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The Revolutionizing Impact of Artificial Intelligence on Breast Cancer Management

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What Is Artificial Intelligence?

Artificial intelligence (AI) is an algorithm-based strategy of simulating intelligence programmed in a man-made machine for correction and rationalization of actions. AI encompasses a broad range of concepts, including planning, understanding language, recognizing objects and sounds, learning, and problem-solving.

Machine learning (ML) is a way of "training" an algorithm so that it can learn how what? The "training" involves feeding huge amounts of data to the algorithm and allowing it to adjust itself and improve. Deep learning is a branch of ML based on learning data representations, as opposed to task-specific algorithms.[1] Bioinformatics, drug design, and medical image analysis are some of the biomedical applications of deep learning. A clear example of deep learning is an artificial neural network, which includes algorithms that mimic the biological structure of the brain. An artificial neural network is an information-processing paradigm inspired by the way the biological nervous system processes information. It is based on the structure of neurons and neuronal interconnections.

What Are the Applications of AI in Breast Cancer?

Cancer is a collection of diseases, with the unregulated and uncontrolled division of cells being its main hallmark. In breast cancer (BC), this unchecked cell proliferation initially occurs in breast epithelial tissue before forming the actual tumor.

Artificial intelligence promises to revolutionize biomedicine and shape cancer medicine in unprecedented speed and precision.

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This commentary summarizes a number of advances reportedly made in BC basic investigations, drug resistance, disease modeling, mammography screening, etc.

1. Breast cancer modeling

An AI machine called DeepCode has been used to classify xenograft models of human tumors by identifying tumor subtypes with maximum possible accuracy.[2] The machine is indeed able to monitor molecular events during tumorigenesis in xenograft models and the DeepCode-produced data can be cross-compared with the outcomes of human tumor–based investigations on BC tumor evolution. Several ML algorithms were incorporated into DeepCode and applied to 174 human tumors to examine tens of selective genes for constructing a prediction model.[3] As a result, seven interpretable interactions were detected within the informative genes that were verifiable by previous experimental studies.

2. BC tumorigenicity

This is a fundamental segment of oncology studies and its mechanistic investigations have profound implications for personalized cancer management. The advent of next-generation sequencing made it possible, for the first time, to spatiotemporally map tumor genome, meaning that any segment of the tumor cell genome is sequenced at any time during tumor development. It is now AI's turn to make the pace of progress even faster: multiregion sequencing data collected from numerous patients were analyzed by an AI-based method called REVOLVER, which identified previously unknown repeated evolutionary trajectories in subgroups of patients.[4] This is the beginning of a big change as it opens avenues for identifying the molecular roots of the whole tumor formation process. In fact, AI technology is able to detect within tumor genome single mutations,[5] tissue-specific gene expression,[6] and expression of genes shared between xenograft models and tumors of origin.[7]

To elucidate the molecular basis of BC tumorigenesis may require genetic manipulations. AI approaches now facilitate specific cell- and tissue-type targeting. AI-based single-gene delivery can target xenograft model tissues and further expand our capabilities in investigating revolutionary patterns of spatiotemporal gene expression during tumor formation.[8] Such a gene-targeting capacity of AI can be combined with cancer genome–editing ability of the CRISPR/Cas9 system to correct gene mutations and simulate molecular changes within tumor genomes (see subtitle 7: *Detection of BC metastasis*).

AI-based ML is now developed to measure tumor growth profiles and model validation. The TUGROVIS project is aimed to understand the underlying principles of tumor growth by designing and developing algorithms, methods, and tools.[9] The concept is to integrate multiple approaches towards multidimensional connection of open data sets. These works will allow the creation of more personalized models amenable to specific molecular manipulations with applications in human-mouse matched co-clinical trials that heavily depend on mouse models.[10]

3. Distinguishing tumor cells

Microscopic images of cancer cells are scanned and examined by AI-based convolutional neural network so that animal cells are separated from human counterparts and radio-resistant cells are picked up among a population of cancer cells.[11] The findings by the system were gathered on a two-dimensional plot where the results for each cell type clustered together while being clearly separated from the other cells. The system was then trained to accurately identify cells only using their microscopic images. The accuracy and automation of the system can be used to exactly identify cell types present in a tumor or circulating in a patient's body. Such knowledge can be important in deciding chemotherapy or radiotherapy applications.[11]

4. Prediction of drug synergism

Using chemical and genomic information as input, an AI-based program called DeepSynergy models drug synergies. The method improved the performance of other methods by 7.2% in predicting novel drug combinations within the space of explored drugs and cell lines.[12] AI technology can be also effective in predicting and redesigning protein-protein interactions for novel drug discovery. As an example, oncology treatment is an AI-based area of investigation by Boston-based biopharma company Berg. It uses an algorithm and probability-based AI to analyze large cohorts of patients' genotype, phenotype, etc, to find therapies based on cancer biology. Anticancer drug BPM31510 was indeed discovered via AI assistance and is in clinical trial.[13]

5. AI for mammography

False negative and false positive: Mammograms are widely used as a tool to catch BC early on, but they are not accurate. In fact, 20% of them were false negative and 50% false positive in US women tested annually for 10 years. A consortium of AI researchers and health-care professionals in the UK uses Google's AI technology to improve the reading and assessment of mammograms. It analyzes mammograms and finds signs of cancerous tissue more accurately than current techniques detect. The AI approach DeepMind used in this study develops ML algorithms that, by taking a data set and learning from it, ultimately become capable of predictions.[14]

DeepMind Health is training its AI using data from Optimam, a database of over 80 000 digital images collected via the UK's National Breast Screening System, to maximally improve the reading of mammograms. Given that over 30 million mammograms are performed each year in the US alone, DeepMind's ML could save significant time for doctors reading screenings. It could also encompass 3D and other mammography procedures.

