ARTIFICIAL INTELLIGENCE IN SURGICAL ONCOLOGY PRACTICE

Sabirov Sherzod Takhirovich
Head of the Department of Information Technologies
Kimyo international university in Tashkent
ORCID: 0009-0002-7563-2101

Annotation: The aim of this review is to present the fundamental concepts of artificial intelligence (AI) in medicine, with a particular focus on its transformative role in the field of surgery.
A literature search was conducted using PubMed and Google with the keywords "artificial intelligence" and "surgery." Additional references were identified through cross-referencing key publications.
The integration of AI into surgical practice is expected to occur in areas such as medical data acquisition, storage, and analysis. The pace of adoption will likely correlate with labor costs and the growing demand for transparent and reliable statistical information.

Keywords: artificial intelligence, surgery, oncology, machine learning, neural networks

JARROHLIK ONKOLOGIYASI AMALIYOTIDA SUN'IY INTELLEKT

Sabirov Sherzod Taxirovich
Axborot texnologiyalari kafedrasi mudiri
Toshkent Kimyo xalqaro universiteti
ORCID: 0009-0002-7563-2101

Annotatsiya: Ushbu maqolaning maqsadi tibbiyotda sun'iy intellekt (SI)ning asosiy tushunchalarini, ayniqsa uning jarrohlik sohasidagi o'zgaruvchan rolini yoritishdan iboratdir.
Adabiyotlarni qidirish PubMed va Google ma'lumotlar bazalari orqali "sun'iy intellekt" va "jarrohlik" kalit so'zlari yordamida amalga oshirildi. Qo'shimcha manbalar muhim nashrlarni o'zaro bog'lash orqali aniqlangan.
Sun'iy intellektni jarrohlik amaliyotiga integratsiya qilish, asosan, tibbiy ma'lumotlarni yig'ish, saqlash va tahlil qilish kabi yo'nalishlarda amalga oshishi kutilmoqda. Ushbu texnologiyaning joriy etilish sur'ati, ehtimol, mehnat xarajatlari hamda ishonchli va shaffof statistik ma'lumotlarga bo'lgan talab oshishi bilan bog'liq bo'ladi.

Kalit so'zlar: sun'iy intellekt, jarrohlik, onkologiya, mashinali o'rganish, neyron tarmoqlar

ИСКУССТВЕННЫЙ ИНТЕЛЛЕКТ В ПРАКТИКЕ ХИРУРГИЧЕСКОЙ ОНКОЛОГИИ

Сабиров Шерзод Тахирович
Заведующий кафедрой информационных технологий
Ташкентский международный университет Кимё
ORCID: 0009-0002-7563-2101

Аннотация: Цель данного обзора — представить фундаментальные концепции искусственного интеллекта (ИИ) в медицине, с особым акцентом на его трансформационную роль в области хирургии.
Поиск литературы проводился с использованием баз данных PubMed и Google по ключевым словам «искусственный интеллект» и «хирургия». Дополнительные источники были идентифицированы методом перекрёстных ссылок на ключевые публикации.
Интеграция ИИ в хирургическую практику, как ожидается, будет происходить в таких направлениях, как сбор, хранение и анализ медицинских данных. Скорость внедрения, вероятно, будет зависеть от затрат на рабочую силу и растущей потребности в прозрачной и достоверной статистической информации.

Ключевые слова: искусственный интеллект, хирургия, онкология, машинное обучение, нейронные сети

Introduction

Medical practice has traditionally been viewed as an "art," with clinical decisions grounded primarily in expert opinion, experience, and authoritative judgment. Historically, the dominance of senior clinicians' opinions and skepticism toward scientific methodology—whether in biomedical research or statistical epidemiology—posed significant barriers to the adoption of evidence-based tools in clinical practice, or at best made them rare.

In the spring of 1990, Dr. Gordon Guyatt, a residency program coordinator at McMaster University, introduced a new concept called *Evidence-Based Medicine*—an innovative approach to clinical education at the bedside that emphasized critical evaluation methods. Initially, this approach was met with skepticism from his peers, particularly among surgeons who believed their decision-making algorithms were effective, albeit less "scientific." Nevertheless, Dr. Guyatt laid the foundation for a new curriculum centered on evidence-based practice. Since then, a significant portion of medical research has adhered to the principles of evidence-based medicine, with clinical decision-making increasingly informed by levels of evidence and the strength of clinical recommendations.

