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APPLICATION OF LUNG CANCER CT ARTIFICIAL INTELLIGENCE TECHNOLOGY IN LOW-DOSE COMPUTED TOMOGRAPHY FOR EARLY DETECTION OF LUNG CANCER

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ABSTRACT

Relevance: *In recent years, there has been an increase in the use of artificial intelligence (AI) technology in chest low-dose computed tomography (LDCT), which has attracted considerable attention. LDCT scans are widely used for early detection and monitoring of lung diseases, making the accurate analysis of these scans crucial for effective diagnosis and treatment.*

The study aimed to *evaluate the diagnostic effectiveness of an AI system in clinical practice by comparing its sensitivity in detecting pulmonary nodules and differentiating between benign and malignant processes with radiologists. Additionally, it aimed to provide a theoretical basis for the clinical application of AI in LDCT.*

Methods: *The study is based on a retrospective analysis of LDCT scans performed in a pilot lung cancer screening project. High-resolution tomography followed standardized low-dose scanning protocols, and experienced radiologists and an expert with many years of practice interpreted the results. Modern deep learning frameworks (TensorFlow, PyTorch) were applied for data analysis and nodule segmentation.*

Results: *The study results demonstrated that the deep learning model detected pulmonary nodules with a sensitivity of 63.4% (95% CI: 54.0-72.8%) and a specificity of 81.6% (95% CI: 79.8-83.4%), consistent with previous studies findings.*

Conclusion: *Like previous published studies, this study demonstrates that AI can enhance the LDCT interpretation process. However, despite the obtained diagnostic value, it requires further refinement for full implementation in clinical practice.*

Keywords: *artificial intelligence (AI), low-dose computed tomography (LDCT), lung cancer.*

Introduction: Lung cancer is the second most common type of malignant tumor in men and women (after prostate and breast cancer, respectively) and a leading cause of cancer mortality worldwide. According to the World Health Organization (WHO), in 2020, there were 2.2 million new cases of lung cancer and 1.8 million deaths from this burden [1].

Lung cancer is an urgent health problem both throughout the world and in the Republic of Kazakhstan, as it ranks second in morbidity and the main cause of mortality from malignant neoplasms. In 2021, 3,615 new cases of lung cancer and 2,086 deaths were registered in Kazakhstan [2].

Early lung cancer diagnostics is critical for successful treatment and improvement of overall survival rates. According to the literature, low-dose computed tomography (LDCT) is an effective lung cancer screening method. It makes it possible to find cancer at an early stage, resulting in a decrease in mortality from this pathology [3-6]. LDCT screening requires the interpretation of a large number of images. It can be a time-consuming process subject to variability depending on the radiologist's experience. Artificial intelligence (AI) can improve the accuracy and efficiency of lung cancer screening using LDCT by automating image analysis and providing decision-making support to radiologists [7], as well as reducing the time to interpret LDCT images.

Over the past 10 years, significant advances have been made in using AI technology for early lung cancer diagnostics using LDCT. Several studies have demonstrated that AI algorithms can accurately identify and classify lung nodes on CT scans. It greatly improves and is critical for the early diagnostics of lung cancer. Besides increasing lung cancer detection in the early stages, AI can also increase the efficiency of LDCT screening [7-9].

Despite the promising results of the AI models developed in lung cancer screening, aspects still need to be studied. The AI algorithms developed should be improved with more diverse data sets to increase generalizability in different populations, for example, for Central Asians to validate based on the results obtained.

The study aimed to evaluate the diagnostic effectiveness of an AI system in clinical practice by comparing its sensitivity in detecting pulmonary nodules and differentiating between benign and malignant processes with radiologists. Additionally, it aimed to provide a theoretical basis for the clinical application of AI in LDCT.

Materials and methods:

Materials: The data of LDCT studies conducted as part of a pilot project for lung cancer screening from June 1, 2018, to September 31, 2023, in the cities of Almaty, Ust-Kamenogorsk, and the Almaty region were studied retrospectively.

