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Automated Morphometry of the Prostate Gland by the Results of Magnetic Resonance Imaging

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ABSTRACT

BACKGROUND: *Within the framework of the experiment on using the innovative technologies in the field of computer vision for analyzing the medical images and on further usage of these technologies in the healthcare system of the City of Moscow, the research was carried out using the equipment based on the artificial intelligence (AI-service) for the purpose of automatization of the morphometry of the prostate gland using the magnetic resonance imaging (MRI), for the issue is topical due to the high incidence of urological diseases among men. Unlike the 11 previous systems, oriented at the retrospective analysis, this solution helps the radiologists in shortening the time of describing the examination results and in increasing their accuracy.* ***AIM:*** *to evaluate the quality and the validity of automatic morphometry of the prostate gland by the MRI results using the technologies of artificial intelligence in the settings of practical healthcare.* ***METHODS:*** *A prospective diagnostic research in accordance with the methodology of reporting results of scientific research involving the STARD 2015 diagnostic tests was conducted during the period from April until October of 2024. A total of 560 MRI results were used and compared to the data from the morphometric AI-service.* ***RESULTS:*** *An evaluation of the accuracy of using the AI-service for the morphometry of the prostate gland was carried out. A total of 7 clinical monitoring procedures were conducted using 560 MRI datasets with the complete conformity reported in 71.6%. The rate of false-negative cases was 3.9%, technical defects were found in 3.8% of the cases. The integral clinical evaluation has achieved the range of 88.0–97.0%, confirming the high diagnostic quality. The predominant errors were the ones related to the contouring of the gland (52%) and incorrect measurements (13%), often related to the prolapsing of the prostate gland apex.* ***CONCLUSION:*** *The automatization of routine measurements greatly contributes to the standardizing the processes of describing the results obtained by radio-diagnostic methods. This aspect is of special importance from the point of view of providing the continuity of medical aid in case of patients presenting to various medical organizations. The artificial intelligence technologies for the automatization of the prostate gland measurements have demonstrated high clinical value in 92.0%, which indicates their accuracy and quality. These data can be used for developing new MRI-based automated morphometry products.*

Keywords: *artificial intelligence; prostate gland; morphometry; magnetic resonance imaging; MRI; radiology; diagnostic accuracy.*

For citation:

Nasibian NM, Vladzymyrskyy AV, Arzamasov KM. Automated Morphometry of the Prostate Gland by the Results of Magnetic Resonance Imaging. *Journal of Clinical Practice*. 2025;16(2):23–33. doi: 10.17816/clinpract677719 EDN: VNHQYP

Submitted 25.03.2025 Accepted 23.05.2025 Published online 25.06.2025

BACKGROUND

In recent years, an unswerving growth is observed in the interest to using the artificial intelligence technologies (AI) in healthcare in general and in the radiodiagnostics in particular [1–6]. The automated analysis of the results of diagnostic examinations is considered a potentially effective tool for increasing the productiveness and the quality of operations performed by radiologists, for optimizing the processes in the radiodiagnostics departments along with solving the issues of staff shortage. Constant growth is observed in the number of scientific publications on the AI topic,

Автоматизированная морфометрия предстательной железы по данным магнитно-резонансной томографии

