

Agentic AI Driven Drug and Pharmaceutical Management-A Scientific Study

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ABSTRACT

Agentic AIs constitute a qualitative leap in the development of artificial intelligence, defined by their capability to set complex goals in a changing and uncontrolled situation and to pursue them through autonomously managing their resources. These systems are good at doing well defined tasks within certain boundaries but prominently fail whenever the attempted tasks have no end state or specific parameters to manipulate. Multiple agents workflows enhance the execution of tasks in chain. Agentic AI act play role as leader to run multiple tasks without any intervention human and it has decision making ability as similar to human intelligence. Generative AI on the other hand only creates or regenerate the content but agentic AI associated with multiple tasks management and controlling automatically. Therefore, it has the significant roles in improvement of pharmaceuticals workflows and tasks automation. For pharma industry development Agentic AI is involving in Research and Development, Drug Discovery, Manufacturing and Production, Regulatory Compliance, Marketing Strategic Improvement and Quality enhancements, and Supply Chain Management. This paper is about the applications, impact and issues and challenges in regard to the Agentic AI in Pharmaceutical Industry.

Keywords: Agentic AI, Artificial Intelligence, AI Applications, Emerging Technologies, Pharmaceutical Industry, Drug Development

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INTRODUCTION

As per the autonomous molecular design and optimization, multiple AI agents work simultaneously that Reinforcement Learning agents involve to communicate with chemical spaces, decide taking action same as make changes in molecular structure, and receive feedback to rectify and optimize the attributes in real time. Chemistry42 used generative AI, which is involved in designing new efficient molecule and updates according to the metabolic stability and synthetic accessibility which take lots of time manually [4], [7]. Some AI agents optimize specific features or goals with scoring techniques

to update generated molecules to confirm that it maintain critical semantic requirement or viable drug. In terms of the automated design build test learn cycle, agentic AI is embedded into closed loop system which automate the early stage discovery process. In self driving laboratories multiple AI agents are involved in research by rapidly steering the chemical spaces and instruct the robotic systems to blend and test chemical compounds without the human interaction. Different AI agents work together in research and development of the molecules. Here Figure 1 has depicted key applications and roles of Agentic AI.

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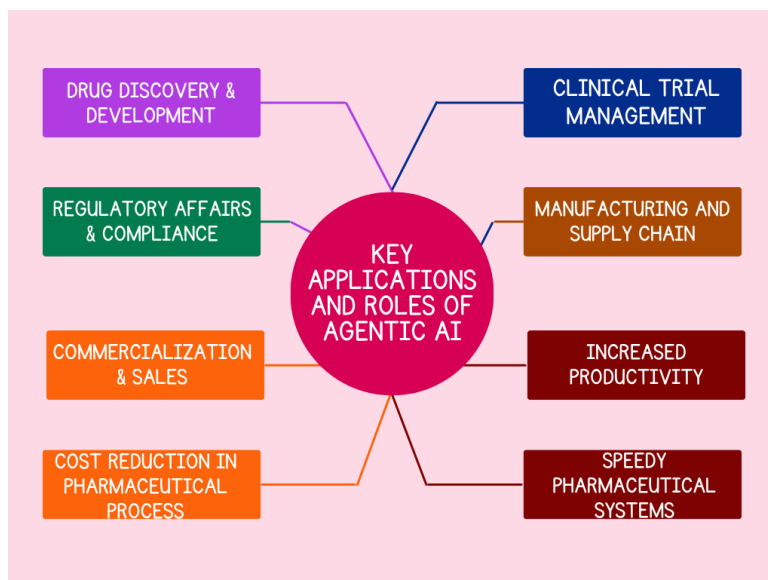


Fig: 1-Key Applications and Roles of Agentic AI

Like NVIDIA’s BioNeMo and Insilico Medicines Pharma AI combined the multiple function-specific agents that work together as one for the new target discovery as for example PandaOmics, one for molecule generation, example Chemistry42, one for find out the probability of clinical trial achievement like example InClinico. Regarding the autonomous control of experimental system, Organ on a Chip (OoC) and tissue engineering, AI is evolving from a tool for post-experimental analysis to an active controller. AI agents are work to control the all the parameters related to the functionalities of OoC like by maintaining or by adjusting the flows conditions to sustain the stability over long time experiments or it manage the drug distribution in the different organ module very effectively. As per the closed loop feedback, AI agents are able to perform continuous monitoring of microenvironment including Oxygen, pH, and metabolites [1], [21], [22]. It can takes decision automatically to optimize culture conditions or trigger drug delivery. Artificial Intelligence enabled OoC system enhance the capability to provide fundamentally natural and perfect controlling on the biological microenvironment than human operator can manage. All the applications of Agentic AI in drug discovery and for drug delivery technology, play the critical roles to accomplished the tasks automatically. Therefore, agentic AI has broad applications in wide rage of field to automate the workflows and tasks. The use of Agentic AI in the pharmaceutical industry is increasing day by day. Though it has lots of benefits for incorporation in the pharmaceutical industry, it also has many challenges and issues. One of the important challenges is the technical challenge. It is very difficult to incorporate the Agentic AI-based new system with the existing system. The new model is very difficult to be interpreted by the existing one. As it has poor interoperability between systems, it is not able to communicate with the existing system properly. Apart from that, it faces algorithmic bias. The efficiency of the algorithm depends on the complexity of the algorithm. With changes in the algorithm, the