An AI approach applied by the French startup Therapixel could cut down false-positive rates by 5%, while over 99% accuracy in detecting the signs of BC risk by reading mammograms has been achieved at Houston Methodist Research Institute in Texas, and the method is reported to read those images 30 times faster than humans. Such approaches are also being applied to other cancers such as brain tumors.

6. Changes in breast density

Deep learning algorithms are capable of precisely identifying increases in breast density, a strong risk factor for BC. A deep convolutional neural network–based algorithm has been developed, trained, and tested at Massachusetts General Hospital using over 41000 digital mammograms obtained from over 2700 women. The accuracy of 10763 mammograms determined by the algorithm as either dense or non-dense tissue turned out to be 94%, with a 6% disagreement rate with radiologists. This technology already helps to categorize vast amounts of information into more personalized, more targeted care for BC patients and predict the chance of every woman to develop cancer in the future.[13]

7. Detection of BC metastasis

AI innovation has been able to detect the spread of BC to the lymph nodes and it does better than pathologists. A simulation study compared the performance of the system with those of 11 pathologists by analyzing digital scans of tissue slides of sentinel lymph nodes using AI-based computer algorithms.[16] Given the complexity of detecting lymph node involvement, the AI-based approach can take huge pressure off pathologists and help them to make the right decisions.

We summarized some of the current applications of AI tools and technologies in BC management. On the horizon lies a glimpse of expanding revolution to storm-wise shake the foundations of traditional views and actions on BC investigations, prevention, diagnosis, and cure.

References

1. Deep learning [Available from: https://en.wikipedia.org/wiki/Deep_learning.]
2. Yang P, Abo R, Liu C, Chen Z, Wu H, et al. Novel feature selection strategies for enhanced predictive modeling and deep learning in the biosciences. AACR; 2017.
3. Wang D, Li J-R, Zhang Y-H, Chen L, Huang T, et al. Identification of differentially expressed genes between original breast cancer and xenograft using machine learning algorithms. Genes. 2018;9(3):155.
4. Caravagna G, Giarratano Y, Ramazzotti D, Tomlinson I, Graham TA, et al. Detecting repeated cancer evolution from multi-region tumor sequencing data. Nat Methods. 2018;15(9):707-14.
5. Way GP, Sanchez-Vega F, La K, Armenia J, Chatila WK, et al. Machine Learning Detects Pan-cancer Ras Pathway Activation in The Cancer Genome Atlas. Cell Rep. 2018;23(1):172-80 e3.
6. Li J, Chen L, Zhang YH, Kong X, Huang T, et al. A Computational Method for Classifying Different Human Tissues with Quantitatively Tissue-Specific Expressed Genes. Genes (Basel). 2018;9(9).
7. Zinn PO, Singh SK, Kotrotsou A, Hassan I, Thomas G, et al. A Coclinical Radiogenomic Validation Study: Conserved Magnetic Resonance Radiomic Appearance of Periostin-Expressing Glioblastoma in Patients and Xenograft Models. Clin Cancer Res. 2018;24(24):6288-99.
8. Allen D. AI Could Revolutionize Gene Therapy 2018 [Available from: http://emag.medicalexpo.com/ai-could-revolutionize-gene-therapy/.]
9. Project TUGROVIS – Tumor-Growth Machine Learning 2015 [Available from: https://hci-kdd.org/project/tumor-growth-machine-learning/.]
10. Afzali F, Akbari P, Naderi-Manesh H, Gardaneh M. The Next Generation Personalized Models to Screen Hidden Layers of Breast Cancer Tumorigenicity. Breast Cancer Res Treat 2019.
11. Toratani M, Konno M, Asai A, Koseki J, Kawamoto K, et al. A convolutional neural network uses microscopic images to differentiate between mouse and human cell lines and their radioresistant clones. Cancer research. 2018;78(23):6703-7.
12. Preuer K, Lewis RP, Hochreiter S, Bender A, Bulusu KC, et al. DeepSynergy: predicting anti-cancer drug synergy with Deep Learning. Bioinformatics. 2017;34(9):1538-46.
13. ubidecarenone nanodispersion BPM31510 [Available from: https://www.cancer.gov/publications/dictionaries/cancer-drug/def/ubidecarenone-nanodispersion-bpm31510.]
14. Samala RK, Chan HP, Hadjiiski L, Helvie MA, Wei J, et al. Mass detection in digital breast tomosynthesis: Deep convolutional neural network with transfer learning from mammography. Med Phys. 2016;43(12):6654.
15. Lehman CD, Yala A, Schuster T, Dontchos B, Bahl M, et al. Mammographic breast density assessment using deep learning: clinical implementation. Radiology. 2018;290(1):52-8.
16. Bejnordi BE, Veta M, Van Diest PJ, Van Ginneken B, Karssemeijer N, et al. Diagnostic assessment of deep learning algorithms for detection of lymph node metastases in women with breast cancer. Jama. 2017;318(22):2199-210.