ORIGINAL ARTICLE

USING ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING APPROACHES TO ENHANCE CANCER THERAPY AND DRUG DISCOVERY: A NARRATIVE REVIEW

Khurram Shahzad[1], Marwan Abu-Zanona,[2] Bassam Mohammad Elzaghmouri[3], Saad Mamoun AbdelRahman[4], Ahmed Abdelgader Fadol Osman[4], Asef Al-Khateeb[5], Fahmida Khatoon[6]

[1]HIESS Department, Hamdard University, Karachi-Pakistan, [2]Department of Management Information Systems, College of Business Administration, King Faisal University-Saudi Arabia

[3]Department of Computer Science, Faculty of Computer Science and Information Technology, Jerash University-Jordan, [4]Applied College, King Faisal University-Saudi Arabia, [5]MIS department, College of Business Administration, King Faisal University, Al Ahsa-Saudi Arabia

[6]Department of Biochemistry, College of Medicine University of Hail-Saudi Arabia

Background: This paper looks at how AI and machine learning have been applied over the last ten years to the development of anti-cancer drugs. By speeding up the synthesis of more desirable compounds and the identification of new ones, artificial intelligence (AI) has demonstrated substantial contributions to the research and therapy of anti-cancer therapies. **Methods**: This work is a narrative review that examines numerous uses of AI-based techniques in the development of anti-cancer medications. **Results**: Future developments in human cancer research and treatment are anticipated to be significantly influenced by AI. Protein-interaction network analysis, drug target prediction, binding site prediction, and virtual screening are examples of innovative techniques. Drug design and screening are enhanced by machine learning, and the use of multitarget drug development approaches has made it possible to develop cancer treatments with fewer side effects. AI does, however, have several drawbacks, such as a heavy reliance on data and a narrow scope of explanation. Interpretable AI models, which combine data and computation in AI-assisted cancer treatment research, will be the new development path in the future. **Conclusion:** For more than thirty years, computer-aided drug design techniques have been a key component in the advancement of cancer therapies. Artificial intelligence is a new and powerful technology that has the potential to speed up, lower the cost, and improve the efficacy of anti-cancer therapy development.

Keywords: Cancer therapy; Machine learning; Artificial intelligence; Drug discovery

Citation: Shahzad K, Zanona MA, Elzaghmouri BM, AbdelRehman SM, Osman AAF, Al-Khateeb AA, Khatoon F. Using artificial intelligence and machine learning approaches to enhance cancer therapy and drug discovery: A narrative review. J Ayub Med Coll Abbottabad;36(1):183–9.

DOI: 10.55519/JAMC-01-12921

INTRODUCTION

Numerous businesses have increased their R&D (research and development) efforts for anti-cancer medications in recent years.[1] More cancer patients may now have access to therapy thanks to an increasing number of extensive and prolonged clinical trials.[2,3] The American Cancer Society recently reported that from 2014 to 2021, the three-year survival rate for lung cancer increased from 21% to nearly 31%.[4] Research has examined the effectiveness of immune treatments and targeted therapies in treating a range of solid tumours.[5] The long-term survival of cancer patients will therefore benefit from increased investment in immune therapeutics and tailored medicines to realise the benefits of precision medicine.[6–8] Target identification, hit exploration, hit-to-lead development, lead optimisation, preclinical drug candidate identification, and preclinical and clinical research are all included in the anti-cancer drug design and discovery pipeline.[9–11] The development of novel and effective anti-cancer drugs from scratch remains a difficult, costly, and time-consuming process[12], despite advancements in tumour biotechnology and cancer mechanism research. This will necessitate close multidisciplinary collaborations between medicinal chemistry, computational chemistry, biology, pharmacology, and clinical research.[13] A novel drug's introduction into clinical practice can, on average, take between 10 and 17 years and over 2.8 billion dollars.[14,15] In addition, only 10% of clinical trial-tested drugs get commercialized.[16] Due to issues including undruggable targets[17], chemoresistance in oncology[18], tumour heterogeneity[19], and metastasis[20], the development of anti-cancer medications is particularly challenging. The traditional methods for medication design may be ineffective. Cancer patients' treatment outcomes are simply not as good as they may be since there are still so many obstacles to overcome. Therefore, there is an