performance of the system varies significantly. Apart from that, it is very challenging to ensure data quality. There is no standard dataset for the whole system. So, it is very difficult to design a complex dataset. It is also difficult to validate the whole framework. As it requires real-time data, it is necessary to incorporate real-time data into the system, which creates a more complex framework. It consists of different valuable information like patient data, drug data, business data, payment data, and many more. So, it is necessary to establish a system with full protection. It is very challenging to ensure system security. Data authentication and authorisation are primarily necessary for the system. It is necessary to create a strong encryption technique for data security [8], [9], [64]. Cloud security is also very important in this context. As the cloud is maintained by a third party, it is very difficult to ensure data security. Sharing of data between different organisations also creates vulnerability.

Objective of the Paper

The Paper entitled “*Agentic AI Driven Drug and Pharmaceutical Management-A Scientific Study*” is theoretical in nature and deals with following aim and objective

To learn about the basic of Artificial Intelligence and Agentic Artificial Intelligence with its features, characteristics, and nature.

To know about the Basic and Emerging applications of Agentic AI and Allied Technologies in Pharmaceutical Industry.

To learn about the existing works related to the Agentic AI in Pharmaceutical Industries and allied organizations.

To learn about the futuristic aim and agenda of Agentic AI driven Phrama and Drug Development and Industries in brief.

To gather about the basic issues and challenges of Agentic AI in Pharmaceutical Industries and organizations, in brief,

METHODS USED

As far as the work entitled “*Agentic AI Driven Drug and Pharmaceutical Management-A Scientific Study*” is concerned is a theoretical in nature and deals with existing published works related to the *Agentic AI in Drug and Pharmaceutical Management* and thus existing published works are consulted and analyzed and lastly reported in this particular piece of work scientifically. All the aspects reported sub category wise and highlighted with main parts and sections.

4.0 EXISTING WORK AND REVIEW OF LITERATURE

A literature review is a key component of this study as such, it will help identify what is currently known about this area and where further investigation is required to better understand how advanced AI systems can be integrated into pharmaceutical processes. Significant advancements in healthcare and pharmaceutical management have occurred through the use of agentic AI systems, which are autonomous, goal-driven, and decision-making. Such systems can aid in drug discovery, optimize supply chains, manage inventories, validate prescriptions, and plan treatments for individual patients. This chapter provides an overview of some of the most relevant studies concerning artificial intelligence and its applications using agentic systems in drug and pharmaceutical management.

Ali et al. (2024) [2] The research identified how machine learning can be used by developers to evaluate a drug's physical/chemical properties; and formulate the best combination of a drug's active ingredient with other ingredients such as excipients to create a stable drug product. This research stated that through simulation using Artificial Intelligence techniques, it is possible to test many formulations without conducting each experiment in a lab. In addition, the study described the potential uses of AI in creating new types of drug products that provide longer duration or targeted release, thus improving efficacy while minimizing side effects. The study further reported on how AI will become increasingly important in (QbD) approaches within pharmaceutical development. According to the report, AI has the ability to greatly enhance innovation, accuracy, and speed of pharmaceutical formulation processes. **Bengio et al. (2021) [59]** offered an overview of the development of deep learning (DL) approaches and the increasing presence of DL in healthcare. The authors explained how the advanced architecture of artificial neural networks, specifically convolutional neural networks (CNNs) and recurrent neural networks (RNNs), can analyze large amounts of biomedical information, that is, genomic sequences, clinical records, and drug-interaction databases. This information can be analyzed using these models to find hidden relationships or patterns that would otherwise be difficult to identify using standard statistical analysis tools. In addition to demonstrating this capability, the research showed that DL has the capacity to increase the speed at which drugs can be developed. Specifically, it demonstrated that DL enables the "virtual" screening of

