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*Original Research Article*

# THE FUTURE OF THE MEDICAL PROFESSION IN THE ERA OF ARTIFICIAL INTELLIGENCE AND HEALTHCARE ROBOTIZATION


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***Abstract***: Artificial intelligence and robotics are increasingly integrated into the clinical practice of physicians and other healthcare professionals. These developments have resulted in improved diagnostic and therapeutic outcomes, as well as enhanced organizational processes within healthcare systems. ***Objective.*** To investigate future prospects for the development of AI-based and robotic technologies in healthcare. **Methods.** A literature search was conducted using the PubMed and Google Scholar databases. ***Results.*** The reviewed publications highlight significant advancements in the development and implementation of AI and robotic systems across various healthcare domains. A notable achievement is the high diagnostic accuracy of AI, comparable to—or even exceeding—that of clinicians. Numerous innovations are also observed in medical robotics, particularly within the da Vinci surgical system family and other specialized platforms. ***Conclusions.*** Based on the literature analysis, the following conclusions were drawn:

1. In the long term, the development of AI in healthcare will lead to the emergence of a "digital expert" capable of highly accurate disease diagnosis and proposing optimal treatment strategies.
2. There is a clear trend toward creating narrowly specialized robotic platforms designed to assist in complex procedures in neurosurgery, dentistry, and other fields.
3. A logical next stage in technological evolution is the development of autonomous modules that combine AI with robotic platforms, capable of delivering care without direct physician involvement or through remote physician oversight (telemedicine). This approach is particularly relevant in remote areas, conflict zones, and settings with shortages of medical personnel.



*Keywords*: Artificial intelligence, algorithm, machine learning, neural network, robotics


## INTRODUCTION

Artificial intelligence (AI) and robotization are frequent topics of discussion in the context of the future of professional employment. Medicine is one of the fields in which AI is being integrated particularly intensively, leading to concerns and uncertainty regarding its potential to replace highly qualified physicians. Nevertheless, in diagnostics and the interpretation of medical imaging, AI assistance appears to be highly valuable [1].

Given the rapid pace of technological development, several researchers predict that around the year 2031, a so-called "singularity" may occur, at which point AI would surpass human intelligence. This could affect future scientific discoveries, communication processes, and various other domains [2]. Such a prospect generates a certain existential crisis in healthcare, casting doubt on the value and competencies of physicians and other medical professionals. Human intelligence differs from machine intelligence not only in the architecture of "thinking," but also in the methodologies used to achieve specific outcomes. Despite its progress, AI has not yet developed the qualities of conceptual reasoning and heuristic thinking that are characteristic of human cognition. In non-standard situations characterized by variable contexts and requiring unconventional approaches, AI still falls short of human intelligence. However, AI possesses the ability to accumulate knowledge without limitation, enabling it to process a vast number of possibilities, identify the most suitable matches, and generate efficient solutions. Therefore, at present, the optimal strategy is to combine AI capabilities with physicians' expertise to achieve superior clinical outcomes.

Robotization is gradually gaining a more prominent role, particularly in the domain of medical procedures, and most physicians view the robot assistant positively within their practice [3]. However, the integration of robotics with AI implies a degree of autonomy, which raises concerns among a significant portion of the medical community. Removing physicians from procedural involvement may lead to the loss of hands-on skills and tactile memory. Currently, robotic procedures are performed under the supervision of specialists. Nonetheless, in the future, with substantial improvements in AI and the mechanical components of such systems, many simple technical procedures may be performed entirely without direct involvement of healthcare professionals.

The relevance of this topic is defined by the increasing role of artificial intelligence and robotization across all areas of modern medicine. The objective of this article is to explore the future prospects for the development of AI-based and robotic technologies in healthcare.

## Materials and Methods

Publications from the PubMed and Google Scholar databases were used for this study. The search was conducted using the following keyword phrases:

- PubMed: "Medicine in the Age of Artificial Intelligence" (705 results, last 10 years);
- PubMed: "Robotic platforms" (6,673 results, last 10 years);
- Google Scholar: "robotization in medicine" (1,130 results, last 5 years);
- Google Scholar: "artificial intelligence in medicine" (12,700 results, last 5 years).