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АННОТАЦИЯ

Обоснование. *В рамках внедрения инновационных технологий в области компьютерного зрения для анализа медицинских изображений и дальнейшего применения этих технологий в системе здравоохранения города Москвы проведено исследование инструмента на основе искусственного интеллекта (ИИ-сервис) для автоматизации морфометрии предстательной железы по магнитно-резонансным томограммам (МРТ). В отличие от 11 предыдущих систем, ориентированных на ретроспективный анализ, данное решение помогает рентгенологам сократить время описания исследований и повысить их точность.* ***Цель исследования*** *— оценить качество и достоверность автоматической морфометрии предстательной железы на результатах МРТ с помощью технологий искусственного интеллекта в условиях практического здравоохранения.* ***Методы.*** *Проспективное диагностическое исследование в соответствии с методологией репортирования результатов научных исследований диагностических тестов STARD 2015 проведено в период с апреля по октябрь 2024 года. Использованы 560 результатов МРТ, сопоставленных с данными морфометрического ИИ-сервиса.* ***Результаты.*** *Оценена точность ИИ-сервиса для морфометрии предстательной железы. Проведено 7 клинических мониторингов на 560 МРТ с полным соответствием в 71,6%. Ложноотрицательные случаи составили 3,9%, технические дефекты — 3,8%. Интегральная клиническая оценка достигла 88,0–97,0%, подтверждая высокое качество диагностики. Преобладали ошибки в оконтуривании железы (52%) и неправильные измерения (13%), часто связанные с пролабированием верхушки предстательной железы.* ***Заключение.*** *Автоматизация рутинных измерений вносит существенный вклад в стандартизацию процессов описания результатов лучевых методов исследований. Особо важен этот аспект с точки зрения обеспечения преемственности медицинской помощи при обращении пациента в различные медицинские организации. Технологии искусственного интеллекта для автоматизации измерений предстательной железы показали высокую клиническую оценку в 92,0%, что свидетельствует об их точности и качестве. Эти данные могут быть использованы для разработки новых продуктов автоматизированной морфометрии на основе МРТ.*

Ключевые слова: *искусственный интеллект; предстательная железа; морфометрия; магнитно-резонансная томография; МРТ; лучевая диагностика; диагностическая точность.*

Для цитирования:

Насибян Н.М., Владзимирский А.В., Арзамасов К.М. Автоматизированная морфометрия предстательной железы по данным магнитно-резонансной томографии. *Клиническая практика.* 2025;16(2):23–33. doi: 10.17816/clinpract677719 EDN: VNHQYP

Поступила 25.03.2025 Принята 23.05.2025 Опубликована online 25.06.2025

however, the number of scientific research products does not mean their quality, both in terms of the publications themselves and in terms of the proposed AI-based decisions. The vast majority of the published developments still includes experimental prototypes, while their underlying mathematical models were taught and tested using limited data samples. The retrospective assessment is predominant in assessing the accuracy of AI-technologies in laboratory settings, while the quantity of clinical research works with proper AI quality and applicability are vanishingly small. In the 21st century, it is difficult to believe in the

https://doi.org/10.17816/clinpract677719

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situation, when a novel drug substance is tested only in a laboratory, not being tested in a full-scale clinical research. In terms of the AI- technologies, exactly this pattern is observed, which is completely unacceptable for modern medical sciences.

In Russia, from the year of 2020, an experiment is carried out on using the innovative technologies in computer vision for analyzing medical images and further use of these technologies in the healthcare system of the City of Moscow (hereinafter — the Moscow experiment; mosmed.ai) [7]. Currently, this is the world's largest scientific prospective multicenter research on the applicability, safety and quality of AI. Within the frameworks of the Moscow experiment, a two-staged research is conducted on using the AI-based software (the so-called AI-services), developed for solving strictly specific diagnostic tasks. The first retrospective stage involves quite a standard testing using the reference data sets, however, the second (the main) and the prospective stages included the evaluation of the quality and the stability of AI-services when operating with the real flow of examination results in the settings of practical healthcare [8–10]. Due to the long-term (lasting months and years) use of AI-technologies in real-time practice, a possibility arouses for studying their effects on the working processes in radiodiagnostics, moreover — not in general, but in a context of solving a strictly specific working operation and clinical task. One of such quite specific tasks is the morphometry of the dimensions and the volume of the prostate gland when interpreting and describing the results of magnetic resonance imaging (MRI) of the lesser pelvis. It should be noted that, within the structure of the urological diseases in men, oncological and inflammatory diseases of the prostate gland prevail, which makes their screening and diagnostics an exceptionally topical issue [11, 12].

Morphometry represents a routine procedure, which takes the working time of the radiologist and creates potential risks due to the subjectiveness of measurements. Its is evident that, for increasing the productivity and the quality of work, this procedure can be easily automated. For exactly the automatization of measurements has shown a significant shortening of the duration of describing the results of radiology examinations along with the parallel increase in the productivity of the operations performed by the radiologist [13]. It is worth noting that previously, a set of data was compiled — the "MosMedData MRI of the lesser pelvis with morphometry parameters of the prostate gland" for the purpose of calibration testing, representing a structurized set of two hundred de-personalized results of multi-parametric magnetic-resonance imaging examinations data among adult men with the presence of morphometry marks (vertical, anterior-posterior and frontal dimensions of the prostate gland in millimeters relative to axis of the organ)[1]. The images are provided in the DICOM 3.0 format, with the marking provided as the XLSX file.