However, the volume of medical data has been growing exponentially, and modern surgeons are expected to navigate not only the intricacies of surgical technique but also have a working knowledge of chemotherapy, radiology, genetics, pathology, and advanced imaging technologies. A 2018 report by the Independent Commission of the Royal College of Surgeons of England identified four key technological domains set to transform surgery over the next two decades:

- Robotic and minimally invasive surgery
- Imaging technologies (including virtual, mixed, and augmented reality)
- Big data, genomics, and artificial intelligence (AI)
- Specialized interventions such as transplantation and stem cell therapy

These advancements promise a more personalized approach to treatment, offering better predictability of outcomes, quicker recovery times, and reduced complication risks. Among these domains, this review focuses on the integration of AI into surgical and surgical oncology practices, summarizing key publications and current trends in the field.

The idea that artificial (machine) intelligence could perform at a human level in cognitive tasks was proposed as early as 1950 by Alan Turing, a pioneer of modern computing. Today, there is growing optimism that AI can assist—and in some areas potentially replace—human surgeons. This is underscored by the fact that in 2016, healthcare became the leading sector for AI investment, surpassing all other industries.

The objective of this review is to highlight the foundational principles of artificial intelligence in medicine, with a particular emphasis on how this technological frontier is reshaping surgical practice. We conducted a literature search using PubMed and Google with keywords such as "artificial intelligence" and "surgery." Additional references were retrieved through cross-referencing pivotal publications. This review presents a variety of AI-based applications that are either already in use or currently being developed for surgical practice.

Types and Mechanisms of Artificial Intelligence

In the 21st century, one area of AI—*machine learning*—has experienced rapid development and has become the dominant paradigm in AI research. Today, the terms "artificial intelligence" and "machine learning" are often used interchangeably. Machine learning encompasses a class of algorithms that improve performance over time by learning from experience, whether human-provided or self-derived, particularly in solving applied tasks. These algorithms identify hidden patterns in data and use them to make predictions.

There are three primary types of machine learning:

1. **Supervised learning** occurs when an algorithm is trained on labeled data, meaning both the input and the correct output are provided. For example, when training a system to identify the gallbladder in laparoscopic

cholecystectomy images or videos, the target structure is manually labeled, enabling the algorithm to learn to recognize it.

2. **Unsupervised learning** involves training on data without labeled outcomes. The algorithm autonomously discovers structures or patterns that may be clinically useful—for instance, clustering patients with a new disease or identifying the unique texture and color of bleeding tissue compared to non-bleeding areas.
3. **Reinforcement learning** is based on the concept of an agent interacting with an environment, learning to make decisions through trial and error by receiving feedback or “rewards” based on its actions.

Of these, supervised learning has seen the most widespread application in medicine. A particularly powerful and widely adopted technique in this category is the **artificial neural network (ANN)**. These networks mimic the structure of the human nervous system, with data processed through layers of simple computational units—artificial neurons. Each neuron receives input data (similar to biological dendrites), performs computations, and passes the output (akin to axons) to the next neuron. Input-layer neurons receive raw data, while hidden layers (which can be many) extract and analyze complex patterns and relationships in the data.

In clinical practice, AI systems often combine multiple machine learning approaches. For practical use in medicine, AI applications are typically divided into two categories:

1. **Virtual AI** – software-based systems accessible through personal computers or smartphones. These include medical apps, electronic health record analytics, and decision-support systems powered by neural network algorithms.
2. **Physical AI** – hardware-integrated systems embedded in medical devices, such as robot-assisted surgical platforms, smart prosthetics for elderly or disabled patients, and other interactive tools with real-world applications.

Applications of Artificial Intelligence

Natural Language Processing (NLP) is a branch of AI focused on enabling computers to comprehend human language. It plays a vital role in large-scale analysis of electronic health records (EHRs), especially in processing physicians' narrative documentation. To truly understand language at a human level, successful NLP systems must go beyond simple word recognition and incorporate analysis of both syntax and semantics.

Computer Vision, another critical AI domain, involves machine-level interpretation of images and video—achieving, and in some cases surpassing, human-level accuracy in recognizing scenes and objects. It relies on mathematical algorithms to extract quantitative features such as color, texture, and spatial position from visual data. These features are then used within datasets to identify statistically significant events, such as the presence of bleeding in surgical videos.

AI in Diagnosis and Prognosis

In the preoperative stage, artificial intelligence can serve as a powerful diagnostic tool—so significant, in fact, that it could merit an article of its own. One key advantage is the AI system's capacity to rapidly analyze thousands of patient cases, far exceeding what a clinician could assess in an entire career. AI-driven decision-making models are especially useful in situations where medical experts disagree—for example, in detecting pulmonary tuberculosis from chest radiographs.

