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ARTIFICIAL INTELLIGENCE IN THE NOVEL DRUG DELIVERY SYSTEM

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ABSTRACT

In the past ten years, artificial intelligence (AI) technology has attracted more and more interest because of its potential uses in biological or genetic data analysis, accelerating medication discovery, and identifying uncommon or specific molecules. AI is posing a serious threat to the healthcare sector by offering innovative solutions for enhancing medication distribution systems. AI-powered drug delivery systems use machine learning algorithms and data-driven insights to optimize drug administration and improve therapeutic outcomes. It explores the critical role of artificial intelligence in medication delivery and shows how AI may advance precision dosing, personalized treatment, and drug formulation. The combination of AI and drug delivery has the potential to completely transform the healthcare industry through a variety of applications in personalized medicine, targeted drug delivery, nanotechnology and drug delivery, and real-time monitoring by lowering side effects, increasing treatment efficacy, and providing a platform for the development of novel medications. This paper explores the critical role of artificial intelligence in medication delivery and shows how AI may advance precision dosing, personalized treatment, and drug formulation. This thorough analysis examines the fundamentals of medication delivery, novel drug delivery systems, artificial intelligence (AI) algorithms used in product development, and their uses. Artificial Intelligence in the Pharmaceutical Delivery System AI's emergence in the medical field AI-optimized drug delivery systems, NDDS applications, AI's Place in Drug Delivery Current Patterns, the advantages, and difficulties of artificial intelligence in innovative drug delivery systems.

KEYWORDS: AI is posing a serious threat to the healthcare sector by offering innovative solutions for enhancing medication distribution systems.

INTRODUCTION

Drug Delivery

Drug delivery is the technique of providing a pharmacological substance to achieve a therapeutic effect in people or animals.[1] Drug delivery is a vital step in the Drug development process. The efficacy of a medicine is determined not only by its pharmacological properties, but also by its ability to reach the intended place within the body. The use of AI into drug delivery shows potential for speeding up the development of new delivery systems and improving therapeutic effectiveness. In essence, drug delivery means giving the precise dosage of medication to the specified place at the suitable time.[2]

Novel drug delivery system

The performance of an existing pharmaceutical molecule in terms of patient compliance, safety, and efficacy can be significantly improved by converting it from a traditional form to a novel delivery mechanism. A previously used medicine molecule can be revitalized as a Novel Drug Delivery System. The new drug delivery system, which is a novel means of administering drugs, addresses the limitations of current drug delivery methods. A properly developed drug delivery system has the potential to significantly improve the capacity to release a medicine at a specific area and pace. Pharmaceutical companies are developing novel drug delivery technologies to ensure that patients receive prescriptions effectively and with fewer side effects. Modern phytopharmaceuticals research can meet the scientific requirements for novel drug delivery systems such as nanoparticles, microemulsions, matrix systems, solid dispersions, liposomes, solid lipid nanoparticles, and so on, by determining pharmacokinetics, mechanism of action, site of action, required precise dose, etc.[3]

Artificial intelligence

Artificial intelligence (AI), defined as computer-based simulations of human intelligence processes, has made significant advances in a variety of sectors, including drug development and delivery. AI's application, particularly in drug delivery, has recently gained substantial interest, fuelled by the advent of breakthrough technologies and algorithms that improve the efficiency of drug transportation.[2]

The use of artificial intelligence (AI) into drug administration is a game-changing breakthrough in the healthcare industry, providing unique and unprecedented chances or options for personalized treatment regimens. AI may use a massive amount of patient data to create treatment plans that are uniquely tailored to each patient, including genetics, medical history, lifestyle factors, and real-time physiological data; however, there are some ethical considerations and privacy concerns associated with the use of such vast patient data; informed consent is critical for trust, and the volume of data increases the risk of unauthorized access. Security precautions are required to protect sensitive health information.[4]

AI has the potential to transform the drug development process by finding promising compounds and predicting their behaviour, hence accelerating the discovery of new medications. AI-enabled robotics and automation streamline medicine manufacturing and distribution operations, reducing human error, increasing efficiency, and ensuring high levels of accuracy. Reliable data sources are critical for the success of AI-powered medicine delivery systems.[4]

AI-powered simulations make it feasible to foresee how drugs will interact with the human body, significantly reducing the time and cost needed for preclinical and clinical research.[4]

AI has the capacity to create drugs delivery systems that maximize therapeutic advantages while reducing side effects, whether it's modifying the makeup of a chemotherapy treatment to limit destruction of healthy cells or adjusting the time of insulin delivery to regulate blood glucose levels.[4] Artificial intelligence technologies include machine learning, deep learning, natural language processing, vision, speech recognition, supervised learning, and unsupervised learning.[5]

The application of automated workflows, databases, and artificial neural networks (ANNs) for the fast analysis of large amounts of data, the creation of new treatment hypotheses and approaches, the forecasting of disease progression, and the evaluation of the pharmacological profiles of potential drugs may significantly improve treatment outcomes.