urgent need for new potent anti-cancer medication design tactics. They will shorten the time needed for clinical trials and lower the cost of medication development. They can also contribute to bettering human health and extending life expectancy worldwide.[4] The technique known as computer-aided drug design (CADD) was first used in the early 1980s.[21] One increasingly significant aspect of drug design is the application of computer-aided techniques to direct drug screening.[22–25] With the aid of computer simulation, medicinal chemists were able to create and optimise lead compounds as well as compute the interactions between ligands and receptors.[26] CADD is typically used in drug design to filter down vast chemical libraries into more manageable clusters of computationally chemistry-predicted active molecules. It can significantly reduce the time and cost associated with anti-drug design while also speeding up the process.[27] Researchers in academia and the pharmaceutical sector are using artificial intelligence to enhance drug creation procedures due to the swift advancements in computer hardware and artificial intelligence methodologies.[28] The simulation of human intelligence in robots that are designed to think and behave like humans is known as artificial intelligence (AI).[15] A widely held belief regarding artificial intelligence is that its objective is to create computers that are comparable in their ability to "understand".[29] These days, artificial intelligence is employed in a wide range of cancer research applications, including image classification of aberrant cancer cells[30], target protein structure prediction[31], and drug–protein interaction prediction[32] These findings show how artificial intelligence methods can completely transform the way anti-cancer drugs are designed. The objective of this study was to evaluate some of the most notable developments in artificial intelligence and machine learning-based anti-cancer medication therapy and discovery, provide some of the most well-known instances, and explain the underlying ideas of these techniques.

MATERIAL AND METHODS

This study is a narrative review of previous research. To locate original papers, we searched PubMed, the US National Library of Medicine. Table 1 displays the search method that was employed in PubMed. Our primary focus was on reviews and articles that had been released in the last ten years. The current narrative review was last searched on December 1, 2023.

Strategy	Descriptors Used
#1	(“cancer” [Title/Abstract] AND “artificial intelligence” [Title/Abstract] AND “drug” [Title/Abstract]) AND (y_10[Filter])
#2	(“cancer” [Title/Abstract] AND “drug discovery” [Title/Abstract] AND “AI” [Title/Abstract]) AND (y_10[Filter])
#3	(“cancer” [Title/Abstract] AND “drug design” [Title/Abstract] AND “machine learning” [Title/Abstract]) AND (y_10[Filter])
#4	(“database” [Title/Abstract] AND “drug” [Title/Abstract] AND “artificial intelligence” [Title/Abstract]) AND (y_10[Filter]

RESULTS

Because AI can assist with rational drug design[16], decision-making support[17], determining the best obviously of treatment for a patient, including personalised medications, and managing the generated clinical data for use in future drug development, one could envision AI being involved in the entire pharmaceutical product development process, from the bench to the bedside. Marketing executives can estimate where to invest and allocate assets to achieve maximum market share gain by using E-VAI, an analytical and decision-making AI platform developed by Eularis. The platform creates analytical roadmaps based on competitors, and important stakeholders, and holds market share to predict key drivers in pharmaceutical sales.[18] It does this by utilising machine learning (ML) algorithms in conjunction with an intuitive user interface. The different applications of AI in drug development and discovery are summarised in Figure 1.

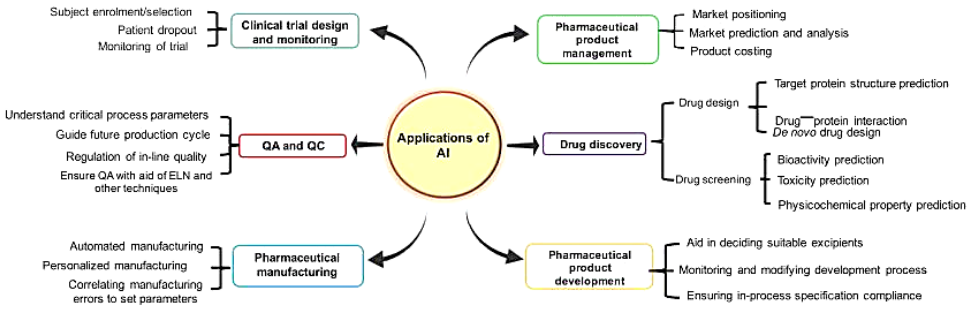


Figure-1: Applications of artificial intelligence (AI) in different subfields of the pharmaceutical industry, from drug discovery to pharmaceutical product management

