РОЛЬ РЕНТГЕНОЛОГА В РАЗРАБОТКЕ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА: ИССЛЕДОВАТЕЛЬСКИЙ ПРИМЕР АВТОМАТИЧЕСКОЙ ОЦЕНКИ СКОЛИОЗА НА РЕНТГЕНОГРАММАХ ПОЗВОНОЧНИКА

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КЛЮЧЕВЫЕ СЛОВА:

- искусственный интеллект
- радиология
- медицинская визуализация

АННОТАЦИЯ:
Введение: искусственный интеллект (ИИ) стал неотъемлемой частью медицинской визуализации, оказывая существенную поддержку рентгенологам. Специалисты лучевой диагностики играют значимую роль в разработке приложений искусственного интеллекта, предназначенных для автоматизированной диагностики медицинских изображений.
Цель: изучить роль рентгенологов в создании приложения искусственного интеллекта для оценки сколиоза по цифровым рентгенограммам.
Материал и методы: для анализа процесса создания приложения Esper.Scoliosis, в котором активно участвовали два врача-рентгенолога, использовался качественный, ретроспективный, углубленный исследовательский подход. Третий радиолог принял участие в тестировании и оценке.
Результаты: рассматривая процесс разработки приложения, мы отметили, что врач-рентгенолог играл основную роль практически на каждом этапе создания приложения. Мы разделили работу радиолога по созданию приложения на три основные части: теория, обработка и маркировка данных, тестирование и оценка.
Вывод: роль радиолога важна в разработке интеллектуального приложения. Активное участие рентгенологов на каждом этапе необходимо не только для оптимизации производительности приложения, но также может побудить их поддерживать использование различных приложений искусственного интеллекта в их повседневной работе.

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RADIOLOGISTS IN ARTIFICIAL INTELLIGENT DEVELOPMENT: AN EXPLORATORY CASE STUDY OF AUTOMATED SCOLIOSIS ASSESSMENT ON SPINAL RADIOGRAPHS

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- artificial intelligence
- radiology
- medical imaging

ABSTRACT:
Introduction: artificial Intelligence (AI) has become an integral part of medical imaging, offering substantial support to radiologists. Radiologists play a prominent role throughout the development of AI applications designed for automated medical image diagnosis.
Aim: was to investigate the contributions of radiologists in creating an AI application for evaluating scoliosis on digital radiographs.
Material and methods: a qualitative, retrospective, in-depth exploratory case study approach was used to analyze the process of creating Esper.Scoliosis application, in which two radiologists had actively participated. A third radiologist took a part in testing and evaluation.
Results: reviewing the application development process, we noted that the radiologist had a main part in almost every phase of creating the application. We divided the work of the radiologist in creating the application into three main parts: theory, data processing and labeling, testing and evaluation.
Conclusion: the role of the radiologist is essential in developing the intellectual application. Active engagement of radiologists at every stage is needed not only for optimizing the performance of the application but also can encourage them to support the use of different AI applications in their daily work.

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Introduction

Artificial Intelligence (AI) is widely applied across various fields, playing a significant role in advancing technology. The adoption of AI in medicine dates back to the 1970s, aiming to enhance the efficiency of medical diagnosis and treatment [1-3]. The integration of AI into medical imaging, has its own challenges. Firstly, there is the task of identifying and defining specific image features and characteristics which are crucial for accurate medical diagnosis. Subsequently, it is necessary to determine the appropriate image labels that will be used for training AI models. This process requires collaboration between radiologists and applicationmers to clarify which essential anatomical structures and abnormalities should be accurately identified and annotated, as well as how to do that effectively, while considering the limitations of AI. Additionally, ensuring agreement and minimizing subjectivity in the labeling process is needed. To achieve this, documenting the labeling procedures, establishing guidelines and reviewing the labels in order to minimize variability. Furthermore, a significant challenge lies in obtaining fully representative data that mirrors the diversity of real-world diagnostic cases. Utilizing such data is essential for training AI models effectively, as the performance of the model is constrained by the parameters of the training sample [4,5]. These challenges emphasize the pivotal role of radiologists, who typically play a significant part in the development of AI applications in radiology. Amian S. et al. [6] provided an insightful overview of the radiologist's involvement in the development process of AI applications, which includes defining use cases and conceptual design, sourcing and curating data, labeling and establishing ground truth, training algorithms, and validating AI applications. In this paper, we focus specifically on the role of radiologists in the development of a single AI application Esper.Scoliosis, which is an AI application for the automated assessment of scoliosis on spinal radiographs. While the integration of AI into medical imaging has numerous challenges, our attention is directed toward understanding the unique contributions of radiologists in addressing these challenges within the context of this particular application. By examining the involvement of radiologists in various stages of the development process, we aim to provide insight into their irreplaceable role in advancing the field of medical imaging through AI technology.