Scanning was performed at the з of Oncology and Radiology (KazIOR) and the East Kazakhstan Regional Multidisciplinary Center for Oncology and Surgery. Computed tomography scanners with a different number of detectors (from 64 to 128) and a slice thickness of not more than 1.25 mm were used for scanning. All scanners had a low-dose scanning protocol: voltage 120 kV, current strength 10-40 mA. The effective dose for the patient did not exceed 1 mSv according to the order on preventive examinations of the population in Kazakhstan [10]. Segmentation, annotation, and interpretation of LDCT scans were performed by 4 radiologists with more than 6 years of experience (Figure 1). The results of LDCT studies were retrospectively analyzed by an invited expert with 30 years of experience in reading computed tomography examinations of the lungs to determine the number of "true" nodes. Lung nodules were classified according to the Lung Imaging Reporting and Data System (Lung-RADS 1.1).

The deep learning model was developed by IT specialists of KazIOR using special deep learning frameworks and sources (libraries) (TensorFlow, PyTorch) (Figure 1).

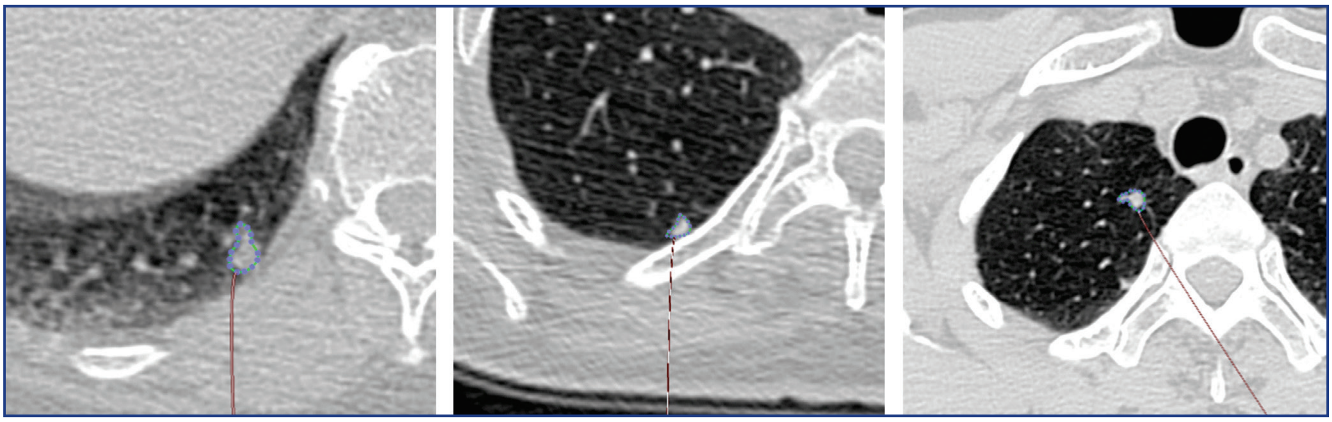

Figure 1 – Segmentation of pulmonary nodule contours on LDCT scans of the patient LDCT0266 performed as part of a pilot lung cancer screening project

Methods:

Data pre-processing:

LDCT obtaining and anonymization.

Extracting regions of interest (ROIs) containing lung nodes from LDCT scans and creating fragments of 2D or 3D images.

Annotations for regions of interest containing nodules in the lungs.

Model development:

Selecting and implementing deep learning architectures for pulmonary nodule diagnostics.

Creating learning models using the annotated CT scans.

Hyperparameter tuning to optimize model performance.

Model assessment:

Assessing the AI model performance using a control set of CT scans and diagnostic value data.

Statistical analysis:

The results were statistically analyzed using appropriate tests (t-tests, chi-squared) and modeling methods (logistic regression). Cohen's Kappa coefficient was used to study the degree of agreement between radiologists and the AI model.

According to international requirements, the statistical significance of findings was checked using the p-value and confidence intervals. The statistical processing results were considered statistically significant at $p < 0.05$ obtained using the Monte Carlo method. All data obtained during the study were statistically processed. The data was statistically processed using SPSS software version 21.0 and Microsoft Office Excel.

The study was approved by the local ethics committee of the Kazakh Institute of Oncology and Radiology JSC (Almaty, Kazakhstan).

Results: The study analyzed LDCT scans of 1,500 lung cancer screening program participants. Our deep learning model for lung cancer screening demonstrated a sensitivity of 63.4% (95% CI: 54.0-72.8%) and a specificity of 81.6% (95% CI: 79.883.4%) when detecting lung nodules by LDCT. The Lung Cancer CT model was trained on a dataset of annotated CT scans and tested on a reference dataset of 1,000 CT scans. Then, we analyzed the efficiency of the deep learning model, comparing it with the work of radiologists with different levels of experience.