With approximately 1060 molecules, the large chemical space promotes the discovery of various therapeutic substances.[19] Because the lack of advanced technology limits the medicine development process and makes it an expensive and time-consuming task, artificial intelligence (AI) can assist address this issue.[15] Artificial intelligence (AI) can be used to find hit and lead compounds, validate drug targets more quickly, and improve drug structure design.[19,20] The multilayer perceptron (MLP) network is a versatile pattern classifier that is often trained by supervised, unidirectional methods. Pattern recognition, optimisation tools, process identification, and controls are a few of its uses.[11] Closed-loop networks known as recurrent neural networks (RNNs) can learn and remember many types of data, such as Boltzmann constants and Hopfield networks.[11,12] CNNs are utilised in advanced signal processing, pattern identification, biological system modelling, processing intricate brain functions, picture and video processing, and more. CNNs are a group of dynamic systems that are differentiated by their topology and have local connections.[13] Among the most complex types are Kohonen networks, RBF networks, LVQ networks, counter-propagation networks, and ADALINE networks. AI still has to cope with a lot of data, including size, growth, diversity, and uncertainty, despite its advantages. Pharmaceutical companies may have data sets available for drug research that contain millions of molecules; traditional machine learning algorithms might not be able to process this volume of information. Quantitative structure-activity relationship (QSAR)-based computational models may accurately predict many different chemicals or fundamental physicochemical properties like log P or log D. However, these models are far from perfect in forecasting complex biological properties such as the potency and adverse effects of drugs. QSAR-based models also address small training sets, experimental data inaccuracy in training sets, and a lack of experimental validations. Recently developed AI approaches, such DL and relevant modelling studies, can be used to overcome these challenges and evaluate the safety and efficacy of pharmaceutical substances based on huge data modelling and analysis. DL models fared better in terms of predictivity than traditional ML techniques when it comes to the absorption, distribution, metabolism, excretion, and toxicity (ADMET) data sets of potential medications.[21,22] It appears as though a map of molecules is being created by the large virtual chemical space that represents the distributions and properties of molecules. Since the idea of the chemical space visualisation is to gather positional information about molecules inside the space to hunt for bioactive compounds, virtual screening (VS) helps pick appropriate molecules for further testing. The public can access several chemical spaces, such as ChemBank, PubChem, DrugBank, and ChemDB. Numerous in silico strategies for virtual screening compounds from virtual chemical spaces, in addition to structure- and ligand-based approaches, provide better profile analysis, faster elimination of nonlead compounds, and more economical therapeutic molecule selection.[19] Drug design techniques, such as coulomb matrices and molecular fingerprint identification, consider the physical, chemical, and toxicological characteristics when selecting a lead ingredient.[23] Several methods, such as prediction models, molecular similarity, the molecule formation process, and the use of in silico approaches, can be used to anticipate the desired chemical structure of a substance.[20,24] The DeepVS technique, as revealed by Pereira et al., performed remarkably well for the docking of 40 receptors and 2950 ligands when 95 000 decoys were tested against these receptors.[25] An other technique assessed a cyclin-dependent kinase-2 inhibitor's pharmacological activity, physicochemical properties, and form similarity to improve its potency profile using a multiobjective automated replacement algorithm.[26] AI-based QSAR modelling methods have been used to find potential drug candidates and can be used to speed up QSAR analysis. These tools include linear discriminant analysis (LDA), support vector machines (SVMs), random forests (RF), and decision trees.[27–29] A statistically negligible difference was found by King *et al.*[30] when six AI algorithms were compared to conventional approaches for rating anonymous compounds according to biological activity.

Targeted treatment uses drugs that attack malignant cells while sparing healthy cells. Mutations in genes that set cancer cells apart from healthy cells are quite prevalent. Genes are instructions contained in a cell's DNA that tell it how to perform various tasks. The behaviour of altered genes differs greatly from that of healthy cells. A cancer cell may proliferate and grow quickly if its genes are altered.[32] Nevertheless, there are various forms of cancer, each with a distinct subset of cancerous cells. For example, variations in gene expression increase the likelihood of breast and colon cancer cells forming and proliferating. Even while two individuals have colon cancer, their specific forms of the disease—such as colorectal cancer—may not be the same. The conditions under which a tumour grows, thrives, or spreads are not always the same. Certain types of cancer are associated with proteins or enzymes that control the growth and multiplication of cells. Drugs that target certain signals can inhibit or block cancer cells' capacity to proliferate or self-destruct. Scientists will create more specialised cancer treatments as they