Priority was given to highly informative, open-access articles related to AI and robotization in medicine. Articles that were irrelevant, duplicated, or insufficiently informative were excluded.

A total of 44 publications were selected for the review. These included systematic reviews as well as original research articles describing recent trends in the development of AI technologies and robotic platforms.

## Results

### Characteristics of Intelligence and the Possibilities for Overcoming Its Limitations

Human cognition, due to natural biological constraints, has limitations in terms of memory capacity and analytical capabilities. In a simplified form, it can be conceptualized as a combination of heuristic processes, accumulated knowledge, and analytical ability. Moreover, human thinking is often influenced by cognitive noise and "anchoring errors."

In an article by G. Dhaliwal, a study is described involving two groups of physicians (one with high-level knowledge and the other with low-level knowledge) who were asked to establish a diagnosis. Into each clinical vignette, researchers inserted a "salient distracting feature." For example, in a case of vitamin B12–deficiency anemia, a "family history of dementia" was added, which significantly slowed the diagnostic process in both groups. The study demonstrated that diagnostic errors were predominantly associated with insufficient knowledge rather than the quality of analytical reasoning. Extended deliberation did not account for diagnostic differences between the groups [4].

Heuristics refers to a human predisposition in thinking, sometimes described as cognitive bias. In its most unfavorable manifestation, heuristics may devolve into a lack of competence, a situation that can be corrected through knowledge, whereas analytical reasoning alone cannot overcome it. In other words, if a physician does not know that macrocytosis and neutrophil hypersegmentation correspond to the presentation of vitamin B12–deficiency anemia, neither analysis nor heuristics will facilitate establishing the correct diagnosis. However, AI is capable of performing this task [4]. To date, AI systems have demonstrated the ability to differentiate melanoma from benign nevi [5] and to detect diabetic retinopathy [6]. Moreover, the diagnostic performance of deep learning models can exceed that of medical specialists in terms of sensitivity (87% vs. 86.4%) and specificity (92.5% vs. 90.5%) [7].

The technological revolution driven by AI introduces a profound epistemological challenge: whereas traditional statistics emphasizes causal relationships, AI focuses on predictive performance, disregarding the underlying causes of observed phenomena. This algorithmic "black box" stands in contrast to clinical thinking, which is grounded in heuristics and analytical reasoning. Consequently, medical professionals may require new competencies in statistics to understand the internal logic underlying AI systems [8].

### Artificial Intelligence: Definition and Operating Principles

Artificial intelligence (AI) is a general term referring to a machine or process that responds to external stimuli (new data) and modifies its functioning to maximize a performance index. The learning process incorporates principles of mathematics, statistics (e.g., k-means clustering), logic, and computer programming. AI training is an iterative procedure in which parameters are adjusted and reinforced through trial and error. The performance index reflects the discrepancy between predicted and observed (experimental) data. The training phase of AI is grounded in the scientific method formalized in the works of Francis Bacon (≈1600). After training, AI systems may be utilized in decision-making, including clinical decisions. Examples include disease diagnosis in pathological examinations or refinement of the clinical variant of skin cancer based on image analysis of suspicious lesions. One of the core tools of AI, the neural network (NN), is characterized by a predefined architecture with a matrix of weights that are iteratively adjusted to optimize the specified performance index [1].

Another definition of AI, provided by Oracle Corporation, states: "AI is a system or machine capable of mimicking human behavior to perform specific tasks and gradually learning from acquired information" [9]. The extraordinary potential of AI leads to a continuous expansion of its application areas, including healthcare.

Artificial intelligence and robotics represent key technologies capable of substantially transforming healthcare operations in the coming years. Robots programmed to perform medical procedures are already in use today. However, the development of more advanced models will require the integration of robotics with AI. Most modern AI systems are based on deductive frameworks (see Table 1). Deductive technologies enhance diagnostic accuracy in dermatology and radiology [10–14].