With a background of the colossal interest in using AI in radiodiagnostics, the challenges of automated analysis of the results of the lesser pelvis MRI are practically not researched. In particular, not so long ago, approximately 11 AI-based developments were published for analyzing the results of the prostate gland MRI. None of them is intended for direct helping the physician by means of the automatization of the routine mechanical procedure of measuring the target organ, though the developers are trying, mainly with no success, to solve the hardest challenges of differential diagnostics. Another substantial defect is that all these developments were tested only retrospectively or in the contest mode (competing with each other), i.e. the verification and evaluation of accuracy in the real clinical settings were not implemented [14, 15].

Research aim — to evaluate the quality and the validity of automatic morphometry of the prostate gland based on the magnetic resonance imaging results using the artificial intelligence technologies in the settings of practical healthcare.

METHODS

Research design

This was a prospective diagnostic research conducted in accordance with the methodology of reporting the results of scientific research with using the STARD 2015 diagnostic tests[2].

Conformity criteria

Inclusion criteria: male patients older than 18 years; MRI scanning performed in the out-patient settings following the standard protocol; scanning protocol: loc (locators), T2-WI (T2-weighted images), T1-WI

[1] Certificate of data base registration — RU 2025620045/09.01.2025. Application No. 2024626323 dated 20.12.2024. Vasilyev Yu.A., Nasibyan N.M., Vladzimirskiy A.V. et. al. MosMedData: MRI of lesser pelvis with the morphometry parameters of the prostate gland. EDN: IXRMQR

[2] Certificate of registration of PC software — RU 2025610804/14.01.2025. Application No. 2024691653 dated 20.12.2024. Vasilyev Yu.A., Vladzimirskiy A.V., Omelyanskaya O.V. et al. Data set preparation platform. EDN: TZQQHN

(T1-weighted images), DWI (diffusion-weighted images) with fat tissue suppression and with computing the ADC (apparent diffusion coefficient) charts along with dynamic contrast enhancement (DCE); the presence of the results of automated analysis (operation of the AI-service); the presence of informed voluntary consent for conducting the research.

Exclusion criteria: motor artifacts, artifacts from foreign objects at the investigated level; technical defects of MRI-scanning; technical defects in the results of AI-service operation.

Research facilities

The examination was carried out within the premises of the State Budgetary Healthcare Institution "Scientific-Practical Clinical Center for Diagnostics and Telemedicine of the Moscow Healthcare Department" (SBHI SPCC D&T, MHD). The research was carried out with using the results of radio-diagnostic examinations, conducted at the medical organizations of the Healthcare Department of the City of Moscow, providing medical aid to adult population in the out-patient settings (municipal polyclinics). The examination results were stored at the centralized archive of medical images of the City of Moscow (the Unified Radiology Information Service of the Unified Medical Information-Analytical System of the City of Moscow, URIS of UMIAS), while their description and compilation of protocols were conducted by radiology physicians of the reference-center within the premises of the SBHI SPCC D&T (Moscow Healthcare Department).

In accordance with the Decree issued by the Moscow Government on November 21, 2019 No.1543-PP[3], SBHI SPCC D&T (MHD) is an operator of the experiment on using the innovative technologies in the field of computer vision for analyzing the medical images and further using these technologies in the Healthcare system of the City of Moscow (the Moscow experiment). The staff of the institution were performing the independent testing and quality control of the operation of the software products based on AI technologies. The developers and the right holders of the said software products are the third parties — the companies and enterprises of various form of incorporation, not affiliated by the SPCC D&T (MHD).