Target fishing (TF) could be particularly useful in linking targets to new compounds by rapidly anticipating or finding biological targets, and the use of microfabrication technology to implanted microchips seems promising for controlled drug delivery. The nano carrierbased drug delivery system (Micro/Nanorobots) is a promising way to improve drug solubility, change drug distribution in different tissues and organs, control drug release rate to achieve sustained release and controlled release profiles, and promote drug aggregation in its target. These multifunctional and advanced devices for controlled and targeted drug release have been used to address a variety of issues related to traditional delivery systems and enhance efficacy, safety, and patient compliance. They can automatically adjust drug concentration and release timing.[6]

AI in Drug Delivery System

Artificial intelligence can be used to improve drug delivery systems in several ways, such as by anticipating drug interactions, predicting how a drug would behave in the body, and improving drug formulations. Machine learning algorithms can analyse large datasets about how drugs behave in the body, which makes it possible to forecast how a drug will work. The use of machine learning algorithms to optimize drug formulations is an example of how artificial intelligence (AI) facilitates drug delivery systems. These algorithms may be trained on large datasets that show how drugs behave in the body, making it easier to predict which formulation would work best for a certain medicine. Predicting possible interactions between various medications becomes possible by training neural networks on large datasets covering drug interactions. This ability is useful for designing medicine delivery systems. Several AI-based drug delivery systems have been used, including hydrogels, liposomes, microspheres, dendrimers, and nanoparticles. By creating novel drug carriers, forecasting drug release profiles, and maximizing drug dosages, artificial intelligence has made a substantial contribution to the optimization of drug delivery systems.[2]

Artificial Intelligence for Pharmaceutical Distribution The pharmaceutics industry's adoption of AI and big data has given rise to computational pharmaceutics, a field that uses multiscale modelling techniques to improve medication delivery systems. Artificial intelligence (AI) algorithms and machine learning approaches are used in computational pharmaceutics to analyse massive datasets and forecast drug behaviour.

Without the need for lengthy trial-and-error studies, researchers can assess multiple scenarios and optimize drug delivery systems by simulating the drug formulation and delivery processes. This shortens the time it takes to develop new drugs, lowers expenses, and boosts output. Drug delivery systems at many sizes, from molecular interactions to macroscopic behaviour, are modelled in computational pharmaceutics.

To forecast drug behaviour at every scale, artificial intelligence systems can analyse intricate correlations between formulation elements, physiological parameters, and pharmacological qualities. This makes it possible to comprehend drug delivery mechanisms in greater detail and facilitates the creation of effective drug delivery systems. It aids in the prediction of the medication's stability, in vitro drug release profile, and physicochemical characteristics. Along with in vivo-in vitro correlation research, the same technique is also used for improved assessment of in vivo pharmacokinetic parameters and drug distribution.

Early in the development phase, researchers can detect possible dangers and difficulties related to drug delivery systems by employing the appropriate set of artificial intelligence techniques. This makes it possible to proactively make changes and adjustments to reduce risks and enhance the effectiveness of medications. The likelihood of unanticipated results is decreased when AI and computer modelling are used instead of costly and time-consuming trial-and-error experiments.[7]

Ai in healthcare

AI approaches have the potential to play important roles in medical research and healthcare delivery. The effectiveness and promise of AI-enabled health applications have been demonstrated by studies. Alongside these technological advancements, governments and tech businesses are now investing heavily in the use of AI in healthcare, and the United States Food and Drug Administration is actively working to facilitate the release of medical devices with AI capabilities into the market. We believe that patient monitoring, clinical decision support, healthcare administration, and healthcare treatments are the four areas where AI-enabled healthcare delivery is most likely to have an impact.[8]

Predictive analytics, personalized medicine, diagnostics, and drug discovery all use AI. For instance, machine learning algorithms can analyse medical photos to detect diseases like cancer early stage.