The data in Figure 2 demonstrate that the proposed model, trained to find lung nodules, successfully identified a lung nodule by indicating its location using labels. It illustrates the potential of AI in the automatic detection and diagnostics of pulmonary pathologies.

However, it should be noted that it is always necessary to consider possible limitations and potential errors when interpreting the results based on AI systems. In this case, despite the successful diagnostics of the mass, there may be situations where the AI mistakenly identifies pleural adhesions at the apices of the lungs (Figure 3) as lung nodules or has limited capabilities to find subpleural nodules.

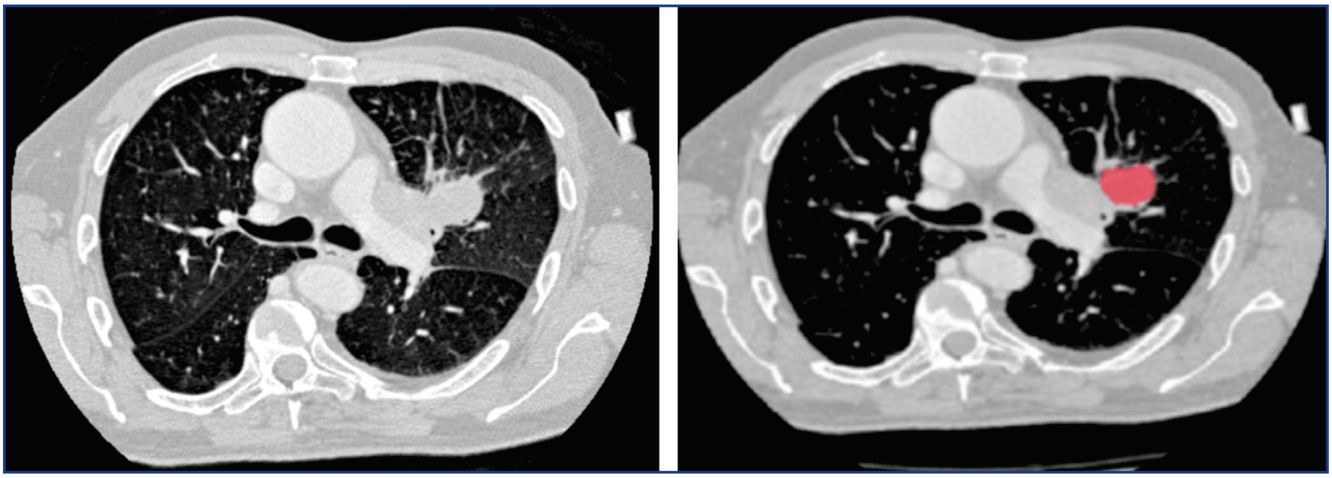

Figure 2 – LDCT image of the central neoplasm S1/2 in the upper lobe of the left lung of the patient LDCT0286 performed as part of the pilot project on lung cancer screening

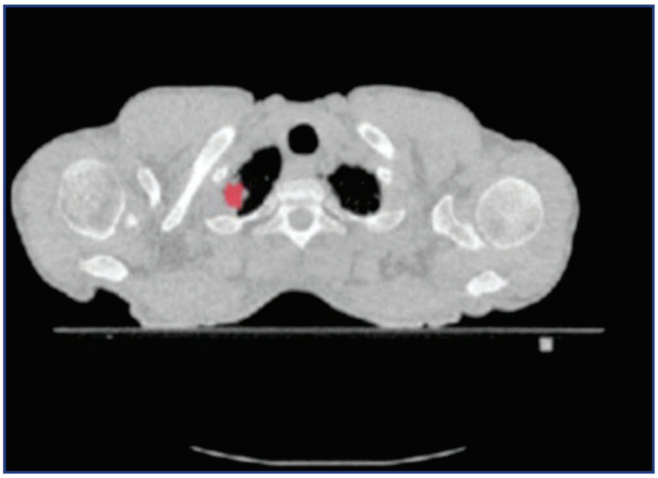

Figure 3 – Pleural adhesions at the apices of the lungs that the AI mistakenly identified as lung nodules, patient images LDCT1106 performed as part of the pilot lung cancer screening project

The AI model's performance was similar to radiologists with less than 5 years of experience, with a sensitivity of 67.1% and a specificity of 83.8%. More experienced radiologists showed higher accuracy in diagnostics of pulmonary nodules, with a sensitivity of 94.2% and a specificity of 98.8%. However, radiologists needed three times more time to interpret LDCT than AI technologies.

