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Editorial Board Member of *Artificial Intelligence in Cancer*, Gizem Calibasi-Kocal, PhD, Associate Professor, Department of Translational Oncology, Institute of Oncology, Dokuz Eylul University, Izmir 35330, Turkey. gizemcalibasi@gmail.com

AIMS AND SCOPE

The primary aim of *Artificial Intelligence in Cancer* (*AIC*, *Artif Intell Cancer*) is to provide scholars and readers from various fields of artificial intelligence in cancer with a platform to publish high-quality basic and clinical research articles and communicate their research findings online.

AIC mainly publishes articles reporting research results obtained in the field of artificial intelligence in cancer and covering a wide range of topics, including artificial intelligence in bone oncology, breast cancer, gastrointestinal cancer, genitourinary cancer, gynecological cancer, head and neck cancer, hematologic malignancy, lung cancer, lymphoma and myeloma, pediatric oncology, and urologic oncology.

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MINIREVIEWS

Artificial intelligence as a future in cancer surgery

Morena Burati, Fulvio Tagliabue, Adriana Lomonaco, Marco Chiarelli, Mauro Zago, Gerardo Cioffi, Ugo Cioffi

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Morena Burati, Fulvio Tagliabue, Adriana Lomonaco, Marco Chiarelli, Mauro Zago, Department of Robotic and Emergency Surgery, Ospedale A Manzoni, ASST Lecco, Lecco 23900, Italy

Gerardo Cioffi, Department of Sciences and Technologies, Unisannio, Benevento 82100, Italy

Ugo Cioffi, Department of Surgery, University of Milan, Milano 20122, Italy

Corresponding author: Ugo Cioffi, PhD, Professor, Surgeon, Department of Surgery, University of Milan, *Via* F. Sforza 35, Milano 20122, Italy. ugocioffi5@gmail.com

Abstract

Artificial intelligence (AI) is defined as the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, and decision-making. Machine learning and deep learning (DL) are subfields of AI that are able to learn from experience in order to complete tasks. AI and its subfields, in particular DL, have been applied in numerous fields of medicine, especially in the cure of cancer. Computer vision (CV) system has improved diagnostic accuracy both in histopathology analyses and radiology. In surgery, CV has been used to design navigation system and robotic-assisted surgical tools that increased the safety and efficiency of oncological surgery by minimizing human error. By learning the basis of AI, surgeons can take part in this revolution to optimize surgical care of oncologic disease.

Key Words: Artificial intelligence; Surgery; Robotic surgery; Machine learning; Pattern recognition; Cancer

Core Tip: Artificial intelligence (AI) has been applied in different fields of medicine to maximize the accuracy of diagnosis and treatment. AI-based navigating systems and surgical robots have helped surgeons to improve their results in terms of safety and efficacy in oncologic surgery. By learning the basis of AI, surgeons can take part in this revolution to optimize surgical care of oncologic disease.

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INTRODUCTION

Artificial intelligence (AI) is defined as the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, and decision-making. Machine learning (ML) is a subset of AI. It is based on algorithms inspired by neural networks, developed to be able to learn to solve problems as a human brain would do[1]. A part of ML is deep learning (DL), based on artificial neural networks (ANNs) (such as deep neural networks, deep belief networks, deep reinforcement learning, recurrent neural networks, and convolutional neural networks). In DL, multiple layers of processing are used to extract progressively an higher level of features from data, with the final purpose 'to learn through experience'[2]. AI, ML, and DL are having greater and greater impact in everyday life and health care providing. Being developed faster and more reliably, they are expected to gain a relevant position in diagnostic and thera-peutic processes.

Cancer is still one of the most common causes of death in developed countries, destined to increase due to the global aging of the population[3]. An enormous effort has been made and it is still going on to employ AI and its future developments in cancer diagnosis and treatment, as it is still a huge priority worldwide. Approximately 30 years ago, surgeons witnessed the birth of robotic surgery, which has been constantly improved with AI technologies to improve its efficiency and minimize human mistake. To be truly part of this revolution, surgeons must understand the foundation of AI technologies.

The purpose of this minireview is to show the basis of AI and its subfields and its role in cancer surgery.

METHODS

A MEDLINE search on PubMed was performed. We screened the resulting articles to identify key concepts and techniques within AI, especially leading innovation in the field of oncologic surgery. Thirty-four articles are cited in our minireview, including reviews and meta-analyses.

AI IN MEDICINE

At present, AI is applied to computers and medical robots to mimic human intelli-gence, assisting in drug design, clinical diagnosis formulation, and robotic surgery[4]. In addition, sophisticated AI software is used to produce medical statistical datasets and recognize tumoral cellular patterns for histological diagnoses, including cancer[5].