[3] Decree issued by the Moscow Government on November 21, 2019 No.1543-PP «On the conduction of the experiment on using the innovative technologies in the field of computer vision for analyzing the medical images and their further use in the Healthcare System of the City of Moscow». Access mode: https://www.garant.ru/products/ipo/prime/doc/73059396/

Research duration

The research work was arranged during the period from 01.04.2024 until 31.10.2024. Within the stated period of time, the tested software product based on AI-technologies was analyzing the results of MRI-scanning of the target area in accordance with the Moscow experiment procedures. A monthly sample was compiled for monitoring the operational quality (see below for detailed description of this procedure). The summarization and the analysis of the results were conducted during the period from 01.01.2025 until 01.03.2025.

Research description

An evaluation was carried out of the applicability of AI technologies for the automatization of the prostate gland measurements in the settings of practical healthcare.

The Index-test (the test method) — is a software product based on AI technologies (AI-service) for the recognition and analysis of MRI-scans of the prostate gland, integrated into the URIS UMIAS in accordance with the procedures of the Moscow experiment.

The functions of the AI-service are the following: measuring the vertical, the anterior-posterior (sagittal) and the frontal (transverse) dimensions of the prostate gland in millimeters relative to the axis of the organ (urethra); calculation of the prostate gland volume [16]. The research includes the IMV PIRADS AI-service ("Imvision" LLC, Russia) — the only participant of the Moscow experiment in the stated field (the limitations of this research shall be provided in the corresponding section at the end of the article).

Reference test: clinical monitoring of the quality of AI-service operation in accordance with the original methods, developed and validated within the settings of the Moscow experiment [14, 17, 18].

Methods of arranging the clinical monitoring of the quality of AI operation. Compilation of the sample from the whole volume of MRI-scans analyzed by the AI-service for the report period. The sample is to be compiled randomly, while its size is pre-justified and equals 80 scans every month [1]. The sample is reviewed by two radiologists with a work experience of not less than 5 years.

Each expert evaluates the results of automated analysis of this examination by two criteria: the correctness of detecting and labeling the location of the pathological signs (labeling by AI-service); the correctness of AI-service interpretation of the results of radiology examination (conclusion from the AI-service).

https://doi.org/10.17816/clinpract677719

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Taking into consideration the morphometric characteristics of the tested AI-service, the first criterion was considered the correctness of segmentation, while the second was the measuring of the volume and size of the prostate gland. For each examination result, the expert was setting the variant of assessment: full conformity (1 point), incorrect assessment (0.5 points), false-positive result (0.25 points), false-negative result (0 points). The assessment variant was defined for each of the abovementioned criteria separately, then all the obtained points were summed; the maximum possible value of the sum for this sample was taken as 100.0%, after which the specific weight was calculated for the added sum of points; eventually, the level of clinical assessment was obtained, varying within a range from 0.0 to 100.0%.

In this context, the following approaches were used: the false-positive result means erroneous measuring of the dimensions or the volume of the prostate gland, resulting in the definition of the case as the pathological with initially normal status of the target organ; false-negative result — erroneous measurement of the dimensions or the volume of the prostate gland, resulting in the definition of the case as normal with the actual presence of pathological changes. Erroneous measurements can be due to incorrect segmentation or due to the defects of mathematical calculation, related to the classification of the results of automated analysis. An incorrect assessment means the presence of discrepancies in the measurements conducted by the AI-service and by the radiologist, however, such discrepancies are not resulting in the occurrence of false-positive or false-negative result.

The sample from the second stage included the results of clinical monitoring sessions, conducted within 7 months (each month, a new sample consisting of 80 results of the prostate gland MRI, processed by the morphometry AI-service, was compiled for monitoring purposes). Respectively, the whole research included 560 cases.

Statistical analysis

The research had not established comparison groups, due to which, the sample size was not calculated. At the same time, the sample size for the regular monitoring of the quality of AI operation is 80 scans each month. The approaches for its determination were published previously [19].

The MedCalc v. 23.1.1 statistical software (MedCalc Software Ltd, Belgium) was used during the research. No special statistical criteria were used, only the descriptive statistics procedures were applied.

RESULTS

Research sample (participants)

In the settings of practical healthcare, an evaluation was carried out of the diagnostic accuracy of the AI-service for the morphometry of the prostate gland. Using this software product in accordance with methodology of the Moscow experiment, a total of seven clinical monitoring sessions were carried out (one monitoring each month, sample size — 80 cases). As appropriate, samples of examination results were compiled, allowing for evaluating the diagnostic accuracy of the operation of AI technologies in the prospective design, i.e. in the settings of practical healthcare. For the monitoring purposes, a total of 560 prostate gland MRI results with the results of automated analysis were selected randomly.