**Table 1. Comparison of different types of AI**

| System Type | Principle of Operation | Example |
|---|---|---|
| Deductive | A deductive system can identify patterns in data that are not detectable by humans | AI system that outperformed radiologists in mammogram interpretation [11] |
| Generative | A generative system can create synthetic data resembling real-world data | Analysis of improper payments in the medical insurance system [12] |
| Workflow Optimization | The system can dynamically plan processes with higher efficiency | AI optimized patient triage in emergency departments [13] |
| AI in Robotics | The system works synergistically with robotic technologies, enhancing their functionality; includes deductive systems | Automated anesthesia systems [14 |

Generative AI models have demonstrated greater consistency, accuracy, and alignment with expert recommendations when determining the need for hospitalization and assessing disease severity. However, AI systems were inferior to practicing emergency department nurses in terms of contextual sensitivity, which is essential in urgent care settings [15].

Robotic forms of AI are already functioning in healthcare systems across various countries. In practice, they operate under human supervision, which limits their speed. AI can be applied not only directly in clinical settings but also in the training of medical professionals, particularly when simulation of clinical scenarios is required [10].

In the future, AI may potentially serve as a "more experienced expert" or an arbiter in disagreements between medical professionals, such as when opinions differ regarding a diagnosis. However, an AI-generated decision may not be accepted by all clinicians, not only due to doubts about competence or professional rivalry. Cases have been documented in which AI systems manipulated statistical data and outcomes, as well as situations where students used ChatGPT to fraudulently complete academic assignments. In such cases, quality assessment required the involvement of AI detectors by reviewers and editors, which themselves could yield false-positive results for AI-generated plagiarism. Thus, the gold standard in expert evaluation remains human judgment [2].

**Application of AI in Healthcare**

***Endoscopy***

Machine learning algorithms assist in performing complex tasks in endoscopy. Annotation of large image libraries forms the dataset against which algorithmic performance is tested. The algorithm learns to recognize lines and patterns, increasing in complexity over time. Some algorithms provide automated quality control through real-time feedback to the specialist during endoscopic procedures.

Significant interest in AI development has been driven by the creation of algorithms that enhance diagnostic performance. For example, algorithms for diagnosing colorectal polyps have led to improved adenoma detection rates [16]. In a study by A. J. De Groff et al., an automated system for detecting Barrett's neoplasia during real-time endoscopic procedures was described. The accuracy, sensitivity, and specificity of this system were 90%, 91%, and 89%, respectively [17]. Training of the machine-learning algorithm was performed using a large dataset of endoscopic images of the intestine, both with and without early neoplasia.

***Ophthalmology***

Machine learning (ML) algorithms in ophthalmology continue to advance. AI-based programs have become highly sought after for the detection and assessment of primary angle-closure glaucoma (PACG), demonstrating high performance in identifying angle closure. More sophisticated deep learning algorithms have outperformed traditional ML models in comparative analyses and have been able to accurately differentiate angle status (open, narrow, or closed) and automate the measurement of quantitative parameters [18].

***Histology***

Histopathology currently serves as the definitive diagnostic method for bronchopulmonary carcinomas. During evaluation, specialists assess nuclear atypia, mitotic activity, cell density, tissue architecture, and other parameters, all of which are critical for accurate tumor classification. The phenotypic presentation reflects altered molecular processes occurring in cancer cells. However, the subjective component inherent to human assessment can reduce diagnostic accuracy. Despite established algorithms and criteria, interobserver variability remains a significant issue.

Content-based image retrieval (CBIR) is one AI approach used in image analysis, while the extraction of visual features involves mathematical transformations calculated from the pixel structure of digital images. Artificial neural networks, particularly convolutional neural networks, enable highly efficient image analysis, including interpretation of histological patterns. Therefore, AI represents a promising tool for the histological evaluation of lesions suspicious for malignancy [19].

***Radiology***

In a recent review by S.C. Kotoulas et al., which summarized the findings of 473 studies, it was demonstrated that AI can detect suspicious pulmonary nodules using radiological imaging and differentiate between benign and malignant lesions. In several cases, diagnostic performance exceeded that of experienced radiologists. Incorporating additional factors into the differential algorithm—such as anamnesis, biomarkers, cytological data, and others—improved tumor type identification [20]. For example, in an AI-based early prediction model for lung cancer (n = 560) that integrated radiological data, liquid biopsy results, and clinical parameters (age, smoking history), the system achieved high diagnostic performance, with a sensitivity of 89.53% and a specificity of 81.31% [21].

To differentiate between immune checkpoint inhibitor–induced pneumonitis and progressive non–small cell lung cancer, the model additionally incorporated dyspnea, cough, hypoxia, and serological markers, in combination with radiological findings [22].