Aim: was is to investigate the contributions of radiologists in creating an AI application for evaluating scoliosis on digital radiographs.

Material and method

To investigate the role of the radiologist in creating AI applications, we conducted an exploratory case study based on the research question: what was the role of the radiologist in creating a new AI application for the automatic analysis of scoliosis on digital spinal radiographs. We used our individual experience in participating in a postgraduate research project which was carried out through the period from 2020 to 2023 in Saint Petersburg university with the title of (The abilities of neural networks in the automatic analysis of scoliosis grade on digital radiographs), in which a multidisciplinary team consisting of two radiologists and one engineer/AI developer participated to create an AI application. Other data were collected retrospectively from presentations of team meetings held during the development of the application. We analyzed the process of creating the application retrospectively, in which 2 radiologists had engaged intensively, one radiologist of 25-year experience, and the other of 10-year experience. A third radiologist who evaluates spinal radiographs for scoliosis screening (with more than 20-year experience) participated only in the process of evaluating the application. Limitation of this study is that it only focuses on a single case of AI application development, limiting generalization to other contexts or settings.

Results and discussion

By reviewing the scientific project, we divided the work of the radiologist in creating the application into three main parts: theory, data processing and labeling, testing and evaluation **(fig. 1)**.

Part 1 – Theory

The theoretical aspect of the work of a radiologists primarily involves defining the function of the intelligent tool. The utility of the AI application in daily clinical practice and its intended purpose should be determined by the main user, that is the radiologist. In our case, the objective of the AI application, as specified by the radiologists, is to automatically determine the severity and grades of scoliosis and measure Cobb's angles. Additionally, the radiologist explains basic terminology and important definitions of the disease to the engineer. This includes terms such as end vertebrae, apex, structural curve, and others. Radiologists suggest references to the literature for a deeper understanding of the disease. This enables the AI application creator to grasp the significance of the application's values and choose the appropriate methods for its development to achieve optimal results. Finally, radiologists define the main tasks of the application in order to get the best results. These tasks are established according to specific standards provided by radiologists, often derived from international or local guidelines. In our case, the primary tasks included identifying the largest angle within each identified curve, measured between the upper endplate and lower endplate of the upper and lower end vertebrae, known as the Cobb's angle (as per the standard definition). The application was also tasked with defining the grade of scoliosis according to predefined categories: grade I (1-10°), grade II (11-25°), grade III (26-50°), and grade IV

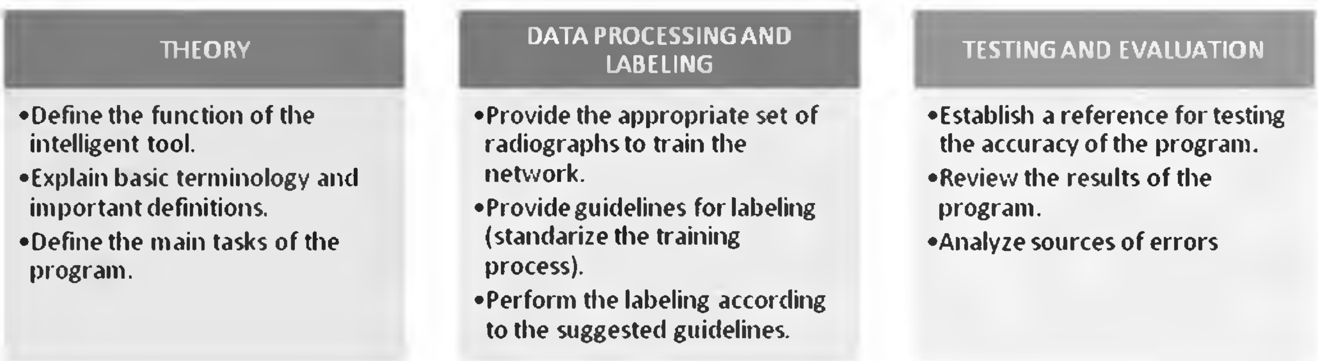

Fig. 1. The radiologist role in the main parts of the process of creating Esper.Scoliosis

(more than 50°), in accordance with the federal law of the Russian Federation No. 565 [7].

