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Artificial Intelligence from Research to Clinical Practice

Nahla A M Hamed*

Professor of Hematology, Hematology Department, Faculty of Medicine, Alexandria University, Egypt

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***Corresponding author:** Nahla A M Hamed, Professor of Hematology, Hematology Department, Faculty of Medicine, Alexandria University, Egypt

Abstract

The difficulty in early diagnosis of some cancers due to their vague presenting symptoms, the easy relapse of other cancers after treatment in addition to the difficulty in predicting accurately disease prognosis with high certainty all these make it vital to use high-resolution diagnostic tools and better predictive models in clinical cancer research. Artificial intelligence (AI) can solve many of these problems since it nearly affects all aspects of oncology—from enhancing diagnosis to personalizing treatment and discovering novel anticancer drugs. This motivated researchers in the biomedical and bioinformatics fields to develop more effective machine learning tools that can classify cancer patients into high- or low-risk recurrence groups to refine prognosis.

Abbreviations: AI: Artificial Intelligence; ANN: Artificial Neural Network; ML: Machine Learning; DL: Deep learning; NGS: Next Generation Sequencing

Introduction

"Artificial intelligence" (AI) is simply defined as the ability of a machine to learn and recognize patterns and relationships from enough fed representative examples and use this information for effective decision-making on unseen data [1]. AI can be broadly referred to as "thinking machines [1]. It nearly affects all aspects of oncology—from enhancing diagnosis to personalizing treatment and discovering novel anticancer drugs [1].

Machine learning (ML) is a subdomain of AI [2]. ML is a term that refers to the development of neural network base algorithms that allow the machine to learn and resolve problems like the human brain [3]. ML can influence healthcare processes ranging from fully autonomous cancer diagnosis to non-autonomous mortality predictions. It can affect treatment decision as well [3].

Deep Learning (DL) refers to a subfield of ML [2]. DL mimics the human brain's ability for data processing. It can work and suggest an output without human supervision [1]. DL can process various types of collected data for a given dataset by artificial neural network (ANN) which mimics the structure of the nervous system [3]. DL is preferable over ML because of its high performance and AI-based cognitive ability [3]. Most neural networks employed in healthcare are deep networks [4]. The reduced cost and process length [3] of image classification by DL [1] allowed its application in accurate automatic detection of cancer from analyzing images of stained tumor slides or radiology images. It can also improve diagnosis; upgrade drug discovery, assist humans in decisions making and in precision medicines [1].

Basic concept of deep learning

The basic units of communication in a neural network are called nodes or neurons [4]. Neural network is composed of input, output, and various hidden multi-layer networks to enhance machine learning processing powers [3]. They are arrayed in sequential layers, with connections of varying strength between each layer. Any neural network with more than one hidden layer is referred to as "deep learning" or "deep neural networks". The initial layer of a neural network receives input data such as an array of pixels, a series of words, or an array of categorical data. These data are transmitted through intermediate, "hidden" layers, which can create representations of relationships within data. Hidden layers ultimately feed into an output layer, which can perform standard classification/regression tasks or create more sophisticated outputs [4].

Applications of AI in oncology research:

i. Molecular characterization of tumors and their microenvironment [5].

ii. Analysis of pathologic clinical images prepared with AI strategies which enables tumor characterization i.e. identification of the borders of diseased tissue, tumor subtype classification [5] and various cancer growth stages [6]. Furthermore, it has a role in detection of tumor infiltrating lymphocytes in tissue slides images [5]. It can help in classification of dermoscopy images, precise annotation of skin lesions [5], and distinguishing between benign and malignant breast cancer images based upon cellular characteristics [3].

iii. Radiomic analysis i.e. automated extraction of clinically relevant information from radiologic images, radiomic biomarkers, histologic, genetic and other forms of correlative data without actual sampling, what is called "virtual biopsy" [5].

iv. Introduction of novel biomarkers for cancer diagnosis [3], classification [1], grading, and prognostic biomarker interpretation [5].

v. Establishment of Tumor Atlas from stored diagnostic and treatment data of Medical experts. This helps early disease prediction and diagnosis by NGS sequencing and high-resolution imaging techniques [3] for example AI-based screening of lung cancer by analysis of plasma ctDNA and miRNA which is more efficient procedure than low dose CT scan method [3].

vi. Cancer detection and diagnosis: diagnosis of cancer prostate and esophagus, detection and tracking of pulmonary nodules, identification of enlarged lymph nodes or colonic polyps, track potentially cancerous lesions and prediction of lung malignancy [5].

vii. Clinical treatment decision-making [3], such as stereotactic radiosurgery for brain metastases [5].

viii. Discovering of novel anticancer drugs [1] and delivery of potential treatment strategies by generating significant datasets and using specialized bioinformatic tools [3].

ix. Precision medicine: AI can be used for early-stage precise cancer diagnosis, prognosis, and designing novel personalized drugs. This requires ML background of novel biomarkers, selective target sites, and precise diagnosis by NGS sequencing, and high-resolution medical imaging technology to design algorithm for cancer detection. This algorithm base can link genetic information with the molecular pathways responsible for the onset of cancer. Any detected genetic variation from the regional genetic pool data and all other relevant biological parameters defined by ML algorithm, could be linked to early cancer prognosis and drug discovery [3].

x. Predicting treatment outcomes: imaging-based ML models can predict the future outcomes of cancer patients, such as locoregional recurrence, distant recurrence, overall survival, disease-free survival and mortality [5]. This information may drive surveillance and optimized strategies to prevent recurrence of cancer in the future in cancer survivors [5].

xi. Predicting drug efficacy and synergy: ML algorithms can be applied in predicting drug efficacy based on molecular features. The drawback of using DL in this aspect is the need of availability of large cancer drug efficacy datasets and the lack of interpretation with the underlying biological mechanisms. Recently, researchers have translated genomic features such as mutations and gene expression values into drug efficacy in the form of IC50 values. Using predicted IC50 values, patients are splitted into high and low-sensitivity cohorts and their survival under certain treatment regimens can be determined [1].

xii. Drug discovery: The precise high resolution tumor images produced by digitalizing the medical pathology can guarantee understanding of biological complications in cellular architect and develops a new generation of biomarkers and effective cancer therapy [3]. Suberi et al. [7] proposed an image-based computer-aided system to enhance the preparation of vaccine with Dendritic Cells (DCs) immunotherapy [6].

Challenges faced by the researchers in the construction of AI-based prediction models:

a. A small sample data size [8] in real life of certain biomedical samples. An accurate DL models require a large amount of training data [6].

b. High dimensionality i.e. vast number of features of cases [8].

c. Class imbalance problem. Uneven distribution of the size of multi-class samples results in biased classification models [8].

d. The deep learning-based approaches are highly complex and cost high computational time [8].

e. Efficient feature selection technique. The requirement of a computationally effective selection method to eradicate the data cleaning procedures while generating high cancer prediction accuracy [8].

f. The requirement of the generalizability of the prediction model that is validated on multiple sites [8].

g. The practical implementation of the dominant models in clinical setting to assist the medical practitioner in confirming the diagnosis verdict [8]. Oncologists need to learn AI technology to ensure its safe ethical use and to avoid general pitfalls [3].

Conclusion

The successful translation of AI-based application requires expertise in "cancer cell biology" and DL base algorithm to diagnose cancer in its very early stage. Also, oncologists need to learn AI technology to ensure its safe ethical use and to avoid general pitfalls. The lack of computational algorithms and the knowledge of information technology by clinicians prevent the implementation of AI in developing countries.

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