The most common uses of AI in healthcare are for the following functions: 1) aiding in diagnosis; 2) managing healthcare businesses; and 3) maintaining a healthy lifestyle. The primary obstacles to the use of AI in healthcare are as follows: 1) the need for specialized architecture in businesses; 2) public prejudice against AI; 3) the requirement for information security and privacy; and 4) the requirement for excellent service quality and dependability.[9]

Emergence of ai in healthcare

Artificial intelligence (AI) has advanced significantly in recent years thanks to advancements in deep neural networks, robotics, computer vision, natural language processing, and computer vision. These methods are presently being used extensively in the healthcare industry, with predictions that AI will eventually replace many of the administrative and clinical tasks currently performed by clinicians in the years to come. But there has also been a great deal of hype around AI's capabilities, with the false belief that AI will completely replace human therapists.

These viewpoints are unreliable, and by adopting a fair assessment of AI's drawbacks and opportunities, one can determine which aspects of the healthcare system AI can be effectively applied to. AI would primarily impact four areas: clinical decision support, patient monitoring, patient administration, and healthcare interventions. One could refer to this AI-powered health system as an AI-enabled or AI-augmented health system. In this post, we go over how this system might be created using a practical evaluation of the state of AI now and its expected future state.[10]

Artificial Intelligence-Based Drug Delivery Systems /AI algorithms employed in product development and their applications

Historically, the field of pharmaceutical research and development has favoured tiny molecules with inherent stability, sufficient potency to achieve therapeutic goals, and tolerable toxicity for most users. More and more attention has recently focused on the development of novel technologies for effective, targeted drug administration with minimal side effects. Researchers have focused on controlled drug administration to overcome problems with traditional drug delivery methods, such as their narrow therapeutic index, systemic toxicity, and difficulty controlling drug doses during long-term therapy.[6]

1) Recurrent neural networks47 (RNNs) -It is employed in the modelling or characterization of medication release from formulations with modified release. Ibric et al. 48 created an extended-release aspirin neural network with four inputs and one pill output by using the multi-layered perceptron (MLP). Ten aspirin matrix pills were produced using the NEURAL programme. Peppas equation 49 was estimated using the following information: parts of MCC and GMS in the formulations; in vitro dissolution–time profiles at four distinct sampling time points; the difference between the sampling time points; and coefficients n release (release order) and log k (release constant) from the single similarity factor, f, as

release parameters. Formulation and process parameters for optimal formulations that might produce the required in vitro drug release patterns were identified using the optimized GRNN model.[5]

2) Artificial neural networks and Genetic algorithm50-51 (ANN&GA)- It is applied to formulation optimization, including controlled release systems. Artificial Neural Networks (ANNs) are artificial intelligence systems that use nonlinear processing units (NPUs), which have the capacity to learn from experience, to mimic certain aspects of the human brain. Artificial neurons, or ANNs, are vastly parallel distributed computers composed of typically completely linked artificial neurons.[6] Yongqiang Li et al.optimized the controlled release nanoparticle formulation of verapamil hydrochloride by combining artificial neural networks with a genetic algorithm. They were able to effectively optimize the formulation using the ANN methodology and the spherical central composite design. With its small mean particle size of 100 nm and high drug loading efficiency of 92%, the resultant formulation is perfect for oral administration for lymphatic transport. Because ANN can handle more complex and non-linear functional relationships than (Response Surface Methodology) RSM, it is observed that ANN suited the experimental data better.[5]

3) Multilayer Perceptron (MLP) Network-It is employed in the creation of formulations with controlled release, medication dissolution profile prediction, and formulation optimization.53–55 Betamethasone (BTM) and betamethasone acetate (BTMA) release profiles were predicted by Mohammad Rafienia et al. 56 using multilayer perceptron (MLP), radial basis function network (RBFN), and generalized regression neural network (GRNN) as implant controlled-release systems. MLP is found to be more dependable and performs better than GRNN and RBF networks in estimating BTM and BTMA release profiles when the release profiles computed by ANNs are compared to the release profiles measured by HPLC.[5]

4) Micro/Nanorobots-The advancement of micro and nano-electromechanical systems has made it possible to create implanted robots that can carry out a range of functions, including as delivering medications or genes under control. Chemical sensors that identify the target molecules are essential to nanorobots. Its thousands of nanowires aid in the identification of proteins and other indicators left by cancer cells, which may make it possible to identify and diagnose the disease early on. Drugs with a nano size (ranging from 1 to 100 nanometres) can be utilized at lower dosages and start working therapeutically earlier thanks to nanorobots.