A three-tier AI system was developed for lung cancer diagnosis, incorporating three machine learning approaches—decision trees, artificial neural networks, and support vector machines. The system processed 14 clinical and epidemiological variables combined with five tumor markers and CT results (22 features in total). At the third diagnostic tier, the area under the curve (AUC) reached 0.908 for the C5.0 decision tree, 0.910 for the artificial neural network, and 0.849 for the support vector machine. Thus, the model demonstrated high diagnostic accuracy [23].

*Other **Applications** of AI*

Beyond the aforementioned fields of medicine, AI has also been successfully applied in: pharmacology (reducing drug development timelines); dermatology (diagnostic accuracy surpassing clinicians); oncology (performance comparable to physicians); genetics (genomic analysis); prenatal ultrasound (fetal anomaly detection); neurology (assisting in stroke diagnosis); psychotherapy and psychiatry (enhancing confidentiality) [9].

*Insurance Medicine*

In the article by S. Dogra et al., an important issue is raised concerning reimbursement for AI-based services within medical insurance systems. In particular, the authors examine the potential of General Radiology Artificial Intelligence (GRAI), which, in addition to clinical tasks, can perform functions related to coding, evaluation, and insurance coverage policy. Reimbursement for AI services is expanding across multiple areas of medicine. The FDA defines AI as software intended to achieve one or more medical purposes and capable of performing these functions without being part of a hardware medical device.

To date, only two machine learning algorithms have been assigned Category I CPT (Current Procedural Terminology) codes:

92229 — Retinal imaging for detection or monitoring of disease, with automated point-of-care analysis and a diagnostic report, unilateral or bilateral;

75580 — Coronary fractional flow reserve derived from augmentative software analysis.

Additionally, five other algorithms have been assigned Category III codes. Thus, the legal and regulatory framework for integrating AI into insurance coverage for medical services is currently under active development [24].

***Robotic Systems***

Robotic technologies in surgery possess several advantages, including high precision (absence of physiologic tremor), enhanced maneuverability, optical magnification of the operative field, and complete surgeon control, ultimately resulting in improved surgical outcomes (aesthetic results, reduced complications, etc.). Robotic surgery is particularly effective in minimally invasive procedures.

In the review by D.G. Parfeev et al., medical robotic systems were categorized into three groups:

1. robotic systems for patient assistance (wheelchairs, companion robots, and others);
2. systems that optimize specific healthcare processes (laboratory analyzers, diagnostic and

 

transport systems);

3. robotic surgical systems [25].

The authors examined the complex evolutionary pathway of robotic medicine—from its earliest systems to the advanced robotic platforms used today.

The use of robotic systems in surgery spans approximately 35 years, and since the early 2000s their adoption has increased, largely due to the emergence of innovative technologies. Unexpectedly, advances in the aerospace sector—specifically the need for remote telemanipulation—stimulated the development of telemedicine, including the creation of virtual reality headsets and robotic telemanipulation systems for microsurgery. Two key concepts—telepresence and robotic telemanipulation—served as catalysts for the evolution of tele-surgery [26].

The first robotic platform, Unimation Puma 200, integrated with a computed tomography scanner, was employed for brain tumor biopsy as early as 1985. Even at that time, improved procedural accuracy was noted following correct calibration of the robotic system [27].

The first model of a robotic arm, AESOP 1000, was approved for clinical use in 1994 and was operated via foot pedals. Two years later, the pedal interface was replaced by voice control, enabling the surgeon to utilize a "third arm," thereby eliminating the need for a surgical assistant. Since then, numerous robotic systems have been developed.

Among the most notable advancements were the Zeus and da Vinci surgical platforms. The Zeus system, introduced by Computer Motion in 1998, featured three instrument-holding robotic arms controlled directly by the surgeon and incorporated the concept of telepresence. In 2003, Computer Motion merged with Intuitive Surgical, discontinuing production of Zeus and yielding to the more advanced and promising da Vinci system.

The differences between these systems, which highlight the technological progression of surgical robots, are summarized in Table 2 (see Table 2) [26, 28].

