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A REVIEW ARTICLE ON TRANSFORMING HEALTHCARE: THE INTERSECTION OF AI AND 3D PRINTING

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ABSTRACT

AI and 3D printing are separately gaining momentum, but the connectivity of both these technologies has opened up new horizons in the field of personalized medicine. Hence it has facilitated the improvement of drug development, diagnostics, and therapy among other aspects. The purpose of the article is to assess the disruptive role of virtual simulations and the 3D printing processes in addressing the challenges posed by conventional systems such as design and production mesh losses. Other causes of delays in development could include the use of AI devices predictive modeling for predicting disease or drug targeting. At the same time, 3D printing allows for the production of specific designs of dosage forms, drug delivery systems, and methods of treatment, ranging from a combination pill to at home drug dispensing. Phenotypic personalized medicine PPM takes a different approach in AI usage, it is more datasparing and centers on the specifics of the patient's genes. Developments like CURATE.AI or PPD Parabolic Personalized Dosing help solve design of experiments for drug agencies and reap the maximum outcome in interventions where these problems are encountered including organ transplants and ARDS. Where the two technologies are most effective include organizing treatment strategies for advanced stage cancers like hepatocellular carcinoma HCC, where mHealth and gaming technologies structural and 3D bioprinting are being incorporated into the approach. The challenges experienced however include legal issues, privacy issues, and business processes. Moreover, accelerated developments in the processes of digital image classification and computation have led to the improved precision in 3D printing processes, but challenges such as lack of adequate annotated data, unbalanced classes, and limitations of computation in real time still present. The convergence of many fields such as AI, machine learning, 3D printing conveys the future which is characterized by customized medicine and this also solves the challenges of slow processes in drug discovery and health care systems. Nevertheless, equal distribution, ethical consideration and improvement of existing structure are among the many challenges which need to be solved in order to fully benefit from these incredible innovations. This synthesis illustrates when those challenges are overcome, there well be no turning back in progress towards using AI and 3D bioprinting in medicine, hence news ways of healthcare will be developed.

1. INTRODUCTION

Adding new hardware and software for easy software productivity is causing a lot of disruption. The design environment is constantly evolving, and so does any computer-aided design (CAD) technology as recent researches have proven. When it comes to simulations, AI-driven solutions tend to be the best and easiest option available even for high fight management of internal system efforts of numerous parameters[1]. In most simulations, one of the main problems is the meshing process, which is tedious and very error-prone. Old fashioned meshing tools usually discard any internal surfaces information and deal only with the exterior of the model[2]. Hence, in the design cycle, parametric variations are experienced and remeshing is repeated several times and a new mesh structure is rebuilt completely with each variation. In the same vein, the size of the mesh plays a crucial role in the efficiency of the meshing process[3]. For example, Abbasi et al. (2020) studied the effect of mesh size in both conventional and underwater friction stir welding of Al6061-T6 using three-dimensional finite element analysis. Researchers, employed the Deform-3D software in order to control excessive mesh distortion during the course of welding due to severe plastic deformation. In general terms, the process of achieving the best possible meshing design takes a lot of time; however, due to innovations like SimSolid, one can jump straight into the simulations without having to be concerned about the mesh. SimSolid-compatible designs empower the users to carry out quick design changes without worrying about the placement of the mesh in the regions where the high stress levels are expected thus lessening the simulation time[4]. The goal of personalized medicine is to provide treatments that are specific to an individual by using the information such as the individual's biological and genetic characteristics as well as individual responses to drugs. 3D printing is one such technology that is contributing significantly to this transformation, as it can be used with great accuracy in the manufacture of medical products, Pharmaceuticals in particular[5]. This involves the construction of a