Additionally, it supplies ingredients for precise and regulated medicine distribution by guiding carriers to a predetermined spot. The diverse applications of nanorobots in medicine, neuroscience, dentistry, haematology, microbiology, cancer therapy, and quality care, including drug delivery, tissue engineering, gene delivery systems, cardiology, analysis of vital signs, diabetes monitoring, minimally invasive brain surgery, imaging, and detection capabilities, and targeting and early cancer diagnosis.[6]

5) Drugs embedded with Sensors (Smart Pills)- Ingestible capsules with mechanical or electronic components that pass through the gastrointestinal (GI) system for a variety of uses, such as surgery, sampling, diagnosis, or therapy, are known as smart pills. Most people can swallow these pills with ease, which leads to less discomfort and increased patient acceptance. They can also pass through the entire gastrointestinal tract. In terms of diagnosis, these tablets make it easier to employ cutting-edge sensors and imaging tools to enhance our comprehension of the etiology of GI diseases. From a medicinal standpoint, these devices provide the opportunity for transepithelial delivery of biologics for systemic delivery or localized, targeted delivery of therapeutic medicines to GI tract regions.[6]

Role of AI in Drug Delivery

The pharmaceutics industry saw the development of computational pharmaceutics, which uses multiscale modelling approaches to optimize medicine delivery systems. This field emerged from the merging of big data and artificial intelligence. Machine learning and artificial intelligence algorithms are used in computational pharmaceutics to analyse large datasets and predict drug behaviour. By simulating the drug formulation and delivery processes, researchers can analyse various situations and optimize pharmaceutical delivery systems without requiring lengthy trial-and-error investigations. This reduces costs, speeds up production, and cuts down on the amount of time needed for drug development. One important aspect of computational pharmaceutics is modelling drug delivery systems at different scales, from molecular interactions to macroscopic behaviour. Artificial intelligence systems can examine complex relationships between pharmacological properties, formulation components, and physiological data to predict drug behaviour at every scale. This facilitates a deeper understanding of drug delivery mechanisms and facilitates the development of efficient drug delivery devices. It helps with the prediction of the physicochemical properties, stability, and in vitro drug release profile of the treatment. Additionally, the same technique is applied for improved assessment of in vivo pharmacokinetic properties and drug distribution in addition to in vivo-in vitro correlation studies. With the right set of AI tools, researchers can identify possible risks and challenges associated with drug delivery systems early in the development process. This makes it possible to proactively modify and enhance medication performance while lowering risks. By reducing the need for costly and time-consuming trial-and-error procedures, the use of AI and computer modelling reduces the possibility of unexpected outcomes. Artificial intelligence (AI) has enormous potential to transform healthcare by enhancing the efficacy, safety, and precision of medication delivery.

1. **Personalized Medicine:-** The practice of treating patients according to their unique characteristics, including genetics, environment, and lifestyle, is known as personalized medicine. Artificial intelligence (AI) is crucial to the creation of customized medicines, both in terms of discovering intervention targets and assessing their utility. Artificial intelligence (AI) can analyse patient data to provide tailored treatment regimens that produce more effective medications with fewer side effects. Moreover, it can generate insights through sophisticated computation and inference, adding intelligence to the decision-making process for clinicians. AI-enabled personalized medicine removes uncertainty from diagnosis and treatment plans by concentrating on identifying anomalies based on DNA, medical history, and family history. Additionally, it makes it possible for small businesses to invest in the wellbeing of their workforce. But concerns about quality, privacy, and data security as well as intellectual property rights must be addressed.[11]

2. **Optimized Drug Formulations:-** Artificial intelligence (AI) must be used to improve drug formulations and delivery systems. AI models can be used to predict stability, physicochemical properties, and drug release kinetics. Artificial intelligence (AI) systems investigate complex relationships between pharmacological properties and formulation components, enabling improved comprehension of drug delivery mechanisms. AI can create formulas for many different products, such as adhesives, polymers, coatings, vaccinations, and more. AI is also capable of predicting when novel medications will be released from state-of-the-art delivery systems. Combining computational techniques with experimental expertise for drug formulation optimization can lead to opportunities for the development of novel materials, creative formulations, and superior pharmaceuticals.