Part 2 – Data processing and labeling

The next important and labor-intensive part of the radiologist's work is data processing and labeling. Firstly, radiologists provide the appropriate set of radiographs to train the network. The selected radiographs must accurately represent the clinical scenarios encountered by radiologists. In our project, the radiographs were carefully chosen to create a database of digital radiographs (in DICOM format) encompassing various grades of scoliosis [8]. Each radiograph in the database was reviewed by a radiologist, and information about it was organized in an Excel table **(fig. 2)**. This information included details such as age, gender, presence or absence of scoliosis, location, grade, and shape of scoliosis, as well as any artifacts present on the image. The radiologist collected this data for network training stage. Secondly, radiologists establish guidelines for labeling to standardize the training process. These guidelines help reduce variability in the training process by providing clear instructions to follow. In our case, we aimed to provide the network with standard vertebral marking (labeling) to optimize the performance of the AI application. Vertebral marking was conducted according to the following general guidelines suggested by the radiologists:

- Initially, the key points that define the vertebral body are identified.
- Only thoracic and lumbar vertebrae are labeled, as scoliosis is mostly thoracic, thoracolumbar, or lumbar. T1 is recognized by the thoracic ribs, either as the first vertebra with a rib or by counting up from T12 (the last vertebra with a rib). Both counting methods are often used together for confirmation, as anomalies such as 11 or 13 thoracic vertebrae are sometimes found.
- The vertebral body should be marked by its typical shape, usually rectangular or square.
- When a vertebra is displaced posteriorly, its upper endplate intersects with the body of the vertebra above. Marking lines of both vertebrae should not intersect. To avoid this, a line defining the upper surface of the lower vertebra is drawn parallel to the line defining its lower surface but does not intersect with the body of the upper vertebra.
- When the boundaries of a vertebra cannot be accurately defined, adjacent vertebrae can be used as indicators, and the markings are drawn parallel to their edges **(fig. 3)**.
- The points defining the upper and lower sides of the vertebra, and the line, should be along the edge of the vertebral body. If the lower and upper endplates of the vertebral body are not clearly distinguishable, then the line should be drawn parallel to the pedicles.
- To define the lower surface of the L5 vertebral body, a line is drawn along the upper edge of the lateral sacral masses (S1). The reference in this case is the intersection between the lower articular processes of L5 and the upper part of the lateral sacral masses **(fig. 4)**.
- For training the network, radiographs with vertebral anomalies such as wedge vertebrae or any variability in number (e.g., 11 thoracic vertebrae) were not included in the dataset. Also, images with S1 lumbarization or L5 sacralization, which alter the typical shape of L5, were excluded from the training set **(fig. 4)**.

Lastly, performing the labeling according to the suggested guidelines is a crucial step in the training process. Training the network is considered an essential part of creating the application, as the accuracy of vertebral detection largely depends on the input of the expert (the radiologist) during the learning process. In our study, the radiologist labeled over 1000 radiographs to train the network. The dataset used for the training process had the following characteristics:

- All grades of scoliosis were included in the dataset. Achieving an exact equal number of radiographs for each grade of scoliosis proved to be challenging, particularly in providing a substantial number of radiographs with severe scoliosis. Radiographs depicting severe scoliosis often exhibit altered vertebral body shapes and less defined borders, posing difficulties in training the network. Nevertheless, we included over 150 radiographs (>15%) depicting grade 4 scoliosis to train the network.
- Various types of radiographs were incorporated into the dataset, including chest X-rays, radiographs of the entire spine