compounds for efficacy and safety before they are synthesized into actual product(s). Additionally, DL was shown to predict various molecular characteristics. Finally, the research indicated that DL could assist in identifying possible therapeutic targets. **Kumar et al. (2025) [31]** This research identified the application of advanced artificial intelligence (AI) for pharmaceutical research including drug discovery, quality assurance and process improvement. A significant finding from this research was that advanced AI technologies can use large amounts of data and identify trends and make predictions regarding future events. Further, the research identified applications for AI in simulating pharmaceutical processes, detecting anomalies in the manufacturing process, and providing continuous product quality assessment through online monitoring. The study also focused on "intelligent" decision support systems that mimic human expertise when assessing the efficacy and safety of drugs. The study identified several challenges to be overcome in the adoption of AI for pharmaceutical R&D, including integrating data into a single platform, scaling up an AI system, and addressing ethical issues. The findings of this study showed that AI has increased the efficiency, innovative capabilities, and dependability of pharmaceutical R&D.

Patil et al. (2023) [43] Pharmaceutical Regulatory Affairs uses Artificial Intelligence (AI) to improve regulatory compliance; improve documentations; and manage risks within regulatory process. In particular, pharmaceutical regulatory affairs used AI to automate the creation of and review of regulatory documentation and to create accurate and consistent regulatory documentation across all global regulatory jurisdictions. The natural language processing capabilities of AI are utilized to analyze regulatory guidelines and extract the information needed to make decisions based on those regulations. Additionally, AI can assist in the pharmaco vigilance process by monitoring adverse events caused by drugs and identifying potential safety issues related to drug use in real-time. AI can minimize a company's workload, reduce the number of human errors made during the regulatory process, and increase the efficiency of the regulatory process. As such, the authors concluded that AI plays an important role in updating pharmaceutical regulations and increasing compliance with ever-changing global regulations. **Yadav et al. (2025) [61]** conducted a review that illustrated a broad range of applications of intelligent systems in optimizing drug discovery and development. The authors pointed out that data analysis through AI-based modeling enables rapid predictions of drug-target interactions, as well as the ability to rapidly identify potential new leads, and ultimately the selection of lead structures to be further developed into commercial products. High-throughput screening technologies were integrated with various machine learning-based modeling algorithms, which enabled the rapid and cost-efficient identification of candidate drugs. Additionally, AI-based tools and technologies are being utilized in the clinical trial process to optimize aspects such as patient recruitment, trial design, and outcome prediction. Overall, AI has reduced

the amount of time it takes to develop a new drug from multiple years to a fraction of that time, while reducing the financial risk associated with developing new drugs. Ultimately, the authors stated that AI technology will continue to improve operational efficiencies in addition to transforming the entire pharmaceutical innovation model.

5.0 ARTIFICIAL INTELLIGENCE AND AGENTIC AI: FUNDAMENTALS

AI, Which can be described as AGENTIC has its core differences when compared to the other advanced types of AIs in terms of autonomy, function and scope among others. Such AI systems are integrated into specific tasks like image analysis, translation and other recommended engines, which can be able to perform designated tasks through ultimate focus. On the other hand, Agentic AI systems can be described as possessing the characteristic of open-endedness where there is no prescription of how the task should be achieved. They work with and adapt to rapidly changing conditions. The conventional AI might be accurate, they do not have the situational awareness and goal directed dynamics inherent in Agentic AI. Classical AI systems are primarily rule based or supervised learning models designed for specific tasks, It integrates autonomy and adaptability, enabling broader functionality [5], [20], [38]. The differences between these are illustrated with best examples

Classical Agents: These agents excel in controlled environments. For Example, rule based financial trading algorithms functionally effectively when predefined parameters remain constant. However they struggle with volatile market changes are unpredictable disruptions.

Agentic AI: In contrast, Agentic AI provide trading systems dynamically adjust strategies based on real time

data historical trends and unexpected market shifts making them more resilient and adaptive.

Reinforcement Learning versus Language Model Based Agents: While reinforcement learning focus on optimizing cumulative rewards in a specific task environment, language model based agent extend this by interrupting complex natural language inputs and interacting with humans seamlessly.

The development of Agentic AI systems relies on core algorithms and frameworks that enable goal directed behavior contextual adaptation and autonomous decision making. These technical foundations incorporate advances in reinforcement learning goal oriented architectures and adaptive control mechanisms. Reinforcement learning is central to many magnetic systems as it equip AI models with the ability to learn through trial and error. Goal Oriented Architectures provide a structural framework for managing complex objectives within magnetic AI systems. Adaptive control mechanisms ensure that agnetic AI systems can adjust to changing environments [10], [25]. By incorporating adaptive control, agents recalibrate their parameters in response to external variations such as data shifts or unexpected disruptions. By combining reinforcement learning goal oriented Architectures and adaptive control, Agentic AI systems a level of autonomy and resilience that allows them to operate effectively in diverse environments. This section establishes the technical basis for understanding the advancement capabilities of Agentic AI providing a foundation for methodologies and applications discussed in the section (also refer Fig: 2).