3. **Real-time Monitoring:-** Real-time monitoring is critical to individualized care and is made possible by wearable sensors and dynamic predictive modelling. AI can analyse the

data from these sensors to identify changes in a patient's condition, reduce human error, and facilitate tailored therapy. Furthermore, these sensors continuously assess drug concentrations, reducing concerns about toxicity. Digital endpoints collected outside of a clinical context can be used to monitor medication side effects and cognitive decline. AI-powered gadgets can also alter the delivery of drugs based on available data.

4. **Nanotechnology and Drug Delivery:-** Nanoscale medicine delivery systems can be developed with the aid of artificial intelligence (AI). Drugs can be distributed at the cellular or even molecular level in a targeted and controlled manner with the aid of nanotechnology, minimizing side effects and boosting effectiveness.

5. **Robotics and Automation:-** Artificial Intelligence has a major role in the development of robotics and automation in drug delivery systems. AI can optimize medication delivery systems, develop customized treatment plans, and enhance nanorobots for regulated drug delivery. Pharmaceuticals can be delivered to certain cells or tissues using robotic medication delivery devices, and artificial intelligence can continuously track changes in the patient's condition. Artificial intelligence (AI) can assess medical imaging, provide remote patient monitoring, increase diagnosis accuracy, and offer virtual triage or medical counselling services.

6. **Artificial Intelligence in the Healthcare Ecosystem:-** Medication distribution systems will be part of a larger AI-powered healthcare ecosystem. This ecosystem includes diagnostic tools, predictive analytics, and electronic health records, all of which enable comprehensive and proactive patient care.

7. **Interdisciplinary Collaboration:-** AI-driven medication distribution will require collaboration with specialists in several fields, including computer science, engineering, medicine, and ethics. Interdisciplinary research and collaborations will spur innovation in this area.

8. **Global Access and Affordability:-** Providing universal access to these discoveries will become more crucial as AI-driven medicine delivery advances. To do this, it will be important to address healthcare disparities and find ways to make AI-enhanced healthcare affordable and available to everybody.[4]

Applications of AI in NDDS

1. Targeted drug delivery

Because targeted drug delivery helps patients receive medication by gradually raising the drug concentration on the targeted body areas, it is regarded as a crucial component of precision medicine for cancer treatments.

AI has a rare chance to fully achieve its promise in precision medicine for cancer diagnosis and therapy thanks to its advancements and possible contribution to bio nanotechnology. This is due to AI's enormous potential for automation and quicker patient analysis of complicated disease information. By processing complex medical data more quickly and producing correct results, AI can boost treatment outcomes. The work highlights how biomarker detection using AI can improve tailored drug delivery systems. In the end, the research may provide a basis for resolving issues related to low response rates and unsuccessful clinical trials, comprehending drug synergies, and providing extra tools for analysis and molecular docking to support computer- and AI-enabled drug design processes, and advancing the development of more reasonably priced treatments employing nanomedicines and AI. In order to improve human therapies and create targeted medication delivery systems, nanotechnology is essential. Like all new developments, NP-based medication delivery systems are still in their infancy but have a bright future ahead of them. New nanotechnology strategies are always being researched to improve medication administration, but there are still a lot of obstacles to overcome, including: (a) a lack of understanding about the components and characteristics of NPs; (b) inconsistent toxicity; (c) a lack of standardized model systems and assays; (d) a lack of standard synthesis protocols; (e) a lack of effective and sophisticated analytical tools; (f) a lack of understanding about how NPs may affect or interact with biological systems; (g) a lack of in vivo monitoring systems; and (h) a lack of standardized safety guidelines.[14] Artificial intelligence therefore has a lot of promise to help with some of these issues and enhance targeted medication delivery.[12]

2. Toxicity prediction

Forecasting Toxicity AI systems that analyse the properties and chemical structure of molecules can forecast the toxicity of drugs. Machine learning algorithms that have been trained on toxicological databases are able to recognize potentially dangerous structural features or predict negative consequences. By doing so, researchers can reduce the possibility of unfavourable reactions in clinical trials and prioritize safer compounds. All things considered, AI-driven methods in drug research and development have the potential to simplify and hasten the process of finding, optimizing, and designing novel therapeutic candidates, which will ultimately result in more effective and efficient drugs.[7]