				Наличие	Proximal thoracic			Main thoracic			Thoracolumbar			Lumbar			Классификация (МО РФ)				Классификация	область	Наличие
КОД	ВОЗРАСТ	ПОЛ	ДАТА	сколиоза	end vertebrae	apex	angle	end vertebrae	apex	angle	end vertebrae	apex	angle	end vertebrae	apex	angle	PT	MT	TL	L	По форме	исследования	артефактов
295	13	М	01.04.2016	нет																	C	весь позвоночн	**
296	12		15.02.2106	да				Th9/L1	Th11	8,6								1			C	грудной	нет
297	11		20.01.2016	да				Th6/Th10	Th7	10,7								2			C	весь позвоночн	*
298	31		27.01.2020	да										Th12/L5	L4	7,6				1	C	весь позвоночн	*
299	13		20.02.2020	НЕТ																		весь позвоночн	*
300	22		21.11.2018	НЕТ																		весь позвоночн	**
301	10		04.07.2019	НЕТ																		весь позвоночн	*
302	9	Ж	10.10.2016	да	Th1/Th5	Th4	11,4	Th6/Th10	Th9	25,1	Th11/L3	L1	31,8				2	3	3		S	весь позвоночн	**
303	11	Ж	22.08.2016	да				Th5/Th10	Th8	17				Th11	L3	19,5		2	2		S	весь позвоночн	нет
304	8	Ж	18.04.2016	да				Th4/Th11	Th7	17,2				Th11/L4	L2	18,7		2		2	S	весь позвоночн	нет
305	10	Ж	09.09.2016	да				Th5/Th11	Th8	15,6	Th11/L2	L1	14,3					2	2		S	весь позвоночн	**
306	5	Ж	31.07.2018	да							Th6/L3	Th11	33,6						3		C	весь позвоночн	нет
307	8	Ж	12.09.2016	да				Th8/L1	Th11	8								1			C	весь позвоночн	*
308	14	Ж	29.01.2018	да							Th11/L2	Th12	22,5						2		C	весь позвоночн	нет
309	16	Ж	09.04.2019	да							Th11/L2	Th12	11						2	2	C	весь позвоночн	нет
310	15	Ж	12.04.2018	да							L1/L4	L2	13,5						2	2	C	весь позвоночн	*
311	11	Ж	01.04.2016	да							Th8/L2	L1	13,3						2	2	C	весь позвоночн	нет
312	15	Ж	20.10.2016	да				Th6/Th11	Th9	12,3				Th12/L3	L2	12,6		2		2	S	весь позвоночн	**
313	17	Ж	20.01.2020	да							Th10/L3	Th12	27						3		C	весь позвоночн	**
313-	17	Ж	20.01.2020	да							Th10/L3	Th12	12						2		C	весь позвоночн	**
314	15	Ж	14.05.2018	да							Th10/L2	Th12	14,3						2		C	весь позвоночн	**
315	16		14.01.2020	да				Th9/Th12	Th11	15,4				L1/L4	L3	14,1		2		2	S	весь позвоночн	*
316	13	Ж	15.12.2016	да				Th6/Th10	Th7	17,8	Th11/L2	L1	10,8					2	2		S	весь позвоночн	**
317	15		05.07.2018	да										Th11/L4	L2	16,3				2	C	весь позвоночн	**
318	12	Ж	04.02.2016	да				Th7/Th10	Th8	16,4								2			C	вес позвонок	нет

Fig. 2. Example of the Excel table in the data base (XrScl).

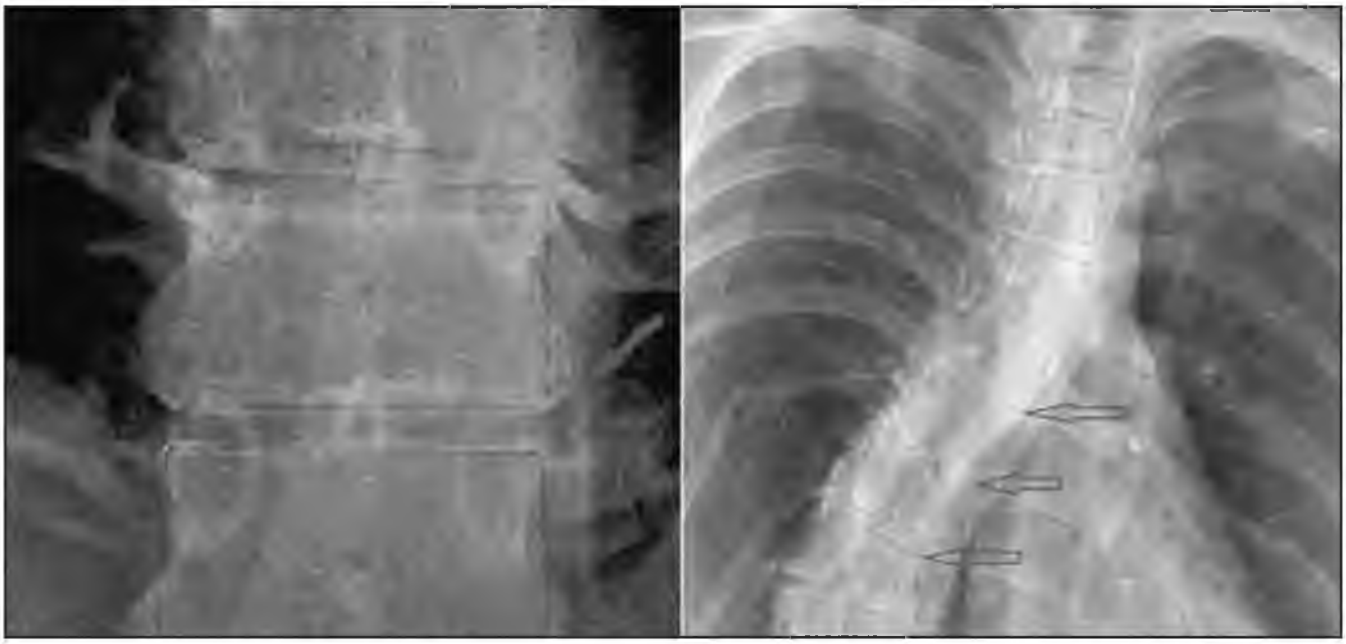

Fig. 3. Vertebral marking. The key points can be predicted by adjacent vertebrae if the borders are not well visualized.