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three-dimensional object using successive layers of materials, which are controlled by a computer program. In regard with dosage forms 3D printing is of great promise in the development of various dosages forms with tailored designs, specific drug release profiles and multiple active pharmaceutical ingredients. Techniques such as inkjet printing, binder jetting, fused filament fabrication, selective laser sintering, stereolithography and pressure assisted microsyringe are being evaluated in the field of pharmaceutical sciences[6]. These platforms allow the creation of customized drugs such as adjusted dosages, polypill forms, and medications that fit a particular consumer. In these scenarios, 3D printing may also play an even more important role in the future clinical practice by making it possible to produce medications using 3D printing technology directly in the medical facilities if needed. The medicines prescribed will be based on individual demands which will in turn increase the effectiveness of treatment and improve results of patients. But, there are some issues which still need to be resolved, for example, legal aspects, production scale-up, and reproducible quality provision. The ability to overcome these issues will be instrumental in employing 3D printing processes in the field of personalized medicine.3D printing, if applied to pharmaceutical development, will not only make it more flexible and inventive, but will also greatly enhance the concept of individualized/bespoke medicine barbarians in the way populations of patients are treated and medications are delivered to patients[5,6,7]

1.1 Empowering Personalization: The Role of AI in Tailored Healthcare Solutions"

The entire process of drug development is associated with numerous costs and takes a long time to complete, with the majority of candidates failing in the course of clinical trials. Predictive modelling powered by Artificial Intelligence is concerned with these issues by incorporating target therapies, candidate drugs and clinical studies[8]. Artificial Intelligence encompasses large amounts of data and utilizes structured and unstructured data to create probabilistic models that help in making decisions in the different processes of drug discovery, development and its approval[10].Some of the important and applicable AI compositional technology in the drug development is mentioned below:

- Disease Modeling: Building a molecular profile for the existing 'disease' variations.
- Target Identification: Mapping out the disease-causing molecular pathways and respective therapeutic targets.
- Drug Optimization: Producing drug candidates with better efficacy through the design and synthesis processes.
- Efficacy Evaluation: using virtual or real patients to predict clinical outcomes using clinical data[9,10].

1.2 Phenotypic Personalized Medicine: A Patient-Centric Alternative to Data-Driven Approaches"

PPM (phenotypic personalized medicine) is a simpler solution than data hungry AI. PPM instead aims to use the genetic sensitivity of the patient to these drugs rather than population characteristics. CURATE.AI develops and finetunes dosing levels which is an interactive way of dealing with therapy without large amounts of data[11]. The employment of artificial intelligence is transforming healthcare drug innovation as it facilitates medicine becoming an individualized practice and quickens the drug development pipeline. Sadly, all these advantages can be compromised by factors such as data prejudice and lack of adequate infrastructure aimed at equitable and effective usage. The use of artificial intelligence in combination with other technologies will enhance treatment, lower costs and improve patient care signaling the dawn of personalized medicine [8,9,10,11]. After receiving a transplanted organ, all patients are put on a robust set of medications and procedures to keep their body from rejecting the organ. When it comes to the for example, tacrolimus, physicians often follow the dosing recommendations available for the particular drug. However, more frequently, they have to resort to wild guesswork as patients biochemistry makes every one of them different. To resolve this issue, Zarrinpar and colleagues came up with a mathematical strategy known as ** parabolic personalized dosing (PPD)** to remove this doubt. This method of PPD employs algebraic equations to correlate a drug concentration with the phenotype of a patient, which in the above example is the trough concentration of tacrolimus. In order to define the next optimal dose, this technique draws a two-dimensional (2D) geometric parabola on the patients' graph over the elapsed time[12,13]. The parabola is flexible enough in that it can change its structure with respect to the addition of drugs or procedures such as hemodyalisis, which modifies the distribution of drug(s). During the initial assessments in which four subjects participated, the PPD strategy had better outcomes than the standard dosing or dose adjustment by the physician, with less number of patients out of the acceptable trough levels. Future research aims to advance PPD by creating a three-dimensional (3D) PPD that will be able to consider many drugs and other clinical health objectives. This is not only applicable in transplant medicine but can also help in tailoring treatments in other conditions and therapies as well[13]. Similar trends can be seen with regards to 'personalized medicine' in diseases such as **acute respiratory distress syndrome (ARDS)**; a concept that is adequately represented but epidemiologically complex. Patients with ARDS exhibit acute hypoxemia, bilateral infiltrates, and non-cardiogenic pulmonary edema; ARDS is not a simple syndrome and the clinical picture varies tremendously owing to risk factor and lung injury physiology, microbiology, and biology differences. These differences probably caused[14].