DeepTox: 22 It is employed to forecast toxicity. The following URL can be used to access it: www.bioinf.jku.at/ research/DeepTox. Multi-task learning, which involves learning all hazardous effects in a single neural network and hence learning highly informative chemical characteristics, is naturally supported by deep learning. The DeepTox pipeline was developed to predict toxicity using Deep Learning.[5]

3. AI Application for Parenteral, Transdermal and Mucosal Route

Items Artificial Intelligence can be used to develop and produce complex formulations such as biologics and injectables. AI systems that predict complex physicochemical properties of medicinal formulations could be useful in formulation development. AI models analyse formulation ingredients, excipients, and manufacturing procedures to improve pH, solubility, stability, and viscosity. In doing so, stable parenteral formulations are produced.AI can maximize the quality, efficiency, and variability of parenteral product manufacture. Through the analysis of real-time process data, AI algorithms have the potential to identify process parameters that impact product characteristics and provide suitable adjustments. As a result, industrial productivity rises along with batch failures and product uniformity. Large datasets from analytical testing, such as spectroscopy, chromatography, and particle size analysis, may contain trends and variances in product quality that can be discovered by AI algorithms. In order to ensure high-quality products, this helps find and address quality issues early on. By utilizing historical data and process variables, AI models may predict contamination, stability, and regulatory deviations. During the production of parenteral products, AI-based monitoring systems may analyse crucial process parameters in real time. By merging data from sensors, instruments, and process controls, AI algorithms may quickly detect irregularities, forecast deviations, and take appropriate action. This reduces noncompliance and preserves product quality. AI streamlines complex parenteral product manufacturing equipment maintenance processes. AI models estimate equipment failure or deterioration and schedule proactive maintenance by analysing sensor data, equipment performance history, and maintenance records. This reduces maintenance, increases output, and saves needless downtime. AI can support complex biological product and parenteral drug regulatory compliance. By analysing process data and product attributes, AI algorithms may analyse compliance, identify potential noncompliance issues, and offer suggestions for process improvement. This supports regulatory compliance as well as GMP compliance.[13][7]

4. Application of nanorobots for ocular drug delivery

The advancement of micro- and nano-electromechanical systems has made it possible to create implanted robots that can carry out a range of functions, including as delivering medications or genes under control. As a result of the astounding advancements in nanotechnology, there is growing interest in creating nanorobots with built-in sensors, artificial intelligence, and internal or external power sources. These intelligent structures can process information, signal, sense, actuate, communicate, carry out biological functions at the cellular level, and administer medications locally, improving the effectiveness and lowering the negative effects of traditional therapies. Nanorobots have enormous potential for both therapeutic and toxin detection.

It is possible to apply magnetic microrobots for ocular medicine administration. A promising method for minimally invasive targeted therapy is the wireless placement and modification of medication delivery into the eye. However, a number of problems have persisted, such as those pertaining to biocompatibility, managing interactions with intricate biological systems, and the production process. Efficient route design is essential for accurate targeting and regulated medication administration.

5. Personalized Medicine

In modern medicine, a patient might see a doctor when they experience symptoms. The doctor then administers medicine in a universally applicable manner. But according to modern genetics research, different genetic compositions can have varying effects on medications, therefore each patient should have their medicine tailored to their specific needs. Providing the appropriate intervention, including medication, to the appropriate patient at the appropriate time and dosage is the fundamental tenet of "individualized medicine."

For the purpose of precisely and accurately diagnosing diseases, treating them, and administering medications, artificial intelligence techniques must be used in the establishment or development of personalized medicine. The regulation of adverse drug reactions and enzyme metabolism causes some people to have problems getting rid of drugs from their systems, which can lead to overdoses, while other people get rid of medicines from their bodies before they have a chance to do their intended job. page number 439 Indeed, without artificial intelligence (AI) tools to retrieve data from the pool, personalized treatment would not have been able to take off. In particular, an AI tool known as Machine Learning (ML) is used to use statistical inference to uncover correlation and pattern in the data.[14]

AI-Optimized Drug Delivery Systems

A. Nanoparticles: Dispersions of solid particles with sizes ranging from 10 to 1000 nm are known as nanoparticles. A nanoparticle matrix can be used to dissolve, trap, enclose, or attach the medication. Among the many benefits that nanoparticles offer are improved medication and protein stability and advantageous controlled release characteristics. Moreover, it is possible to modify these nanoparticles to accomplish both active and passive targeting. Furthermore, the medicine has a very high loading capacity and can be taken orally, intraocularly, nasally, orally, or by any combination of these methods. It is noteworthy that the design and optimization of medication delivery systems utilizing nanoparticles has involved the application of artificial intelligence (AI).