gain greater insight into the anomalies in cancer cells.[33] These days, this medication is frequently utilised to treat a select few cancers. Patients receiving targeted therapy can require chemotherapy or surgery. The increased availability of FDA-approved drugs and statistical genomic samples from the human genome project has prompted ideas for network pharmacology and drug repurposing. Cytotoxic medications target certain mitotic or DNA recompilation mechanisms to kill rapidly dividing cells. Targeted therapies prevent the onset and spread of cancer by interacting with the molecular targets involved in the growth, progression, and dissemination of cancer. Researchers may be able to better comprehend computational pharmacology, find new therapeutic targets, and repurpose currently available medications with the help of these successful treatments and their data. Drug-disease/target networks study will help us improve FDA-approved anticancer medications and comprehend the molecular mechanisms underlying therapeutic advantages. Of the 30,000 genes found in the human genome, 6,000–8,000 are believed to be pharmaceutical targets. [WHO 2021b] Even so, only a small percentage of these proteins are useful for creating new drugs. Cancer offers a wide range of biological targets for therapeutic intervention, in contrast to many other human ailments. Unreported links between several target proteins and various disorders have been found.[34] "Best practice" suggestions for developing and implementing AI solutions that benefit patients are progressively being adopted by organisations. To promote and standardise ML-based therapy, new checklists were created. For AI systems to be used effectively, patients and healthcare professionals need to respect their recommendations. Well-thought-out and validated human-computer interfaces enable human-computer cooperation. A study[35] claims that in the upcoming years, AI may be used to generate precision oncology, which would assist patients all around the world.

Medication is utilised in precision oncology to target genetic abnormalities seen in patients' malignancies. Molecular profiling has been increasingly used in medical oncology in recent years, and many medications with molecular targets have been licenced and authorised to improve patient outcomes. Recently, immune checkpoint drugs have been licenced for the treatment of cancer patients with microsatellite instability symptoms. Clinical phenotypic predicting can be enhanced by personalised oncology, which can also reduce test costs and enhance patient care. They are capable. All parties involved must admit that achieving these goals will be difficult. AI and ML can be used to identify medically significant trends from large, heterogeneous data sets.[36] Machine learning (ML) could thereby improve personalised care. Pioneers in digital pathology and computer vision have shown how machine learning (ML) models can improve diagnostic procedures while requiring less human intervention, assisting generalist pathologists in expediting clinical diagnosis while performing procedures. Early cancer diagnosis is another benefit of the diagnostic radiography area. Several machine learning experiments using methylation patterns gathered in nucleic acids free of plasma cells have demonstrated high performance, and random front approaches may be a viable way to identify circulating microRNAs.[37] AI-powered decision support systems are being used by cancer patients more and more. Using machine learning (ML) models that incorporate tumour growth kinetics, genetic profile, and pharmacological properties, the best course of therapy for cancer patients may be predicted. For this, access to population-scale data sets with clinical and molecular classifications is required. ML models can also be used to increase prediction accuracy by choosing the best patient feature mix, which may incorporate non-genetic tumour traits.[38] ML models have been trained using responses from large-scale in vitro drug response studies or patient-derived xenograft experimental systems in order to predict clinical characteristics. Preclinical models are certainly useful in drug development, but their applicability to precision oncology remains unclear. But this emerging market might change accuracy. It is anticipated that, despite multiple attempts, integrating digital technology with medical procedures would enable AI systems to flourish in the medical field. The creation and application of artificial intelligence systems that are most helpful to patients has been made possible by these "best practises". In order to standardise and advance ML-based therapy approaches, new checklists were created. For AI systems to be successful in clinics, patients and healthcare professionals must accept them. It is necessary to correctly develop and test collaborative interfaces, and users should standardise on AIpublicize operational principles and interpretability. Precision oncology is currently utilising artificial intelligence (Figure 2). The present surge in proof-of-concept studies offers insights into the potential future of precision oncology. Before AI has a significant influence on medicine, a number of issues need to be resolved. Though this exploratory investigation raises some fair expectations, productive practices necessitate a deeper understanding of the constraints that have already been discussed. In the upcoming years, AI might aid in the advancement of precision oncology, benefiting people everywhere.

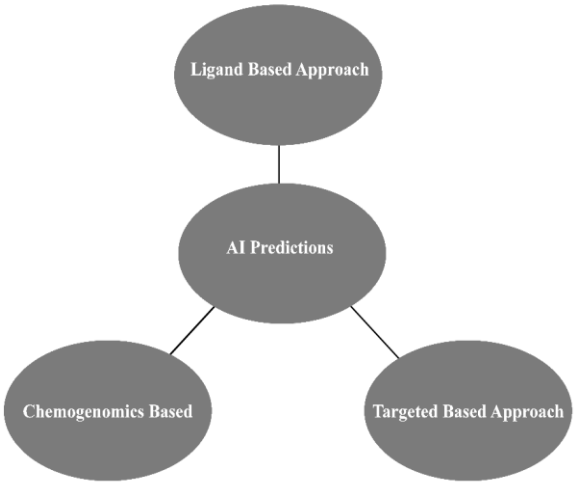
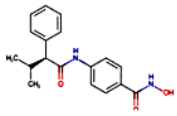
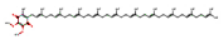
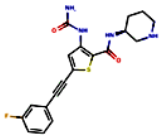