Fig: 2- Basic AI and allied technologies applications in Pharmaceutical Industry

6.0 ROLE OF AGENTIC AI IN PHARMACEUTICAL INDUSTRY

Agentic AI evolving in pharmaceutical industry in recent days and Agentic AI is the innovative advancement of AI in this era that enhance the productivity of the system by

making autonomous system [12], [27]. Agentic AI implementing in pharmaceuticals industries to increase the production and also speed up the task execution by automate 75-80% tasks workflows. Followings are the roles of the agentic AI in pharmaceutical industry. Here Fig. 3 & Fig.4 scientifically depicted about the basic and possible role of Agentic AI in pharmaceutical industry.

6.1 Drug Discovery and Research Development

Agentic AI has many potentialities in research and development in pharmaceutical industries. It plays leadership roles in improvement of research and development regarding invention of new drugs, and prevention of diseases by imposing doses of drugs. Traditional Research in the pharmaceutical industry is very costly and time taking process and it converted using data driven process that enhance the speed of discovery and research quality. Agentic AI applied in the research field of the pharmaceutical domain to make automated research workflow and tasks. In research development, agentic AI work on the data analysis to interact with the environment, automate the complex experiments. Specifically, agentic AI implemented for the emergence of automated, goal-directed AI system, which is perform as agents inside the pharmaceutical research pipeline. Agentic is used in three primary aspects including autonomous molecular design and optimization, automated design build and test learn cycle, and autonomous control of experimental system [13], [40], [54]. LLM operated multiple AI agents automate the tasks including taking planning, uses tools for research, and reasons to generalize behind the small

molecules as represented by SMILES strings for realistic drug discovery. AI agents are perform the tasks based on the literature data mining, synthesis planning, and basic molecular design.

6.2 Manufacturing and Production

Agentic AI has the significant role in the manufacturing and production unit of the pharmaceutical industries. It makes manufacturing autonomous, self-optimizing production by utilizing AI agents to observe assets, determine the maintenance requirements, decreasing downtime and extend the quality control. Contributions of Agentic AI in manufacturing and production unit are lab automation, intelligent quality control, predictive and autonomous maintenance. As per the lab automation, Agentic AI operates, control and optimize the pharmaceutical laboratory or clinical workflows to enhances the speed of the development and the formulation [11], [16], [17].AI agents involving in continuous evaluation of the production line, detecting the small deviations from the standard as tablet formulation and instant recommendation for the corrective actions according to the intelligent quality control. In terms of predictive and autonomous maintenance, agents are used to analyze the real time data received from the sensors devices for forecasting the failure of equipment and intimate the maintenance requirement proactively to avoid costly production shutdown. Therefore, agentic AI has many potentialities in manufacturing and production field of the pharmaceutical industries.

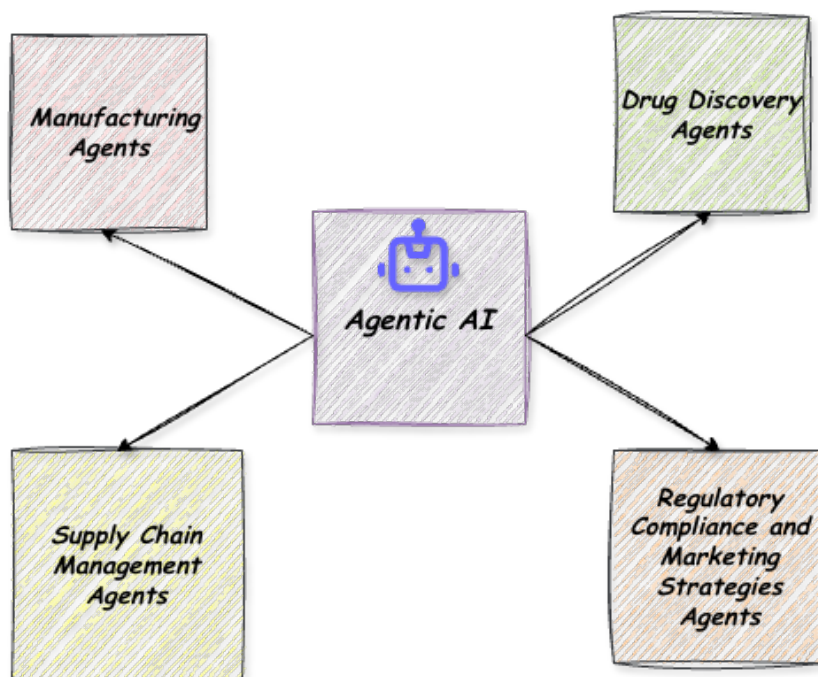


Figure-3: Basic roles of Agentic AI in Pharmaceutical Industry

6.3 Regulatory Compliances

Agentic AI is used for the management of regulatory compliances in pharmaceutical industries. Agentic AI is