In some studies, AI has demonstrated the ability to interpret visual data—such as images of skin lesions (e.g., carcinoma, pigmented nevi, or melanoma)—with an accuracy comparable to that of experienced dermatologists. In the context of surgical oncology, several retrospective studies have shown that AI can accurately identify clinical indicators that may influence treatment strategies. Its diagnostic performance has been found to be on par with that of clinicians, radiologists, and pathologists (see table).

Moreover, in one study conducted by Google, an AI model analyzing mammograms of patients with confirmed diagnoses produced **2.7–9.4% fewer false negatives** and **1.2–5.7% fewer false positives** compared to expert radiologists.

Artificial Intelligence in Medical Education

Given that just **one minute of high-definition surgical video** is estimated to contain up to 25 times more data than a high-resolution CT scan, education is one of the most promising areas for AI integration. Artificial intelligence can be employed to process large volumes of surgical video and imaging data in real time, enabling the detection or prediction of adverse events and supporting intraoperative clinical decision-making.

For example, real-time analysis of laparoscopic sleeve gastrectomy procedures achieved **92.8% accuracy** in automatically identifying surgical steps and detecting missed or unexpected phases of the operation. Similarly, in laparoscopic cholecystectomy, the system identified the critical view of safety with an accuracy ranging from **62% to 79%**, depending on the procedural phase. A machine learning model also achieved competitive accuracy in standard surgical training tasks such as suturing (**92.5%**), needle passing (**95.4%**), and knot tying (**91.3%**).

Artificial Intelligence in the Operating Room

Initial AI applications in the OR focused on simple skill-based tasks such as suturing or knot tying. However, researchers led by A. Shademan at Johns Hopkins University demonstrated the capabilities of an autonomous system called **Smart Tissue Autonomous Robot (STAR)**. Coupled with advanced algorithms, STAR was able to independently perform **ex vivo** and **in vivo** intestinal anastomoses in animal models with quality metrics comparable to human surgeons.

Their evaluation included surrogate indicators such as suture placement consistency, spacing, anastomotic burst pressure, error rates requiring needle retraction, anastomosis completion time, and reduction of intestinal lumen diameter. While these results remain preclinical, they illustrate the potential of AI-powered autonomous surgical systems.

Artificial Intelligence in Postoperative Care

Natural language processing and machine learning have also proven useful in predicting **postoperative complications**, such as anastomotic leakage. In one study involving colorectal surgery patients, a combined analysis of multiple data types yielded a **92% predictive accuracy**. In contrast, isolated analysis of individual data sources showed lower accuracies: **65%** for vital signs, **74%** for laboratory tests, and **83%** for clinical notes.

The Economic Rationale for AI Integration

Beyond clinical applications, AI also holds significant economic value. Predictive analytics and big data processing are projected to save the U.S. healthcare system between **$300–450 billion annually**. These cost-saving opportunities drive strong incentives to integrate AI and data-driven technologies across healthcare systems globally.

Such savings appear even more significant when considering that global healthcare expenditures were expected to reach **$10 trillion by 2022** (WHO), with the U.S. accounting for **$5.7 trillion** of that total. In contrast, Russia's federal healthcare budget in 2021 was projected at **572.5 billion rubles** (~**$8.8 billion**), which pales in comparison to the **$500 million** investment made in the **Verb Surgical collaboration**—a joint AI initiative between Johnson & Johnson's Ethicon and Google's life sciences division, Verily.

Russian healthcare researchers based at the University of Cambridge have argued that despite efforts by the Ministry of Health since 2010 to improve care quality through new resources and reforms, few initiatives have undergone rigorous evaluation. They emphasize the need for large-scale investment in health systems research to fully realize improvements in care quality. In this context, the collection and processing of big data at the institutional or regional level could reasonably be entrusted to AI systems.

Conclusion

Surgeons are in a unique position to lead the adoption of artificial intelligence in clinical settings rather than passively waiting for its maturity. As AI technologies evolve, their applications in medicine—and particularly in surgery—are expanding rapidly. AI is likely to become an integral part of the healthcare ecosystem, offering support in medical education, diagnostic imaging, decision-making, and robot-assisted surgery.

Its clinical value is already evident, and the volume of research in this domain continues to grow. The **pace of AI integration** will likely be **directly proportional to the cost of medical labor** and the **demand for transparent, reliable data collection and analysis**.

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