Figure 2: Predictions of artificial intelligence about natural product[39]

Table 2 lists a few anticancer medications that have successfully entered human phase 2/3 clinical trials in the previous five years to illustrate how AI aids in the discovery of anticancer therapies. For example, Recursion's patented AI-driven drug discovery platform, Recursion OS, helped identify REC-2282 as a viable therapeutic candidate for disorders caused by mutations in the NF2 gene. A permeable, orally accessible, small-molecule HDAC inhibitor called REC-2282 is being developed to treat meningiomas that have NF2 gene mutations. In contrast to other HDAC inhibitors, this chemical seems to be well tolerated, even in people who have been taking it for a number of years. It may also lessen cardiotoxicity. The U.S. FDA gave it fast-track status in addition to orphan drug status.[41] Relay Therapeutics used an artificial intelligence platform to analyse the dynamic balance of protein conformations in order to develop the FGFR2-specific inhibitor RLY-4008. According to preclinical research, RLY-4008 shrinks tumours with little effect on other targets while exhibiting remarkable selectivity for FGFR2 targets in cancer cell lines.[42] Using an artificial intelligence platform, Breg created a novel medication called BPM 31510, which is presently undergoing clinical trials. By altering the way cancer cells metabolise, the medication spares patients from chemotherapy and promotes cancer cells' natural death.[43] EXS-21546 is an antagonist of the A2A receptor created by AI. Elevated adenosine production from certain tumours binds to and activates A2A receptors on immune cells, suppressing the immune system's ability to fight tumours .[44] An AI-driven drug discovery platform created the selective checkpoint kinase 2 (Chk2) inhibitor PHI-101, which is accessible for oral use.[45]

Table-2: Some of the AI-designed anti-cancer drugs that have successfully entered human phase 2/3 clinical trials in the last 5 years

Name	Chemical Structure	Company	Therapeutic Area	Target/Function	Phase
REC-2282		Recursion	Neurofibromatosis Type 2	HDAC	Phase 2/3
RLY-4008	not disclosed	Relay Therapeutics	Solid tumor	FGFR	Phase 2
BPM31510		Berg	Solid tumor	Protein cbcl2 modulators	Phase 2
EXS-21546	not disclosed	Exscientia	Solid tumor	A2aR	Phase 1
PHI-101		Pharos iBio	Ovarian cancer Breast cancer	Flt3 tyrosine kinase inhibitor	Phase 1

DISCUSSION

Although AI has been successfully used in many aspects of anticancer drugs development as shown by our literature search but still is in infancy and faces many problems. Because these data are utilised for the system's subsequent training, the availability of a sizable volume of data is essential to AI's effectiveness. A business may have to pay more for access to data from several database providers, and for accurate result prediction, the data must also be dependable and of good quality. The lack of trained personnel to run AI-based platforms, small organisations' limited budgets, the fear that replacing humans will result in job losses, scepticism about the data generated by AI, and the "black box" phenomenon, i.e., the method by which the AI platform draws its conclusions—are additional obstacles preventing the full-fledged adoption of AI in the pharmaceutical industry.[46] Over time, automation

of some jobs in clinical trials, manufacturing, supply chains, medication research, and sales will occur; nevertheless, these tasks are all classified as "narrow AI," meaning that the AI must first be trained on a vast amount of data to be appropriate for a specific task. Thus, for the AI platform to be developed, implemented, and run successfully, human intervention is required. But since AI is already replacing monotonous tasks, leaving room for human intelligence to be used for more complex insights and creative expression, the fear of unemployment may not be as real as it seems. However, several pharmaceutical companies have embraced AI, and by 2023, it is anticipated that the pharmaceutical industry will generate US$2.199 billion in revenue from AI-based solutions, with an investment exceeding US$7.20 billion made in more than 300 transactions between 2013 and 2023. Pharmaceutical companies want clarity regarding the ability of AI technology to solve issues after it is put into practice, as well as knowledge of the realistic objectives that can be met. To fully use the potential of the AI platform, competent data scientists and software engineers with a solid understanding of AI technology can be produced, as well as a clear awareness of the business target and R&D goal of the company.