In medicine, AI has two main branches: Virtual and physical[6]. The virtual component applies DL information management to control electronic health records and guide physicians to take treatment decisions. The physical branch is represented by robots[7]. Robotic systems have been used in surgery since the late 90 s; also robotic assistants are also used in the care of elderly patients and nanorobots are currently being developed to deliver drugs to a specific target[8]. In the next future, this new way to administer chemotherapy will change cancer treatment, improving its efficacy by reducing global toxicity.

Nevertheless, as any new technology introduced in a critical field like healthcare providing, societal and ethical controversies of these new technologies need a special focus on their true utility, economic and environmental sustainability, and constant widening of their applications[9].

SUBFIELDS IN AI: ML, NATURAL LANGUAGE PROCESSING, ARTIFICIAL NEURAL NETWORK, AND COMPUTER VISION

To better understand AI and its role in oncologic surgery, it is crucial to discuss AI's principal subfields and their role in medicine.

ML allows machines to recognize specific patterns and, by doing that, automats can learn and make predictions. Actually, there are two types of ML: Supervised and unsupervised. Supervised ML utilizes partial labelling of the data to predict a known result or outcome. Unsupervised ML, instead, analyses the structure detected in the data itself to find patterns within data[10]. ML is particularly useful to identify hidden patterns in large datasets. In fact, they can easily detect complex non-linear relationships and multivariate effects compared to conventional statistical analysis[11]. Also, part of ML is reinforcement learning, where accomplishing a task depends on previous success or failure.

Natural language processing focuses on machine's understanding of human language beyond simple word recognition including semantics and syntax. At present, it has been used to analyze large datasets in search of adverse events and postope-rative complications. Moreover, it has found an interesting use in surgery: By analyzing operative reports and postoperative notes, it has been able to elaborate an algorithm that predicts the anastomotic leak after colorectal surgery. Of interest, the software did not only include obvious data like the type of surgery and time to first oral feeding, but also could understand and codify how the patient was described by doctors (weak, irritated, at ease, *etc.*) and include this data in the analyses[12].

ANNs are the base of DL. They get their inspiration from human neural networks. These networks are made of many layers of connections and are able to learn from previous experiences. Based on previous feedbacks, in fact, in-put and out-put patterns change to complete the due task. In clinical practice, these technologies have been proved more accurate than traditional scores in predicting patients' outcomes[13].

Computer vision (CV) is the ability of computers to understand and process images. Its applications in clinical practice are huge and in continuous growth: Computer-aided diagnosis, image-guided surgery, and virtual colonoscopy are only few of the new technologies developed and introduced in everyday medical practice[14].

AI IN CANCER SURGERY

AI technologies, especially the field of DL, have a huge role in cancer diagnosis and treatment. At present, early detection is the key to preventing neoplastic affections to become incurable. The role of AI in the diagnostic field of oncologic affection is well known and widely described in the medical literature. As a matter of fact, DL has been applied to clinical radiology and histopathology to obviate the operator's sensitive level of precision. DL has proved great success rates in imaging pattern recognition, thus the expectations on its future clinical applications have grown exponentially in the last decade. Early results published in the literature showed how DL-based imaging recognition provided superior performances compared to traditional computer-mediated techniques, or in some cases, they were even more accurate than experienced physicians[15].

High impact examples of this are dermatologic software able to perform dermo-scopies to detect melanoma. In the literature, these technologies have been proved to have same accuracy as expert dermatologists[16]. CV has been extensively used in oncologic radiology. Recent studies have demonstrated that AI software is able to interpret mammographic images for breast cancer screening as an expert physician would do[17]. Moreover, computer aided-detection improved by ANN, generated a software program able to detect imaging alterations on computed tomography (CT), like enlarged lymph nodes and suspect colonic lesions for colon cancer early diagnosis[18].

Another interesting cancer-related field in great expansion is automatic histopa-thology analysis. Of interest, in cancer treatment, tissue biomarker positivity (expressed in scores) is essential to plan a chemotherapy schedule. Recently developed DL-based computational approaches can automatically score the presence of a specific biomarker. For example, a recent study demonstrated that the DL-mediated scoring of HER 2 in breast cancer samples was more accurate than the human-mediated scoring and lead to identification of few cases at high risk of misdiagnosis[19].

When explaining the role of AI in histopathology analyses, it is crucial to emphasize how ML-based increased accuracy can influence physicians' therapeutic choices and, therefore, a patients' history. In fact, DL models can recognize high risk cancer lesions at fine needle biopsy with greater accuracy than traditional methods. This can affect surgery too, since the diagnosis of a benign neoplasm can prevent or limit surgical excision, reducing patients' risk of developing complications or carrying impairing lesions. As an example, in an interesting study by Juwara *et al*[20], AI assistance significantly reduced mastectomies by 30.6% by increasing the detection of benign lesions at core biopsy, which usually were diagnosed only after extended surgery.