Fig. 4. Vertebral marking. Marking the lower edge of L5.

or specific segments (thoracic or lumbar). We aimed to simulate real clinical scenarios, as radiologists frequently diagnose scoliosis in images acquired for other medical indications. This approach ensures that the application can accurately analyze different types of radiographs after completing the training process.

• Several radiographs exhibited metallic artifacts, such as those caused by surgical instrumentation, which obscured part or all of one or more vertebral bodies. Consequently, the AI application was trained to evaluate images with postoperative instrumentations.

• The dataset is comprised of different age groups with varying types of scoliosis, including infantile, adolescent idiopathic, and degenerative scoliosis. This diversity provided a range of vertebral body shapes, as the shape of the vertebrae in neonates differs from that in degenerative scoliosis.

Part 3 – Testing and evaluation

After the network is trained, the radiologist becomes involved in the testing and evaluation phase, which encompasses several critical steps. Firstly, radiologists review the results of machine learning inference. Determining the adequate number of images necessary for accurate vertebra detection by an AI system is not straightforward. In our study, we conducted repeated assessments of the network's accuracy in delineating vertebral body borders during the training process. To optimize results, we incrementally increased the number of annotated X-rays used in training multiple times. Next, it is essential to establish a reference for testing the application's accuracy. This step is crucial for introducing the system into clinical practice. Comparing the system's results to a standard reference is essential, especially for subjective measurements like Cobb's angle and scoliosis grade. To ensure reliability, we evaluated the system multiple times with different radiologists of varying experience. Finally, it is crucial to analyze the sources of errors in the application's results. Errors can stem from various causes, including input provided by the engineer throughout the application's development. For example, we observed situations where the system produced numerous small angle measurements (1° or 2°), which are typically not clinically significant. To address this, we adjusted the system to display measurements of 5 degrees or more. Additionally, inconsistencies in measuring Cobb's angle in Russian literature posed challenges. To resolve this, our developer incorporated multiple methods of measuring Cobb's angle into the application, allowing radiologists to choose the method according the standards that are applied in their workplace. False results were also attributed to inaccurate vertebral detection by the application, particularly in cases of severe scoliosis with maximum vertebral rotation. Training the network with a larger number of images depicting severe scoliosis helped overcome this issue.

Conclusion

Creating an AI application related to radiology is a multidisciplinary process in which the radiologist plays a crucial role. From the initial stages of defining the system's function to the final step of analyzing errors, the active involvement of radiologists is essential to ensure the reliability and effectiveness of the application. Furthermore, increased participation of radiologists in the development of such applications can enhance their understanding of AI capabilities and its potential benefits in daily clinical practice. This, in turn, may lead to a greater support for the integration of AI applications in clinical practice. ■

Список литературы/References

1. Rong LA, Yan R, Zhehao P. Review of medical artificial intelligence online. *Global Health Journal.* 2020; 4(2): 42-45.
2. Amisha Malik P, Pathania M, Rathaur VK. Overview of artificial intelligence in medicine. *JFMPC.* 2019; 8 (7): 2328-2331.
3. Briganti G, Le Moine O. Artificial Intelligence in Medicine: Today and Tomorrow [Electronic source]. *Front Med.* 2020; 7(27).
4. Gusev AV. Prospects for neural networks and deep machine learning in creating health solutions. *Medical doctor and IT.* 2017; 3: 92-105 [In Russ].
5. Tang A, Tam A, Cadrin-Chênevert A, et al. Canadian Association of Radiologists White Paper on Artificial Intelligence in Radiology. *CAN ASSOC RADIOL J.* 2018; 69(2): 120-135.
6. Scheek D, Rezazade Mehrizi MH, Ranschaert E. Radiologists in the loop: the roles of radiologists in the development of AI applications. *Eur Radiol.* 2021; 31: 7960-7968.
7. Federal law of Russian Federation № 565 of 04.07.2013. «On approval of the Regulations about military medical examination». Moscow; 2013 [In Russ]. http://government.ru/docs/all/87900/
8. Kassab DKHI, Kamyshanskaya IG, Cheremesin VM, Pershin AA. Database of spinal radiographs with different degrees of scoliosis (XrScl). Patent № 2022620577, 2022 [In Russ].

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