CONCLUSION

This paper looks at how AI and machine learning have been applied over the last ten years to the development of anti-cancer drugs. By speeding up the synthesis of more desirable compounds and the identification of new ones, artificial intelligence (AI) has demonstrated substantial contributions to the research and therapy of anti-cancer therapies. Future developments in human cancer research and treatment are anticipated to be significantly influenced by AI. Protein-interaction network analysis, drug target prediction, binding site prediction, and virtual screening are examples of innovative techniques. Drug design and screening are enhanced by machine learning, and the use of multitarget drug development approaches has made it possible to develop cancer treatments with fewer side effects. AI does, however, have several drawbacks, such as a heavy reliance on data and a narrow scope of explanation. Interpretable AI models, which combine data and computation in AI-assisted cancer treatment research, will be the new development path in the future. Collaboration between scientists from several disciplines is necessary to identify promising natural product leads. Using analytical methods and nanotechnology, chemicals with different structures and modes of action are found in natural materials. Biodiversity requires chemistry. To target tumours, delivery mechanisms specific to RNA interference were devised. Among these methods are indirect target-ligand-RNAi molecule conjugation and packing the RNAi molecules inside a precisely engineered delivery vehicle. We'll speed the search for safe, all-natural cancer treatments. AI, in our opinion, will significantly alter the way anti-cancer medications are created.

AUTHORS' CONTRIBUTION

KS, MAZ: Conceptualization of the study design. BMEl, SMAR: Data collection data analysis, data interpretation. AAFO, AAlH, FK: write-up, proofreading

REFERENCES

1. Kumar, R., Saha, P., Kumar, Y., Sahana, S., Dubey, A., & Prakash, O. (2020). A Review on Diabetes Mellitus: Type1 & Type2. World Journal of Pharmacy and Pharmaceutical Sciences, 9(10), 838-850.
2. Saha, P., Nyarko, R. O., Lokare, P., Kahwa, I., Boateng, P. O., & Asum, C. (2022). Effect of Covid-19 in Management of Lung Cancer Disease: A Review. Asian Journal of Pharmaceutical Research and Development, 10(3), 58-64.
3. Daharia, A., Jaiswal, V. K., Royal, K. P., Sharma, H., Joginath, A. K., Kumar, R., & Saha, P. (2022). A Comparative review on ginger and garlic with their pharmacological Action. Asian Journal of Pharmaceutical Research and Development, 10(3), 65- 69.
4. Singh, M. K., Kumar, A., Kumar, R., Kumar, P. S., Selvakumar, P., & Chourasia, A. (2022). Effects of Repeated Deep Frying on Refractive Index and Peroxide Value of Selected Vegetable Oils. International Journal for Research in Applied Sciences and Biotechnology, 9(3), 28-31
5. Roshan, K. (2020). Priya damwani, Shivam kumar, Adarsh suman, Suthar Usha. An overview on health benefits and risk factor associated with coffee. International Journal Research and Analytical Review, 7(2), 237-249.
6. Kumar, R., Saha, P., Lokare, P., Datta, K., Selvakumar, P., & Chourasia, A. (2022). A Systemic Review of Ocimum sanctum (Tulsi): Morphological Characteristics, Phytoconstituents and Therapeutic Applications. International Journal for Research in Applied Sciences and Biotechnology, 9(2), 221-226.
7. Sahana, S. (2020). Purabi saha, Roshan kumar, Pradipta das, Indranil Chatterjee, Prasit Roy, Sk Abdur Rahamat. A Review of the 2019 Corona virus (COVID- 19) World Journal of Pharmacy and Pharmaceutical science, 9(9), 2367-2381
8. Bind, A., Das, S., Singh, V. D., Kumar, R., Chourasia, A., & Saha, P. Natural Bioactives For The Potential Management Of Gastric Ulceration. Turkish Journal of Physiotherapy and Rehabilitation, 32(3).
9. Dubey, A., Yadav, P., Verma, P., & Kumar, R. (2022). Investigation of Proapoptotic Potential of Ipomoea carnea Leaf Extract on Breast Cancer Cell Line. Journal of Drug Delivery and Therapeutics, 12(1), 51-55.
10. Saha, P., Kumar, R., Nyarko, R. O., Kahwa, I., & Owusu, P. (2021). HERBAL SECONDARY METABOLITE FOR GASTRO-PROTECTIVE ULCER ACTIVITY WITH API STRUCTURES.
11. Sahana, S. (2020). Roshan kumar, Sourav nag, Reshmi paul, Nilayan guha, Indranil Chatterjee. A Review on Alzheimer disease and future prospects. World Journal of Pharmacy and Pharmaceutical science, 9(9), 1276-1285.
12. Sahana, S., Kumar, R., Nag, S., Paul, R., Chatterjee, I., & Guha, N. (2020). A REVIEW ON ALZHEIMER DISEASE AND FUTURE PROSPECTS.
13. Nyarko, R. O., Prakash, A., Kumar, N., Saha, P., & Kumar, R. (2021). Tuberculosis a globalized disease. Asian Journal of Pharmaceutical Research and Development, 9(1), 198-201.
14. Kumar, R., & Dubey, A. PHYTOCHEMICAL INVESTICATION AND HEPTOPROTECTIVE EVALUTION ACACIA RUBICA EXTRACT ISONIZED AND PARACETAMOL INDUSED ANIMAL TOXICITY. Turkish Journal of Physiotherapy and Rehabilitation, 32(3).
15. Raj, A., Tyagi, S., Kumar, R., Dubey, A., & Hourasia, A. C. (2021).

