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Artificial Intelligence and Machine Learning in Cancer Care: Current Applications and Future Perspectives

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Cancer is the second most common cause of death worldwide, accounting for an estimated 9.6 million deaths in the year 2018, a number that is expected to grow to more than 13 million by 2030. In the past decade, we have witnessed unprecedented scientific advancement in the understanding of cancer etiology, prevention, diagnosis and development of new therapeutic strategies. However, the hard work made to tackle and manage this disease is inadequate and require more and/or extra efforts for better results. Late diagnosis, ineffective therapy, off-target effects, and drug resistance significantly influence the clinical outcomes of cancer. A remarkable growth in computer engineering in recent years has encouraged cancer researchers to apply computational methods in disease prognosis and outcome analyses. Computational methods including artificial intelligence (AI) and machine learning have revolutionized the field of healthcare and medicine with their wide-range applicability and prediction accuracy. AI is the branch of computer science that can perform tasks that require human intelligence such as learning, planning and problem-solving. AI systems are typically developed to solve complex data-intensive problems. Machine learning and deep learning are applications of AI that are developed to learn from data and adapt to new data without human intrusion. Computer-aided approaches not only assisting in cancer diagnosis, prognosis, and molecular profiling of tumor subtype but also drive therapeutic decisions in daily practice.

An accurate early diagnosis and defining the evidence of benign and/or malignant tumor is essential primary steps to improve the patient survival rates. The speeds of disease diagnosis influence the cancer treatment decision which is directly proportional to clinical outcomes. A convolutional neural network (CNN), a deep learning-based approach that takes an image as input, and later it can differentiate the test images. The CNN model distinguishes different subtypes of breast cancer i.e., benign, ductal carcinoma *in situ*, and invasive ductal carcinoma with about 81.3% accuracy [1]. This model was trained by 221 hematoxylins and eosin (H & E) breast tissue images which achieved an area under the curve (AUC) of 0.962. Tumor microenvironment (TME), which consists of tumor cells, fibroblast, immune cells, stromal cells, soluble and insoluble mediators determine the growth, progression and therapeutic response of cancer. Thus, understanding of TME component in a given tumor is important to develop targeted therapies. The machine learning algorithm developed using 2387 tissue specimens of the breast to gain insights into the TME components demonstrated clinical utility in classifying breast biopsies [2]. Cytological analyses which can typically be performed using cells, body fluids, palpable and non-palpable lesions are important resource for test and diagnosis. AI model has shown to efficiently classify cells either normal or abnormal in smear-based (98.3%) and liquid-based (98.6%) images with high accuracy [3]. A high percentage of lung cancers are non-small cell lung cancer (NSCLC), which is further sub-divided into adenocarcinoma, squamous cell carcinoma, and large cell carcinoma. To plan treatment, identification of cancer subtype is important as they often require different treatment modalities. AI-based CNN model trained using The Cancer Genome Atlas (TCGA) data can differentiate normal lung tissue from NSCLC subtypes [4]. Also, the CNN model identified dysregulated genes (*STK11*, *EGFR*, *FAT1*, *SETBP1*, *KRAS*, and *TP53*) from adenocarcinoma pathology images [4], suggesting that the AI models can assist the pathologist in determining the cancer subtype and gene mutations. Similarly, the CNN model can identify the breast cancer subtypes (luminal A, luminal B, basal-like, HER2-enriched, and normal-like breast cancer) with 78% accuracy [5].

Cancer risk prediction is important in identifying individuals who are at high risk of developing a disease, which could lead to targeted interventions to augment the treatment benefit and reduce the burden of disease. High breast density due to thick connective tissue is considered as a risk factor for breast cancer. However, the current methods are not fully efficient and often fail to recognize breast cancer risk. The new AI-based deep neural network model trained on mammograms of breast cancer cases diagnosed between 2008 and 2012 showed potential for AI in breast cancer risk prediction [6].

Intrinsic and acquired drug resistance is one of the biggest challenges faced by the cancer research community today. Cancer biologists are always looking for better and innovative ways to develop a cancer treatment. The AI and machine learning-based approaches are helping in drug development from start to finish and likely to revolutionize drug discovery. The machine learning methods can recognize the key patterns in complex and multifaceted data through sophisticated algorithms. In the era of precision medicine, or personalized medicine which separates patients into different groups based on their disease predicted response and risk, the focus is more on the treatment that most likely to benefit the patients. The AI model trained through the patient's data predicts the neoantigens for better cancer immunotherapeutic outcomes [7]. Moreover, the AI-based models are developed to predict the antibody epitopes which will help design novel antibodies [8]. AI-based machine learning approaches also demonstrated its potential in the discovery of cancer biomarkers which reveals the existence of disease and are crucial in the determining disease progression and responses to therapy.

The artificial intelligence is emerging as an important tool in cancer care. These approaches are demonstrating their applicability and efficiency in the cancer risk assessment, diagnosis, molecular characterization, drug development and response prediction. AI platform has immense potential in cancer care in terms of disease diagnosis promptly that enlarges the therapeutic window leading to improved patient survival. AI-based models are assisting in the outcome prediction and providing an insight into the therapeutic efficacy to determine the future course of action. However, there are a few areas where we need to focus to improve the efficiency of computational methods. AI-based models require a large amount of data for training and validation. The unavailability of sufficient data compromises the efficacy of the system resulting in the deviations from accuracy. Another challenge that limits the efficacy of AI models is organizational variation in data quality. Bringing innovations and developing novel algorithms for targeted questions will be valuable to go well beyond incremental advances in pattern recognition capacity of AI models. These steps will surely improve the sustainability and reliability of AI in cancer research. Incorporation of artificial intelligence in cancer may lead to the dramatic shift in the quality of cancer care, improve clinical outcomes, drive operational efficiencies, and believed to lower the cost of cancer care.

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