Primary findings

The full conformity of the results of AI-service operation was obtained in 71.6% (*n*=401) of the cases (Table 1). Quite high was the percentage of cases with partial agreement with the expert physician — 20.5% (*n*=115). The specific weight of false-negative cases was 3.8% (*n*=22). Notably, almost the same level was shown for the percentage of technical defects occurring during the processing of MRI-scanning results — 3.8%, i.e. in a total of 21 cases, the AI-service was shown as technically unreliable.

Table 1

The parameters of clinical monitoring the of AI-service operation in the morphometry of the prostate gland based on the results of magnetic resonance imaging

Number (*n*=560)	Evaluation				
	Full conformity	Incorrect assessment	FP	FN	Defect
Abs.	401	115	1	22	21
%	71.6	20.5	0.2	3.9	3.8

Note. FP — false-positive result; FN — false-negative result.

The clinical assessment was conducted each month for the sample of 80 examination results, while its values varied within a range from 88.0 to 97.0%. For the total sample of 560 scanning results, i.e. for the whole period of using the AI-service in the settings of practical healthcare, the clinical assessment parameter value was 92.0%.

Separate analysis is required for the episodes of incorrect operation of the AI-service. In total, 138 results of automated analysis were to one degree or another assessed as low-quality (Fig. 1). Within the structure of the erroneous or incorrect operations of the AI-service, detected during the monitoring, the incorrect delineation of the prostate gland was prevailing — 52.0%; in 14.0% of the incorrect cases, the segmentation of one of the projections was missing. What calls attention to itself is the high percentage of incorrect measurements (including the incorrect arithmetic calculation of the volume) with a background of completely adequate segmentation of the target organ — 13.0%.

The most typical segmentation errors were related to the presence of prolapsing apex of the prostate gland in the urinary bladder, to the contouring of the gland with capturing the dilated venous plexuses or the seminal vesicles. The examples of automated analysis performed by the AI-service for the morphometry of the prostate gland by the MRI results are provided in Fig. 2 and 3.

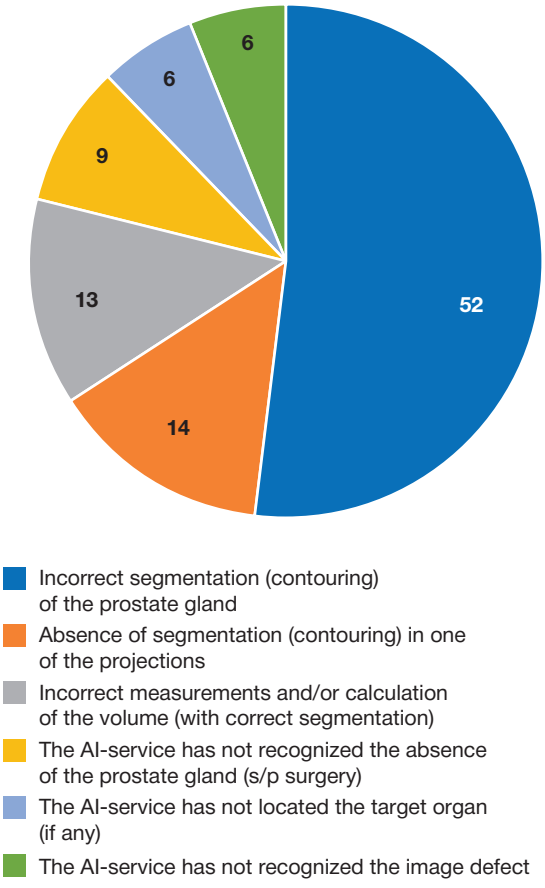

Fig. 1. The structure of incorrect or erroneous operation of the AI-service during the morphometry of the prostate gland on the results of magnetic resonance imaging, %.

The obtained data show quite high diagnostic quality of the tested tool. Hence, the AI technology (computer vision) can be considered applicable for the automatization of the prostate gland measurements.