Effect of isoproterenol and thyroxine in herbal drug used as cardiac hypertrophy. Journal of Cardiovascular Disease Research, 204-217.
16. Naseem Jamil, Tahir Shamsi & Sara Gill (2022). Literature Review on the Efficiency of Planter Fascia Stretching with Myofascial Release Technique. Dinkum Journal of Medical Innovations, 1(01):01-06.
17. Humza Sohail, Markus Peter Chan & Umaima Nagari (2022). Myocarditis after receiving the Covid-19 Vaccine in an Enormous Medical Facility. Dinkum Journal of Medical Innovations, 1(01):07-12.
18. Nida Ishfaq & Yang Chan (2022). An Analysis of Nutritional Awareness among Diabetic Patients. Dinkum Journal of Medical Innovations, 1(01):13-18.
19. Peter John, Irina Yang & Aparna Goel (2022). A Systematic Literature Review of Importance of Emotional Competence in Healthcare Management. Dinkum Journal of Medical Innovations, 1(01):19-26.
20. Marie Diack & Derak Stewart (2022). Development of Cardiovascular Abnormalities Because of Periodontitis in Nepali Population. Dinkum Journal of Medical Innovations, 1(01):27-30.
21. Nyarko, R. O., Saha, P., Kumar, R., Kahwa, I., Boateng, E. A., Boateng, P. O., ... & Bertram, A. (2021). Role of Cytokines and Vaccines in Break through COVID 19 Infections. Journal of Pharmaceutical Research International, 33, 2544-2549.
22. Kumar, R., Saha, P., Pathak, P., Mukherjee, R., Kumar, A., & Arya, R. K. EVOLUTION OF TOLBUTAMIDE IN THE TREATMENT OF DIABETES MELLITUS. Jour. of Med. P'ceutical & Alli. Sci, 9.
23. Nimra Naseem, Rubab Zahra, Umm-e-Aimen & Tahir Rana (2023). Literature Review on Comparison of the effect of Single Oral Dose 150Mg Pregabalin Premedication to Single Oral Dose 100mg Tramadol in Elective Inguinal Hernia Surgery. Dinkum Journal of Medical Innovations, 2(01):01-11.
24. Tahira Amanat, Umm-e-Aiman, Tayyaba Firdus & Zahida Bukhari (2023). A Systematic Literature Review on Suicidal Cases in Pakistan. Dinkum Journal of Medical Innovations, 2(01):12-17.
25. Tahira Amanat, Tayyaba Firdus & Zahida Bukhari (2023). A Systematic literature review on Relationship of Inadequate Birth Weight and Adolescent Diabetes Mellitus. Dinkum Journal of Medical Innovations, 2(01):18-21.
26. Marie Diack, Derak Stewart, Parshu Kirby & David Moris (2023). Challenges with Parent/Caregiver Medication Administration in Peadiatrics and the Importance of Patient Education: A Systematic Review. Dinkum Journal of Medical Innovations, 2(01):22-28.
27. Marie Diack, Derak Stewart & Parshu Kirby (2023). Predisposing Factors and Effects of Re-Procedure after Cardiac Resection. Dinkum Journal of Medical Innovations, 2(01):29-34.
28. KUMAR, R., SAHA, P., SARKAR, S., RAWAT, N., & PRAKASH, A. (2021). A REVIEW ON NOVEL DRUG DELIVERY SYSTEM. IJRAR-International Journal of Research and Analytical Reviews (IJRAR), 8(1), 183-199.
29. KUMAR, A. (2019). The Scenario of Pharmaceuticals and Development of Microwave Assisted Extraction Techniques.
30. SHAFQAT ZAIDI, R. K. MEHRA, Dr. SACHIN TYAGI, ROSHAN KUMAR ANUBHAV DUBEY.(2021). Effect of Kalahari Cactus Extract on Appetitte, Body Weight And Lipid Profile In Cafeteria Diet Induced Obesity In Experimental Animal. Annals of the Romanian Society for Cell Biology, 25(6), 13976-13987.
31. Markham, A. (2017). Copanlisib: first global approval. Drugs, 77(18), 2057-2062.