**Table 2. Characteristics of the Surgical Robotic Systems Zeus and Da Vinci**

| | Zeus | Da Vinci |
|---|---|---|
| Development Start | Production began in 1995, FDA approved in 2001 | First Da Vinci robot FDA-approved in 2000; latest model approved in 2011 and serves as the primary standard for robotic surgery equipment |
| Architecture | Teleoperated system consisting of 2(3) robotic arms controlled by the surgeon via AESOP, with modular design | Teleoperated system with a surgeon console controlling four robotic arms on the patient cart in a "master-slave" configuration (one arm holds the camera, others manipulate surgical instruments). Movements enabled by cable-driven joints at the distal end of instruments |
| Clinical Use | Used in laparoscopic and thoracoscopic surgeries (discontinued in 2003) | Widely used in various surgical procedures (general, urological, gynecological, cardiothoracic, etc.) |
| Cost | Less expensive | Higher cost due to advanced technology and broad clinical use |
| Image Generation | Standard screen providing 2D view or polarized glasses for 3D visualization | Two cameras connected to the main console provide 3D visualization of the surgical field |

In addition to ZEUS, many other robotic systems (M7, Raven IV, PMAR, MiroSurge, Ottava, Bitrack, and MrBot) have also been discontinued [28].

The development of the da Vinci robot began in the mid-1990s as a joint project involving the United States Department of Defense and the Stanford Research Institute. The introduction of da Vinci enabled high-quality three-dimensional imaging, the use of robotic arms, and a reduction in the learning curve. As a result, the system became a benchmark in robotic surgery. The first da Vinci model was presented in 1997 by Intuitive Surgical and was designed for minimally invasive procedures. Remote control of the da Vinci system integrates image-guided navigation, robotic positioning, and teleoperation. Subsequent generations of da Vinci have been developed to further enhance capabilities. For instance, in 2014, the fourth generation, da Vinci Hi, was introduced. The recently launched da Vinci 5 represents a breakthrough in integrating AI-assisted navigation, real-time force feedback, and intelligent energy management, thereby improving surgical precision [29].

An essential factor for successful robotic function is communication between the surgeon and the robot. Voice-based interaction is particularly valuable, as it frees the surgeon's hands to focus on the primary operative tasks. Implementing voice communication allows more efficient control of the surgical robot and enhances the precision of procedures. The integration of voice-command functionality into robotic systems demonstrates that voice control significantly improves human–machine interaction, positively affecting surgical outcomes [30].

**Robotic Surgery in Medicine**

The use of the da Vinci system in dentistry is challenging due to the complexity of pharyngeal anatomy, making it less suitable for dental implantation and other precise manipulations. The robotic arms of da Vinci do not allow the surgeon to fully visualize the operative field. To overcome these limitations, flexible robots (e.g., Flex) have been developed and approved by the FDA. Robotic implant surgery ensures precise implant placement and helps avoid hazardous deviations of instruments during procedures. Automated calibration and drilling with robotic systems minimize the impact of human error, reducing tissue trauma. Currently, numerous implant robots from various manufacturers have received FDA and other regulatory approvals [31].

The application of robotic systems in gastrointestinal surgery began in 2000 with minimally invasive esophagectomy. Two years later, an intrathoracic anastomosis was performed for distal esophageal cancer. Since then, minimally invasive robotic gastrointestinal surgery has advanced significantly, with numerous reports documenting its use in esophageal, gastric, and intestinal cancer procedures. The fourth-generation da Vinci Xi provides excellent visualization through high-quality three-dimensional imaging, dexterous instruments, motion-scaling capabilities, and articulated functions with tremor filtering. As a result, minimally invasive robotic gastrointestinal surgery significantly reduces risks typical of conventional surgery [32].

The da Vinci Xi system also offers enhanced flexibility for rectal surgery. Improved suprapubic access via robotic-assisted resection reduces patient hospitalization. Single-port surgery improves cosmetic outcomes and accelerates recovery. Robotic formation of intestinal anastomoses promotes rapid healing, functional recovery, and tolerance to solid food. Indocyanine green dye is used for lymph node mapping and assessment of anastomotic blood supply [33].