DISCUSSION

The problematics of using AI technologies for analyzing the results of the MRI of the lesser pelvis (in particular, of the prostate gland) in scientific literature is enlightened to a certain degree unidirectionally [20–22]. General compilation is provided for the possible tasks for development in the corresponding topical area, the number of which includes the segmentation and the search for pathological foci, the classification and increasing the quality of multiparametric imaging, the detection and the differential diagnostics of malignant neoplasms, the classification of risk degree by the Gleason score[4] [23–25]. In the real development, the prevailing are the oncological diagnostics, the use of radiomics methods, as well as the multimodal approach expressed as the combined use of the MRI results and the pathomorphological examination of the prostate gland [26]. Specifically, the radiomics models have shown a high accuracy of differential diagnostics for the foci in the prostate gland. The fact that increases the value of such publications is that the developed models also pass the external validation, i.e. the independent verification via a set of new data. The meta-analysis summarizing the data from 43 articles (9983 patients) has allowed for obtaining the mean accuracy values (area under the characteristic curve) of the radiomic models — 0.91–0.93 [27], at the same time, there are still disputable issues of the precision of the results obtained when using such models, their applicability not in the laboratory, but in clinical settings. With this background, the tasks of the prostate gland morphometry have undeservedly little attention. Meanwhile, performing the routine measuring procedures by the radiology physician “manually” leads to wasting time and can always result in errors in terms of accuracy and precision [28–32].

[4] Certificate of state registration of database No. 2024620575 dated 06.02.2024. Application No. 2024620252/26.01.2024. Vasilyev Yu.A., Blokhin I.A., Geleje P.B. et al. A set of biparametric MRI data of the prostate gland with histological verification. EDN: XEAAGM. Access mode: https://telemedai.ru/nauka/nauchnaya-infrastruktura/nauchnaya-deyatelnost/intellektualnaya-sobstvennost

https://doi.org/10.17816/clinpract677719

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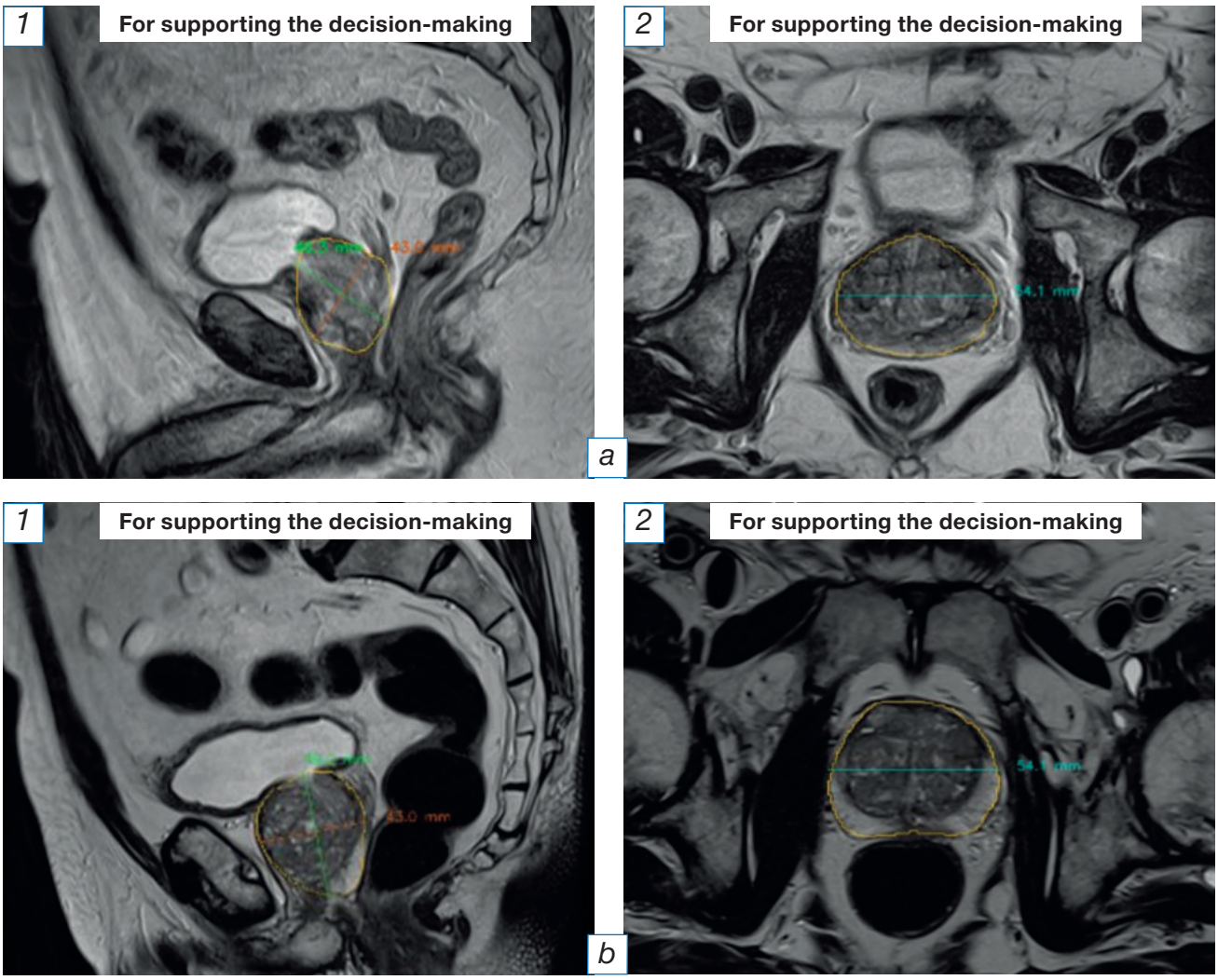