It was also found that the deep learning model improves the radiologists' work by increasing the volume of interpreted LDCT studies within the same time interval by 38%.

However, it should be noted that the AI model showed lower sensitivity (40%) and specificity (82%) during detecting subpleural nodules of different sizes. When the model's performance was analyzed for the size and location of the lung nodules, it was found that the AI showed better results in detecting parenchymal lung nodules in patients with larger lung nodules (> 10 mm in diameter) compared to smaller nodules (< 10 mm in diameter) with a sensitivity of 83.3% and 67.8%, respectively.

Discussion: Our study assessed the efficiency of the deep learning model in lung cancer screening using LDCT. The model achieved a sensitivity of 63.4% and a specificity of 81.6% in detecting pulmonary nodules, and it is consistent with previous studies that reported sensitivity from 63% to 96% and specificity from 60% to 98% [11-14]. It was also found that the AI model performance is similar to that of radiologists with less than 5 years of experience, indicating its potential for development.

This is consistent with previous studies that reported that experienced radiologists have higher sensitivity and specificity than less experienced physicians [15-17]. However, the fact that radiologists in both groups spent more time interpreting the results than the AI model suggests that the AI model may be a more efficient and reliable alternative to manual CT interpretation, especially for less experienced radiologists.

Despite the promising results of AI use in lung cancer screening, our study identified several significant limitations that need to be considered in the clinical application of AI:

Low accuracy in detecting subpleural nodules: In this study, AI demonstrated a significantly lower sensitivity (40%) and specificity (82%) in detecting subpleural nodules, especially those of a small diameter (<10 mm). This limits the model's effectiveness in detecting neoplasms in hard-to-interpret areas, which may lead to the omission of potentially malignant neoplasms.

Error in classifying pulmonary structures: In some cases, AI mistakenly interprets pleural adhesions, especially in the apices of the lungs and vessels, and degenerative changes in vertebral elements as pulmonary nodules. It can lead to false positives, increasing the burden on doctors.

Limited ability to interpret complex cases: Although AI-based technology can significantly improve the diagnostics of pulmonary nodules, its capabilities in complex clinical cases, such as multifocal or diffuse pulmonary parenchymal lesions and central lung neoplasms, remain limited.

The study showed the need to further refine the Lung Cancer CT model to detect subpleural nodules. This may require including additional characteristics of the elements or a large amount of data.

Despite the limitations in detecting subpleural lesions, our study suggests that the AI model could be useful for lung cancer screening with LDCT. The Lung Cancer CT model improved the performance of radiologists with less than 5 years of experience and increased the total volume of LDCT scans interpreted by radiologists. AI technology certainly has the potential to improve the efficiency and accuracy of lung cancer screening using LDCT [16-18]. However, further study is required to test the model's performance on larger, more diverse data sets.

Although many AI models are developed and tested today, there is still a need to find the most optimal models for automatic detection and differentiation of pulmonary nodules on LDCT scans. Our results suggest that such a model could be useful in lung cancer screening with LDCT, especially for less experienced radiologists, and could increase the amount of CT data processed. However, further improvements are needed to increase its sensitivity and specificity, especially when smaller and subpleural lesions are found. Further study is needed to test the model's performance with a larger sample.

Conclusion: In this study, the Lung Cancer CT model has proven the potential of AI models in lung cancer screening. Despite technological limitations in detecting subpleural nodules and small-diameter lung nodules, the model could become a valuable tool for improving the overall efficacy of screening programs. However, further improvement and validation are required to realize the full potential of AI models in lung cancer screening.

