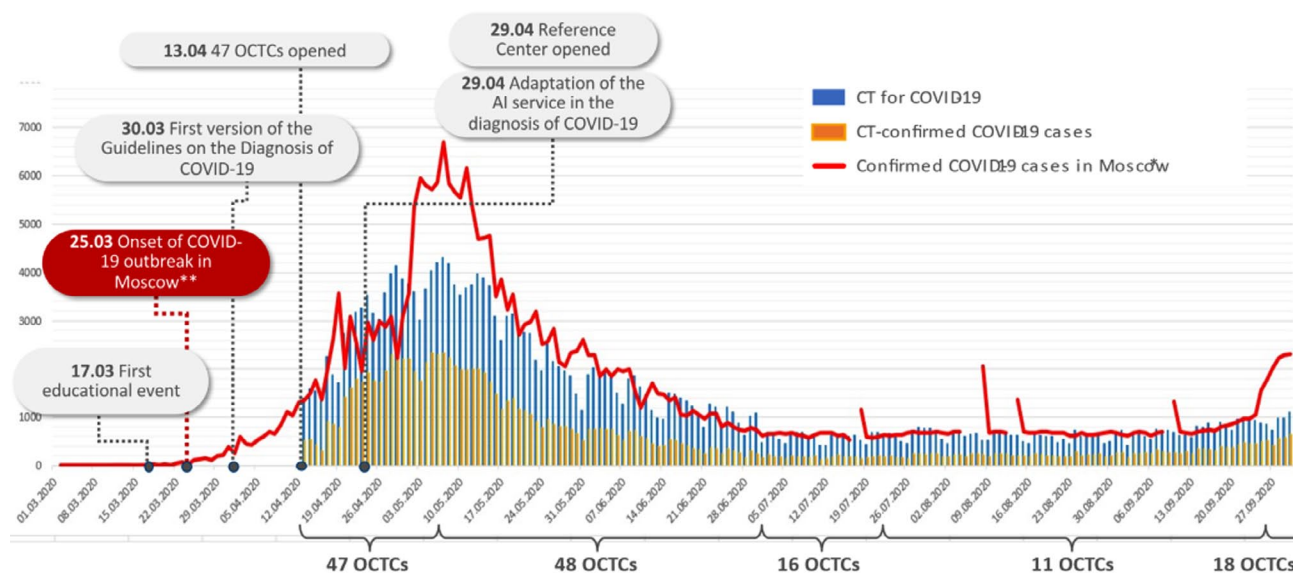
Fig. 1. Activation of the diagnostic radiology resources during the COVID-19 pandemic in Moscow.

the red zone were provided with grade 3 personal protective gear. In the buffer zone, the healthcare workers put on and take off their PPE; the zone is divided into three areas: used PPE area, disinfection area, and clean PPE area. Finally, the green zone contains doctors' offices and control area.

As part of measures taken to implement the strategy, health authorities established the Moscow Radiology Reference Center to supervise the quality of readings, provide distant consultations, and secure administrative and clinical support for OCTC workers.

Social media and messengers became an additional tool that brought together various specialists. An example is the "MRO.LIVE club for radiologists and radiographers" Telegram channel with 3,228 subscribers, most of which are medical imaging specialists. The channel became an invaluable tool for communication and real-time consultations. This is also a place where clinicians share information about the current status of the pandemic, regulatory documents, and educational activities.

The inflow of new health workers and rapid accumulation of scientific knowledge about the diagnosis of COVID-19 called for more educational programs for medical personnel. We have developed several short-term online courses and interactive webinars for different target audiences, such as OCTC administrators, radiologists, radiographers and assistants. Between February and October of 2020, our courses and webinars were attended by over 50,000 specialists. Approximately 10,500 radiographers specializing in different imaging modalities underwent training on chest CT.

To recognize COVID-19 signs, 149 imaging devices from 85 medical facilities in Moscow were connected to an artificial intelligence (AI) service. From April 29 to October 19, the AI service evaluated over 350,000 CT studies for COVID-19 signs. The AI system has accuracy and sensitivity of 0.91, specificity of 0.92, false-negative rate of 7.4 %, and false-positive rate of 1.6%. The implementation of the AI technology to OCTC allowed automation of information delivery, which helped clinicians prioritize the studies in their worklists. This experiment demonstrated the functional capabilities of the automated analysis of medical images by an algorithm that establishes the location of abnormalities and sends notifications to specialists, along with the practical value of the automated preparation of draft radiology reports. In addition, employees of the Moscow Center for Diagnostics & Telemedicine developed and opened free access to the world's largest reference dataset on COVID-19[5].

As of October 19, 2020, OCTC specialists have conducted 268,567 CT studies. The record was achieved by one CT scanner that made 204 CT studies in 1 day. Pneumonia signs were detected in 130,138 patients, 126,761 of which were diagnosed with "clinically confirmed COVID-19 case". As a result, over the specified period, 34.5% of all diagnoses in Moscow were established using medical imaging techniques.

Despite the 24/7 operation, the OCTC personnel were successfully shielded from the infection. In total, the workforce of 48 Moscow outpatient centers consisted of 485 radiologists and 775 radiographers. The average number of infected radiologists was 10 ± 4 (2.1%); the number of affected radiographers exceeded that for a small margin at 22 ± 12 (2.8%).

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The developed operation strategy of Moscow's radiology service (Fig. 1) secured even distribution of health care burden during the pandemic and minimized losses among the medical personnel. Clinical experts played an important role in holding down the infection levels with the help of widely available, well-timed, and high-quality diagnostic and routing services. Emergency activation of the primary care segment and accessible radiology scanning solutions secured sustainable detection of disease symptoms, streamlined the delivery of diagnostic data, and ultimately helped reach the plateau on disease statistics. At present, the world is facing a second wave of the pandemic, and the Moscow Health Care Department is willing to stay ahead of the game at all times. Considering the massive uptake of laboratory testing, the need for mass screening with medical imaging is not as urgent anymore. With that said, our developments and accumulated expertise are among the top requested in other regions of the Russian Federation and abroad. We continuously share our knowledge through educational programs, webinars, and academic publications.

ADDITIONAL INFO

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