Surgical resection is often a crucial point in cancer treatment. AI subfield gets employed in computer assisted surgery (CAS), which has entered everyday clinical practice, and has improved its efficiency and efficacy in the management of oncologic diseases that need surgical attention[21]. CV is widely applied in image guidance and navigation, defined as a system designed to assist surgeons on the basis of pre-operative radiological CT images[22]. It is used to easily explore a patient's anatomy, recognize pathologic or noble structures, and plan their removal or sparing. Radiological imaging combined with specific tracking technologies installed in surgical instruments get set on the patient's coordinate system. The machine recognizes and indicates the structures of interest, even when they are hidden, helping surgeons to easily and safely find their way towards their operative targets[21]. At present, image guidance and navigation have found a prolific field of application in neurosurgery and orthopedic surgery, more in general in all kinds of surgery where anatomy do not get subverted by tissue shifting and organ moving[23]. In these cases, computer-based navigation has found limited application. Great efforts have been made to apply AI surgical navigation techniques to surgeries where plane dissection generates anatomical subversion, like abdominal surgery. As a result, new techniques in study can give insights and orientation for hidden anatomical features, like showing the position of the aorta and the ureter in relation to the instruments in laparoscopic rectal surgery[24]. Another successful example is computer-assisted liver map creation in liver cancer surgery[25]. In future, more structures will be 'mapped' on CT images and will be available for image-guided abdominal surgery like the spleen, pancreas, and esophagus[26,27].

The most popular field of CAS is robotic-assisted surgery. Robotic surgery boasts a 50-year-long history. The use of robotics in the surgery field has been hypothesized around 1964, but it took more than 30 years to finally be approved in medical practice by the United States Food and Drug Administration[28]. Originally, abdominal robotic surgery was thought intended for long-distance trauma surgery in battlefield settings. Since the first 2000 s, when surgical robots became commonly used in worldwide operating rooms, robotic surgery gained more and more popularity. Its advantages, in fact, have been shown in medical studies, international randomised controlled trial, and meta-analyses, winning the trust of the more skeptical physicians[29,30]. At present, the well-known advantages of robotic surgery, like 3-D vision, the elimination of hand tremor, and the expanded degrees of freedom of its tools, led robot-assisted surgery to become frequently used in pelvic surgery, like in prostatectomy and hysterectomy. In recent meta-analyses, robotic prostatectomy was connected to improved urinary function, lower intraoperative complication rates, and improvements in positive surgical margins compared to laparoscopic technique[31]. Thus, there is a chance for robotic prostatectomy to become gold standard for surgical treatment of prostate cancer[32]. Huge expectations rely in the field of robotic surgery. In the next future, assistance systems are expected to be integrated with surgical robots. This imple-mented CV technologies will provide surgeons with answers to their doubts about anatomical structures and resection margins by comparing intra-operative data with millions of inventory images [33].

Again, computer imaging is currently used to create virtual models of surgical fields on which surgeons can be trained to acquire the psychomotor skills and surgical knowledge necessary before operating on real patients. This kind of technology is not only useful to train new generations of surgeons, but in future, 3-D operative simula-tors of patients' specific anatomies will be available. This will be revolutionary in oncologic surgery, allowing the deep anatomical understanding of hardly resectable tumors[34].

Looking at these new technological opportunities, it is easy to predict how the role of AI in oncologic surgery will grow fast and will be applied also to pre- and post-operative phases, aiming to a more patient-targeted type of health care that can minimize mortality and morbidity. As a result, surgeons have a key role in the application of ML and DL in the everyday surgical practice. By understanding the basis of AI, surgeons can be part of the designing process of new machine integrated with AI systems. In fact, by highlighting the surgical point of view and changing their skills to adapt to this new way of delivering clinical care, surgeons can be part of this new way to provide health care that will become more targeted, safer, and always more accurate, improving success rates and reducing mortality and postoperative morbidity.

LIMITATIONS

As a minireview, this article has potential limitations common to all reviews. These include potential bias, like the influence of the authors' personal viewpoints and gaps in literature searching that may lead to the omission of relevant data.

CONCLUSION

AI-based technologies, especially ML and DL, have entered the field of oncology, bringing new perspectives and improving accuracy in different fields. In surgery, new CV system and intra-operative image analyses are currently helping surgeons to be more accurate, reducing human error and improving survival. By learning the basis of AI, surgeons can take part in this revolution to optimize surgical care of oncologic disease.

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ORCID number: Morena Burati 0000-0003-2562-4760; Fulvio Tagliabue 0000-0002-4095-017X; Adriana Lomonaco 0000-0002-4270-4132; Marco Chiarelli 0000-0003-1729-4925; Mauro Zago 0000-0001-9322-0798; Gerardo Cioffi 0000-0001-6751-3335; Ugo Cioffi 0000-0002-5321-5828.

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