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1.3 Personalized Medicine in Hepatocellular Carcinoma: Leveraging 3D Printing and AI for Targeted Therapies

Hepatocellular carcinoma (HCC) is the fifth most-cohesive neoplasm in the world and has the third position in the list of cancers causing deaths. The approach for treatment of HCC has been stage dependent. However, new technologies including three-dimensional (3D) printing, 3D bioprinting, artificial intelligence (AI), and machine learning (ML) make it possible to personalized evidence-based treatment useful and achievable. This review presents the technological advancement in HCC management, barriers to their implementation, solutions to these challenges and the changing health care landscape[15]. In the case of 3D and bio-printing of tissues, cost, cell availability and their viability, safety issues, infrastructure, similar health regulations, political and physical laws are normative concerns. The issues for AI and ML include intellectual property, responsibility, bias, confidentiality, system vulnerabilities, morality, and accountability. Most of those barriers are not insurmountable and already we see artificial intelligence combined with 3D printing technology in the medical field presenting great possibilities in changing the way HCC will be managed which means its application in clinical practice will soon become a reality. This inevitably means that physicians must understand these technologies and how to work with them[16].Besides applications in HCC, 3dimensional printing has developed well beyond its original use as a manufacturing process, now finding application in manufacturing, healthcare, as well as in consumer goods. The quality and accuracy of 3D printed objects relies characterization and model building with the use of digital objects. Digital image classification enhances the accuracy of 3d printing process because it is reliant on CI image classification methods. Nevertheless, there are issues that need to be overcome in the application of CI based image classification [2,14]. One of them is the difficulty associated with digital image classification in 3D applications due to the differing geometrical forms, dimensions and materials of objects. The need to develop strong feature extraction procedures is very necessary for the information useful for classification to be obtained. An area of concern is the lack of adequate annotated data relevant to 3D printing application. For this reason, transfer learning and synthetic data generation are being studied. Class imbalance is also a challenge, where certain object classes are not sufficiently represented in the training dataset.Furthermore, computational resource utilization and real time functioning are also key but mostly in environments that are resource sparing. Without proper methodologies for the training and inference processes, it would not be possible for practical purposes. Last but not least, the emergence of these advanced systems of classification based on comprehensive intelligence raises the issues of interpretability to the users and explainability to potential multisystem interactive processes, which is especially the case for highly reliable systems. These improvements in 3D printing and AI techniques herald a huge revolution in healthcare sector giving opportunities encompassing HCC management and even more[13,14,15,16].

2. DISCUSSION

The use of Artificial Intelligence (AI) and 3D printing technologies in personalized medicine can change the face of the healthcare industry. Apart from the use of AI to develop models from given sets of data, its ability to handle massive data in the same process, progress honed by the precision of 3D Printing can be found in the turning of custom medicines and medical devices. The two technologies respond to the increasing need for personalized treatment, adjusted medicine dosages, and novel treatment methods. Nevertheless, there are problems. The existing regulatory challenges have not been revised to fit the peculiarities of 3-dimensional printed drugs. Reproducibility, scale-up, and quality assurance remain the main challenges. Not to forget, the nature of AI solutions, which often requires a lot of quality data, is associated with other concerns like data discrimination, data protection and data availability. This means that the successful use of these technologies rests on the interaction of pharmacists, data analysts, engineers, and legislators. But as new AI algorithms and 3D printing methods are created, and regulation grows, so too does the possibility of adoption. It is believed that medicine where treatments are based on 3D printing and AI will not only be more effective in such cases but will also result in more satisfied patients and better health outcomes.

3. CONCLUSION

The combination of artifical intelligence and three dimensional printing in Pharmacy is the new age in drug formulation and delivery systems. These technologies enable the health care providers to create treatment plans based on individual needs of respective patients maximizing benefits of therapies and minimizing side effects. Though there are challenges like regulatory and infrastructural backlogs or ethical issues, overcoming these will ensure that a nighmarish yet real utopia of discrete medicine will be achieved. Availability of embedded systems, AI and 3D printing in clinical practices will change the existing practices in a way where it will be possible to easily design needed drugs, produce them as they are needed and treat patients better. The introduction of these improvements

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suggests that those will be a seemingly dramatic change in the ways of business carried on in the pharma sector. It will bring health care to the patients in a completely different way; the focus will be on the full integration of speed and effectiveness, as well as easy customization. The process of accomplishment of this objective will be long, the advantages it holds for the improvement of health globally cannot be contested.

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