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АҢДАТПА

ӨКПЕ ҚАТЕРЛІ ІСІГІН ЕРТЕ ДИАГНОСТИКАЛАУ ҮШІН АЗ ДОЗАЛЫ КОМПЬЮТЕРЛІК ТОМОГРАФИЯДА LUNG CANCER CT ЖАСАНДЫ ИНТЕЛЛЕКТ ТЕХНОЛОГИЯСЫН ҚОЛДАНУ

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Өзектілігі: *Соңғы жылдары өкпенің аз дозалы компьютерлік томографиясын (АДКТ) жасағанда жасанды интеллект (ЖИ) технологиясын қолдану айтарлықтай артқандықтан оған деген назар да артып келеді. АДКТ өкпе ауруларын ерте анықтау және бақылау үшін кеңінен қолданылады, ал тиімді диагностика мен емдеу үшін зерттеуді нақты талдау өте маңызды.*

Зерттеудің мақсаты *– өкпе түйіндерін анықтау сезімталдығын және қатерлі мен қатерсіз үдерістерді ажыратудағы жасанды интеллект (ЖИ) жүйесінің диагностикалық тиімділігін клиникалық тәжірибеде бағалау, оны радиолог дәрігерлердің нәтижесімен салыстыру, сондай-ақ клиникалық қолдануға теориялық негіз ұсыну.*

Әдістері: *Зерттеу өкпе қатерлі ісігін скринингтеу бойынша пилоттық жоба аясында орындалған АДКТ скандарын ретроспективті талдауға негізделген. Ажыратылымы жоғары томографтарда аз дозалы стандартталған сканерлеу хаттамалары қолданылып, нәтижелерді тәжірибелі радиологтар мен көпжылдық тәжірибесі бар сарапшы интерпретациялады. Деректерді талдау және түйіндерді сегментациялау үшін заманауи терең оқыту платформалары (TensorFlow, PyTorch) қолданылды.*

Нәтижелері: *Біз жүргізген зерттеу нәтижесі бойынша өкпедегі түйіндерді анықтауға арнап әзірленген Lung Cancer CT терең оқыту моделінің өкпе түйіндерін анықтауда сезімталдығы 63,4% (95% СИ: 54,0-72,8%) және арнайылығы 81,6% (95% СИ: 79,8-83,4%) екенін көрсетті.*

Қорытынды: *Аталмыш зерттеу жұмысы осыған дейінгі зерттеулерде көрсетілген ақпаратты растай отырып, ЖИ АДКТ талдауын жақсарта алатынын көрсетті. Алайда өкпе түйіндерін ерте анықтаудағы АДКТ сезімталдығы мен арнайылық көрсеткіштеріне қарамастан, ЖИ оларды анықтау үшін қосымша жетілдірулер мен дайындықты қажет етеді.*

Түйінді сөздер: *жасанды интеллект (ЖИ), аз дозалы компьютерлік томография (АДКТ), өкпе обыры.*

АННОТАЦИЯ

ПРИМЕНЕНИЕ ТЕХНОЛОГИИ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА LUNG CANCER CT ПРИ НИЗКОДОЗНОЙ КОМПЬЮТЕРНОЙ ТОМОГРАФИИ ДЛЯ РАННЕЙ ДИАГНОСТИКИ РАКА ЛЕГКОГО

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Актуальность: *В последние годы отмечается рост применения технологии искусственного интеллекта (ИИ) при выполнении низкодозной компьютерной томографии (НДКТ) легких, что, в свою очередь, привлекает значительное внимание. НДКТ широко используется для раннего выявления и мониторинга заболеваний легких, а точный анализ исследований имеет важное значение для эффективной диагностики и лечения.*

Цель исследования *– оценить диагностическую эффективность ИИ-системы в клиническом применении, сравнивая чувствительность к обнаружению легочных узлов и дифференциацию доброкачественных и злокачественных процессов с помощью ИИ и врачей-радиологов, с предоставлением теоретической основы для клинического использования.*

Методы: *Исследование основано на ретроспективном анализе НДКТ исследований, выполненных в рамках пилотного проекта по скринингу рака легкого. Использованы стандартизированные протоколы низкодозного сканирования на томографах с высоким* *разрешением, а интерпретация результатов проводилась опытными радиологами и экспертом с многолетним стажем. Для анализа данных и сегментации узлов применялись современные фреймворки глубокого обучения (TensorFlow, PyTorch).*

Результаты: *Результаты исследования показали, что модель глубокого обучения Lung Cancer CT, созданная для определения легочных узлов, обладает чувствительностью 63,4% (95% ДИ: 54,0-72,8%) и специфичностью 81,6% (95% ДИ: 79,8-83,4%).*

Заключение: *ИИ может улучшить процесс интерпретации НДКТ, однако, несмотря на полученные значения диагностической ценности, все еще требует дополнительной доработки для полного применения в практике.*

Ключевые слова: *искусственный интеллект (ИИ), низкодозная компьютерная томография (НДКТ), рак легкого.*

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