Fig. 2. The results of magnetic resonance imaging of the lesser pelvis organs in males aged 65 (*a*) and 67 (*b*) years, analyzed by the AI-service: segmentation and morphometry of the prostate gland were done correctly. *1* — sagittal projection; *2* — axial projection.

In general, the scientific literature shows a sufficiently high level of diagnostic precision of the AI (based on the typical neural network architectures) when analyzing the MRI of the prostate gland. Thus, upon the automated segmentation of the prostate gland, the Dice coefficient ranges within 0.86–0.9 [33, 34], upon the classification of the pathological manifestations, the area under the characteristic curve also reaches 0.84–0.91 [35, 36]. The accuracy of detecting the pathological foci is lower and falls within a range of 0.64–0.81 [37]. During the comparative research, it was found that AI has surpassed the international group of radiologists (consisting of 62 specialists) in terms of detecting the clinically significant prostate cancer and its classification using the PI-RADS scale (Prostate Imaging Reporting and Data System) [38]. The significant downside of these research works is their experimental pattern. All the

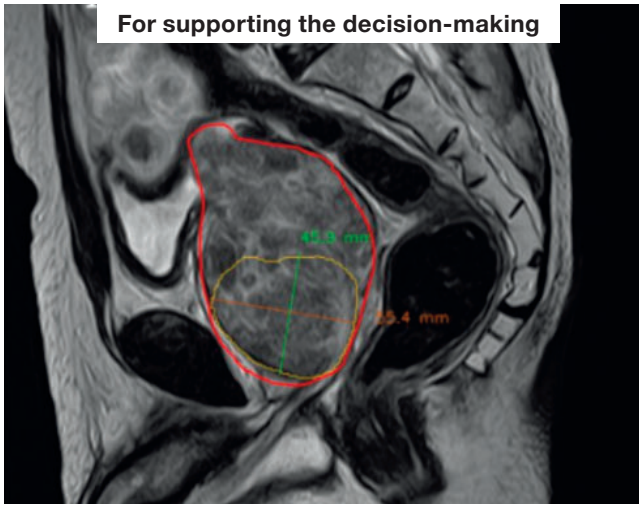

Fig. 3. The results of magnetic resonance imaging of the lesser pelvis organs in a male aged 86 years, analyzed using the AI-service: an example of incorrect segmentation of the prostate gland (the contour of the prostate gland in the sagittal projection is not marked in full range).

AI-related research on diagnostics of abnormalities in the prostate gland were conducted in laboratory settings, using the reference data sets (including the quite vast comparison of accuracy between the AI and the group of 62 physicians). Moreover, the independent analysis of the quality of such articles has shown that 47.0% of them were lacking the full and correct description of the reference data set, i.e. of the main AI accuracy measuring tool. Even more negative is the fact that up to 92.0% articles contained data on manipulating the statistical analysis data for the purpose of concealing the low accuracy of the model [7].