Robotic surgery is also applied to pancreatoduodenectomy, where a key challenge is the en bloc resection of the pancreatic uncinate process. Robotic visualization facilitates the surgeon's ability to address this challenge. Additionally, during lymphadenectomy, the robotic system enables precise skeletonization of the portal vein, mesenteric veins, and hepatic arteries, while facilitating exposure and dissection of lymph nodes around the aorta, celiac trunk, and other difficult-to-reach regions. These capabilities are provided by the high-tech da Vinci robot through superior visualization and dexterity of the robotic arms [29].

For robot-assisted total knee arthroplasty, the ROSA system (Robotoc Surgical Assistant, Zimmer Biomet, Warsaw, IN) has been proposed. The system assists the surgeon, who maintains control over the procedure. ROSA aids in performing distal femoral cuts, determining the size and positioning of the femoral component, executing tibial cuts, and achieving ligament balancing. The system is available in two versions: with or without 3D imaging. Cadaveric studies have demonstrated high accuracy and reproducibility of the device [34].

Ophthalmic surgeries are characterized by limited operative fields and delicate microstructures of the tissues involved. High precision and reproducibility are essential for successful outcomes. Hand tremor and fine control over sensitive tissues are critical factors. The da Vinci system is utilized in ophthalmic microsurgery. Its clear advantages include optical magnification, tremor filtering, and an ergonomically designed surgeon console suitable for microsurgical procedures. The system has been effectively employed in corneal repair, vitrectomy, intraocular foreign body removal, anterior capsulorhexis, penetrating keratoplasty, and pterygium surgery [35].
Robot-assisted surgeries are actively performed in Germany in urgent surgical cases. The da Vinci system was used in 82% of interventions. The most frequently reported procedures were urgent cholecystectomies, followed by incarcerated hernia repairs. Publications did not report any complications specific to robotic surgery [36].

In a review by C. Gelmi et al., currently utilized neurosurgical robotic systems were discussed. The most commonly applied systems included da Vinci and more maneuverable devices for confined spaces, such as NeuRobor, Concentric Tube Robots, and Smart Arm. Reported interventions included skull base resections, third ventricle ventriculostomies, orbital tumor excisions, and microvascular anastomoses. Noted limitations were the bulkiness of the systems and the absence of haptic feedback. While robotic systems were recognized as useful, the authors emphasized the need for the development of new robotic platforms with improved access through narrow anatomical corridors [37].

At the Massachusetts Institute of Technology, a neurointerventional platform with teleoperation based on magnetic manipulation was developed. The system included a magnetically controlled guidewire, a robotic arm, a set of motorized linear actuators for advancing and retracting the guidewire and microcatheter, and a remote control console under real-time fluoroscopic guidance. The system demonstrated the ability to navigate narrow and tortuous vessels in vitro(phantoms) and in vivo in animal models. Procedures such as spiral embolization and thrombectomy with clot retrieval were successfully performed, which are relevant for the treatment of cerebral aneurysms and ischemic stroke. This system is clearly promising for future clinical application [38].

Researchers at the University of Tokyo developed two robotic systems for microneurosurgery. The first system is intended for deep surgical interventions, enabling suturing of vessels in deep and narrow anatomical spaces. The second system is capable of performing ultra-fine manipulations, including creating vascular anastomoses with diameters as small as 0.3 mm. Cadaveric studies demonstrated the impressive potential of these robotic models for real-world neurosurgical applications. Nevertheless, these systems require further refinement before clinical implementation [39].

Robotic endovascular procedures, although still in early stages of development, represent a more effective alternative to conventional robotic laparoscopic vascular interventions. Compared with the latter, endovascular robotic procedures demonstrate superior clinical and economic outcomes. They are minimally invasive and particularly suitable for high-risk patients. It has been shown that robot-assisted percutaneous coronary intervention offers safety and efficacy comparable to manual procedures [40].

Prostate biopsy, when performed manually, is associated with low diagnostic yield (20–30%), and its reliability and accuracy are considered suboptimal. Robotic biopsy systems reduce operator dependency, decrease procedural workload, and improve both the accuracy and reliability of tissue sampling. Various systems are capable of integrating MRI, ultrasound, and image fusion for guidance [41].