32. Mathi, P., Prasad, M. V. V. V., Botlagunta, M., Ravi, M., & Ramachandran, D. (2018). De novo design of selective Sortase-A inhibitors: Synthesis, structural and in vitro characterization. Chemical Data Collections, 15, 126-133.
33. Moreau, P.; Garfall, A.L.; van de Donk, N.W.C.J.; Nahi, H.; San-Miguel, J.F.; Oriol, A.; Nooka, A.K.; Martin, T.; Rosinol, L.; Chari, A.; et al. Teclistamab in Relapsed or Refractory Multiple Myeloma. N. Engl. J. Med. 2022, 387, 495–505.
34. Avery, R.K.; Alain, S.; Alexander, B.D.; Blumberg, E.A.; Chemaly, R.F.; Cordonnier, C.; Duarte, R.F.; Florescu, D.F.; Kamar, N.; Kumar, D.; et al. Maribavir for Refractory Cytomegalovirus Infections With or Without Resistance Post-Transplant: Results From a Phase 3 Randomized Clinical Trial. Clin. Infect. Dis. 2022, 75, 690–701.
35. Cercek, A.; Lumish, M.; Sinopoli, J.; Weiss, J.; Shia, J.; Lamendola-Essel, M.; El Dika, I.H.; Segal, N.; Shcherba, M.; Sugarman, R.; et al. PD-1 Blockade in Mismatch Repair-Deficient, Locally Advanced Rectal Cancer. N. Engl. J. Med. 2022, 386, 2363–2376.
36. Siegel, R.L.; Miller, K.D.; Fuchs, H.E.; Jemal, A. Cancer statistics, 2022. CA Cancer J. Clin. 2022, 72, 7–33.
37. Li, N.; Spetz, M.R.; Li, D.; Ho, M. Advances in immunotherapeutic targets for childhood cancers: A focus on glypican-2 and B7-H3. Pharmacol. Ther. 2021, 223, 107892. [Google Scholar] [CrossRef]
38. Corti, C.; Cobanaj, M.; Marian, F.; Dee, E.C.; Lloyd, M.R.; Marcu, S.; Dombrovschi, A.; Biondetti, G.P.; Batalini, F.; Celi, L.A.; et al. Artificial intelligence for prediction of treatment outcomes in breast cancer: Systematic review of design, reporting standards, and bias. Cancer Treat. Rev. 2022, 108, 102410.
39. Chiu, H.-Y.; Chao, H.-S.; Chen, Y.-M. Application of Artificial Intelligence in Lung Cancer. Cancers 2022, 14, 1370.
40. Hamilton, W.; Walter, F.M.; Rubin, G.; Neal, R.D. Improving early diagnosis of symptomatic cancer. Nat. Rev. Clin. Oncol. 2016, 13, 740–749.
41. Fountzilas, E.; Tsimberidou, A.M.; Vo, H.H.; Kurzrock, R. Clinical trial design in the era of precision medicine. Genome. Med. 2022, 14, 101.
42. Bannigan, P.; Aldeghi, M.; Bao, Z.; Häse, F.; Aspuru-Guzik, A.; Allen, C. Machine learning directed drug formulation development. Adv. Drug Deliv. Rev. 2021, 175, 113806.
43. Olgen, S. Overview on Anticancer Drug Design and Development. Curr. Med. Chem. 2018, 25, 1704–1719.
44. Grandori, C.; Kemp, C.J. Personalized Cancer Models for Target Discovery and Precision Medicine. Trends Cancer 2018, 4, 634–642.
45. Hoelder, S.; Clarke, P.A.; Workman, P. Discovery of small molecule cancer drugs: Successes, challenges and opportunities. Mol. Oncol. 2012, 6, 155–176.
46. Schneider, P.; Walters, W.P.; Plowright, A.T.; Sieroka, N.; Listgarten, J.; Goodnow, R.A.; Fisher, J.; Jansen, J.M.; Duca, J.S.; Rush, T.S.; et al. Rethinking drug design in the artificial intelligence era. Nat. Rev. Drug Discov. 2020, 19, 353–364.

Submitted: February 2, 2024	*Revised: February 24, 2024*	*Accepted: February 27, 2024*

Address for Correspondence:

Marwan Abu-Zanona, Department of Management Information Systems, College of Business Administration, King Faisal University-Saudi Arabia

Email: mabozanoneh11@kfu.edu.sa