Types of nanoparticles:, 1.Nano emulsions 2. Nanopores 3. Nanowires, , 4. Nano shells, , 5. Nanosomes 6. Nanocantilever 7. Noisome, 8. Nano emulsions 9. Nanotubes 10. Quantum dots.

B. Liposome Drug Delivery: Liposomal medication delivery methods are now being developed using artificial intelligence (AI). Liposomes area lipid-based vesicles that are used as drug delivery vehicles. Artificial Intelligence (AI) makes it easier to administer targeted, efficient therapy with fewer side effects. Artificial Intelligence (AI) can predict when a medicine will release and concentrate, which can save time and money on testing and resources. AI can also be used to plan the administration of drugs for the eyes, specifically when utilizing indocyanine green (ICG) liposomes. When coupled with Modu light Cloud, the Modu light ophthalmic laser platform allows for AI-based treatment planning by creating relationships between treatment parameters and the attainment of desired results. Combining artificial intelligence with liposomes has the potential to improve medication delivery effectiveness and treatment success rates.

C. Microsphere: One kind of drug delivery devices with the capacity to provide targeted drug distribution are microspheres. These microspheres have dimensions ranging from 1 to 1000 µm and are made of synthetic polymers or solid proteins. A multitude of approaches can be employed to create microspheres, which confers several benefits such as the ability to deliver anti-cancer drugs to tumour targets and sustained release properties. Microspheres have attracted interest, especially in the field of colon targeted medication delivery, because of their potential application in treating conditions like inflammatory bowel disease and colon cancer. The beneficial properties of microspheres outweigh those of traditional colon-targeted drug delivery systems, regardless of whether they are made with protein-based or biodegradable polymers. In particular, these microspheres have the ability to maintain their structural integrity while they pass through the digestive system and release the medication when they come into touch with colonic fluid. In the end, microspheres can improve medication distribution, which can lead to increased patient adherence, decreased toxicity, and improved efficacy.

D. Dendrimer: Because of their unique properties, including as their homogeneity, surface modification potential, and well-defined structure, dendrimers have been thoroughly studied as drug delivery vehicles. They can be used to chemically bond or encapsulate drug molecules, enabling regulated and precise drug release. Moreover, dendrimers can be altered further to create dendrimer hydrogels, which are three-dimensional hydrogel networks with both fluidity and adhesiveness. This makes them appropriate for use in formulations of topical ocular drugs. Targeted medication delivery is also possible with dendrimers since they may be made to react to particular stimuli like temperature changes and redox concentration changes. Dendrimers have shown promise in a number of applications, including cancer treatment, when used as drug carriers. All things considered, dendrimer-based drug delivery systems offer a flexible means of boosting drug stability, pharmacokinetics, and targeted drug administration.

E. Hydrogel: Polymeric networks known as hydrogels have a three-dimensional structure and are hydrophilic, which allows them to absorb large amounts of biological fluids or water. These networks, which are made up of homopolymers or copolymers, are insoluble because they have both physical and chemical crosslinks, including entanglements or crystallites, as well as tie-points and junctions. Because of their special thermodynamic compatibility with water, hydrogels can swell in aquatic conditions. Hydrogels are at the forefront of controlled drug delivery because they are stimuli- and environment-sensitive gel systems that allow release to be modulated in response to a variety of factors, such as changes in pH, temperature, ionic strength, electric field, or analyte concentration. By using adhesive or receptor-specific gels that are attached to the hydrogel surface via tethered chains, release can be deliberately engineered to occur within particular body regions, such as within a particular pH range of the digestive tract, or alternatively, through specific sites within the body. The use of hydrogels in conjunction with the molecular imprinting process offers significant potential for medication delivery.[2]

Recent trends Artificial Intelligence in Novel Drug Delivery Systems

a) Machine learning for drug discovery: These days, machine learning algorithms are used to analyse large datasets, find possible therapeutic targets, forecast pharmacological efficacy, and improve medication features. This artificial intelligence (AI) driven drug discovery platforms can screen millions of compounds, which drastically lowers the time and expense involved in developing new drugs.

b) Nanoparticle: based drug delivery systems-Drugs can be expertly tailored to be delivered to particular body tissues or cells using nanoparticles. AI is now being used to optimize these nanoparticles' designs in order to increase therapeutic efficacy and reduce toxicity levels.