Teleoperated robotic ultrasound examinations have found application in clinical practice. In such systems, robotic devices are capable of following the hand movements of sonographers both remotely and within local networks. Remote ultrasonography has been performed in geographically isolated areas, demonstrating results comparable to conventional ultrasound examinations. High-bandwidth communication channels are recommended for optimal image transmission. Preference is given to systems with haptic feedback. Future implementations may involve AI-assisted systems capable of guiding scanning planes, identifying pathologies, or even performing autonomous remote ultrasonography. This approach could mitigate the shortage of medical personnel in underserved and resource-limited regions [42].

In patients with neurological disorders, limb spasticity and altered muscle strength are often observed. Manual assessment of these parameters by healthcare professionals is imprecise and demonstrates poor reproducibility. Robotic systems designed to measure spasticity and muscle strength can address these limitations. However, these systems require further refinement in terms of safety, completeness of measurement, expansion of measurable parameters, and improvement of data interpretation efficiency [43–44].

## Discussion

Analysis of the reviewed publications highlights the conventional nature of the term "artificial intelligence", whose function is primarily based on the analysis and processing of large datasets with continuous parameter adjustment to maximize performance indices, thereby developing a predictive capability. This property is particularly valuable in disease diagnostics, as AI can utilize both visual information and other quantitative and qualitative variables as input data. Furthermore, there is a growing trend to involve AI in clinical decision-making, as it effectively differentiates primary clinical findings from irrelevant artifacts, unlike human physicians who may spend prolonged periods analyzing confounding factors, as demonstrated by G. Dhaliwal [4].

Despite the clear successes of AI, concerns remain regarding the potential erosion of physician competencies with continuous AI assistance. Nevertheless, the gold standard continues to be the expert judgment of the professional medical community. While AI may perform well in the context of typical clinical presentations, human experts are likely better equipped to identify, classify, and determine the nature of rare pathologies or novel infectious diseases that fall outside the scope of AI training datasets.

In the future, artificial intelligence (AI) is expected to leverage large datasets to generate high-level abstractions capable of emulating human subjective responses. In clinical settings, the potential of AI will be applied to create a digital expertcapable of transforming research outcomes (e.g., histopathological findings) into written or verbal reports [1]. Approximately 80% of pathologists anticipate that AI will be integrated into medical practice within the next decade [10]. The future of AI appears to involve an expansion of its role in both everyday life and healthcare, where its applications have already demonstrated remarkable successes.

Furthermore, the integration of AI with robotic systems may enable the development of fully autonomous modules capable of providing care independently of human medical personnel. This is particularly relevant for remote, hard-to-reach regions and low-resource countries experiencing shortages of physicians and nurses. A hybrid approach combining such autonomous modules with telepresence of a specialist located at a significant distance from the patient may represent an optimal solution for emergency medical interventions.

Robotic technologies were implemented prior to the widespread adoption of AI, and it is evident that in the future these technologies will be actively integrated. The most promising candidates for such integration include next-generation da Vinci systems and more specialized robotic platforms, for instance, those designed for neurosurgical procedures. Such platforms are already under active development and continuous refinement. The provision of high-resolution (and, if necessary, magnified) three-dimensional imaging will allow neurosurgeons to maintain superior intraoperative control compared to traditional surgical methods.

It is already evident that digital technologies are fundamentally transforming reality, and healthcare is not exempt from this trend. This transition necessitates a challenging period of adaptation and may warrant the establishment of a new specialty at the intersection of medicine and digital technologies (including AI, neural networks, and robotics) to address emerging technical, clinical, legal, and ethical challenges.

## Conclusion

The future development of artificial intelligence (AI) and robotic systems in medicine is associated with their increasing integration, complexity, and the creation of both specialized and general-purpose platforms capable of providing patient care more autonomously, and potentially without direct human involvement. Based on the analysis of current publications, the following conclusions can be drawn:

In the foreseeable future, the advancement of AI in healthcare is expected to result in the creation of a digital expert capable of performing disease diagnostics with high accuracy and proposing optimal treatment strategies.

There is a clear trend towards the development of highly specialized robotic platforms designed to assist in complex surgical procedures, including neurosurgery, dentistry, and other fields.

The next logical stage in technological development is the creation of autonomous modules that integrate AI with robotic platforms, capable of delivering care either independently or via remote physician supervision(telemedicine). This approach is particularly relevant in remote regions, conflict zones, and areas with a shortage of healthcare professionals.

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