With this background, our research was carried out in the prospective design, allowing for determining the accuracy and quality of AI operation in the settings of practical healthcare. For the first time ever, quite a vast set of material was used to obtain the parameters of accuracy and stability of AI-service operation for the morphometry of the prostate gland, distinct by its scientific novelty. The obtained clinical measurement value of 92.0% indicates the sufficiently high accuracy of the tested AI-service operating with the real flow of radiodiagnostics data. At the same time, the analysis of the structure of the defects has allowed for objectively detecting problems with the segmentation of the target organ. Based on the experience of the Moscow Experiment, incorrect segmentation is a typical error of the AI-services, especially often occurring at the early stages of their development (for this specific clinical task) [7]. The studied AI-service was introduced into the experiment relatively recently, which is why the said type of defect is quite explainable. The results of the clinical monitoring can be used both for the elimination of specific defect and for the general improvement of the AI-service along with its preparation for clinical testing for the purpose of receiving the status of the medical device.

Research limitations

The research work included only one software product based on AI technologies. This situation is due to the absence of other developments capable of solving the tasks of automated morphometry of the prostate gland. As of the date of 01.03.2025, in the Russian Federation, there are no AI-based devices for solving this challenge; the research includes only one relevant participant of the Moscow experiment. Evidently, certain measures are required for stimulating the development of other solutions, including the ones having the functional capabilities of supporting the diagnostic decisions based on the radiomics.

CONCLUSION

The automatization of routine measurements greatly contributes to standardizing the processes of describing the results of radio-diagnostic examinations. This aspect has a special importance from the point of view of providing the continuity of medical aid in cases of the patient presenting to various medical organizations.

The AI technologies are applicable for the automatization of the prostate gland measurements when describing the results of MRI-scanning of the lesser pelvis organs. The experience of using the corresponding AI-service in the settings of practical healthcare has shown the clinical measurement value of 92.0%, which allows for characterizing the accuracy and the quality of its operation in a flow of MRI-scanning results as high.

The obtained data can be used as the methodical material for developing other products for the automated morphometry of the prostate gland based on the results of MRI-scanning of the lesser pelvis.

ADDITIONAL INFORMATION

Author contributions. *N.M. Nasibian:* literature review, data collection and processing, analysis of results, manuscript preparation; *A.V. Vladzymyrskyy:* study conception, final editing, manuscript approval; *K.M. Arzamasov:* final editing, manuscript approval. Thereby, all authors provided approval of the version to be published and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Ethics approval. This study was carried out in accordance with the framework established by the Experiment on the Use of Innovative Technologies in Computer Vision for Medical Image Analysis, with subsequent applications in the healthcare system of Moscow. The research received approval from the ethical committee, as documented in protocol No. 2 of IEC of MRB of the RSR dated February 20, 2020. Additionally, the study is registered on ClinicalTrials under the identifier NCT04489992. All patients whose images were included in the study signed an informed voluntary consent upon admission to the hospital to use the results of the examination and treatment for scientific purposes.

Funding sources. This paper was prepared by a team of authors as a part of the research and development project “Development of a platform to generate datasets containing diagnostic imaging studies” (EGISU No 123031500003-8) in accordance

https://doi.org/10.17816/clinpract677719

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with Order No. 1258 dated December 22, 2023: "On approval of state assignments funded from the Moscow city budget to state budgetary (autonomous) institutions subordinated to the Moscow Healthcare Department for 2024 and the planning period of 2025 and 2026".

Disclosure of interests. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Statement of originality. The authors did not use previously published information (text, illustrations, data) in conducting the research and creating this paper.

Data availability statement. The editorial policy regarding data sharing is not applicable to this work, data can be published as open access.

Generative AI. Generative AI technologies were not used for this article creation.

Provenance and peer-review. This paper was submitted to the journal on an initiative basis and reviewed according to the usual procedure. Two external reviewers and the scientific editor of the publication participated in the review.

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https://doi.org/10.17816/clinpract677719