c) Predictive models for drug release: The use of artificial intelligence models makes it possible to predict how drugs will behave in the human body and makes it easier to create regulated medication delivery systems. This beneficial feature makes sure that medications are released into the body at the right time and place, improving therapeutic efficacy and reducing unwanted side effects.

d) Smart drug delivery system: Drug delivery systems that use AI-powered sensors provide real-time drug release monitoring, which gives doctors the ability to customize treatment regimens and adjust dosages.

e) Personalized medicine: Artificial intelligence (AI) in patient data analysis enables the creation of customized medicine delivery systems that address each patient's distinct physiological traits and medical background. This individualized strategy reduces the chance of an adverse reaction while improving treatment outcomes.[2]

Benefits

One of AI's advantages is that it gathers data from various sources and indicates which drug delivery mechanism should be used to achieve the desired outcomes. A sophisticated data analysis process may involve evaluating molecular information, patient data, and pharmacokinetic data in order to determine the optimal active medication to treat a patient's condition or meet their needs. The identification of molecular entity features is done by comparing them with those of known molecules using the passive form of artificial intelligence. The precision with which drug delivery systems are chosen—a function of artificial intelligence—determines the effectiveness of treatment.[7]

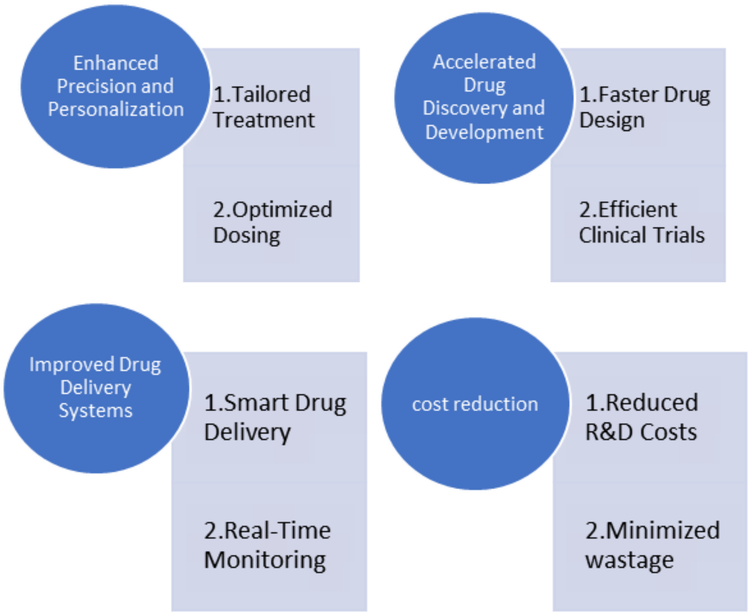

Fig no. 1: Benefits of AI in Drug Delivery.[15]

Challenges

While AI and related breakthroughs are developing quickly and are investing heavily, there is substantial exaggeration and caution is necessary. However, health services stand to benefit greatly from these innovations in terms of reduced resource and administrative burdens. Many AI applications are still in the early stages of development (see Figure I). In addition to the many technical drawbacks of present AI technologies when compared to human language processing, vision, and context-specific reasoning, there are unique difficulties in implementing AI approaches in the delivery of healthcare**.**

Governments everywhere have taken progressively more positive stances regarding the application of AI in a range of fields and endeavours. While some governments have actively participated in the use of AI in healthcare, others have given private firms financial assistance to create pertinent AI applications. Governments and funders may need to develop policies detailing how AI is deployed in healthcare delivery and how this process will be funded as the benefits of AI in medicine become more apparent.[8]

CONCLUSION

The enormous time and expense involved in medication research and development calls for the use of more creative methods and approaches. Artificial intelligence (AI) technologies have enormous potential for analysing vast volumes of multivariate data, resolving challenging issues related to creating effective medication delivery systems, and improving decision-making. Because AI makes it possible to create complex distribution systems, drug delivery is already starting to undergo a revolution. AI would be a crucial component of the medication development process and customized medicine in this regard. Furthermore, artificial intelligence (AI) has a bright future in drug delivery. It has the power to revolutionize healthcare by offering more accurate, easily accessible, and effective medicines. Artificial Intelligence is poised to revolutionize drug delivery, with enormous potential to enhance patient outcomes and healthcare delivery**.**

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