applied to make autonomous multi agent system that automate the different tasks such as dossier preparation, continuous compliance monitoring and change

management. It helps to reduce the time for preparation of regulatory compliances documentations. These AI orchestrated multi agent systems utilize “human-in-loop” validation process to improve the performance when accuracy need to ensure in high regulatory environments. Roles of agentic AI in the pharmaceutical regulatory compliances are automated documentation generations and submission, change management, continuous compliance and observations, regulatory intelligence and reporting [18], [56], [57]. In automated documentation generations and submission, agents has the ability to create fast draft of various regulatory related documents such as clinical study reports, by including internal data linked with external databases, experimental reports. AI agents provide 24x7 hours monitoring every regulatory compliances such as FDA 21CFR part 11, EMA GxP, HIPAA, and GDPR, detect any errors or discrepancies easily and in immediate basis. Agentic AI evaluate the effect on the workflows and suggestion related to compliances modification while regulations changes or operations moved internally. Global regulatory database might be modify by the AI agents to confirm the compliances database is updated properly without any manual mistakes. Agentic AI has the significant roles in the field of regulatory compliance by improving the speed of processing, reducing risk factors, improve the accuracy, enhances operational efficiency, and the audit readiness. Therefore, Agentic AI implementations in pharmaceutical industries improve the efficiency of the drug discovery, delivery, and designing process including the operational works like regulatory compliances and strategies implementations [23], [37].

6.4 Marketing Strategies and Quality Enhancement

Agentic AI in the pharmaceutical industries involve in marketing and sales from the segmentation based approach to autonomous, static, and hyper-personalized engagement. Multiple AI agents makes it easier to targets HCP, automate the workflows, which are hard to flow, and coordinates with multiple channels in real time. It helps business run more smoothly, that speed up the launch of the new product in market, higher ROI provided through targeted, and the useful information. Major important roles of AI agents in improvement marketing and sales strategies in pharmaceutical industries including hyper-personalization at scale, optimized sales coverage, real-time market intelligence, proactive risk management, and real time market intelligence [19], [24]. In the

personalized scale, Agentic AI develop system to generate personal messaging and content system for the healthcare professionals, and patients. It helps to make adjustment of preferences, behaviours, and real world performances data dynamically. AI agents are used to optimize the sales by analysing the various factor and reasons including territory workloads, doctor potentialities according to the optimal sales force distribution, scheduling, and decreases the manual administrative workloads for reps. AI agents can enhance the speed of the launch preparation by managing complicated, cross-functional workflows between marketing and medical affairs. For the instances, they create value dossiers and look at the market related data to customize launch strategies [14], [41]. Agents keep watching the what trends are going on the market, what competitors are doing actually, and monitor social media all the time. According to all these observations and monitoring AI agents generate proactive and data driven changes to business strategies instead of reactive ones. Agentic AI based system continuously monitoring the compliance and data protection and AI agents can easily detect problems very fast such as bad drug reactions, or violations of the rules regulations that makes operations safer and more compliant. Then, it helps to manage the proactive risks in marketing and sales that helps to improve the business strategies or policies. Agentic AI automate the boring and lengthy tasks such as scheduling calls and logging CRM data release sales people to have more valuable face to face meeting and interactions. Agentic AI powered Omni channel marketing can boost the return on the investment (ROI) of a campaign by 15% and it reduce the cost for outsides agencies (McKinsey reports). It helps to take actions faster where the complex tasks take one month to complete that completed within one day.

6.5 Supply Chain Management—

In Supply Chain Management, Agentic AI implemented to make autonomous system, act as intelligent agents for analysing the data, real time decision making, and independently acting for the accomplishment of tasks. Agentic AI make system more flexible by automate inventory management, cold chain logistics, and effective monitoring of compliance. It leading to reduces the logistics costs and manage the constraints in manufacturing. Therefore, Agentic AI can effectively manage supply chain management system by acting as autonomous supply chain manager [28], [42], [44].

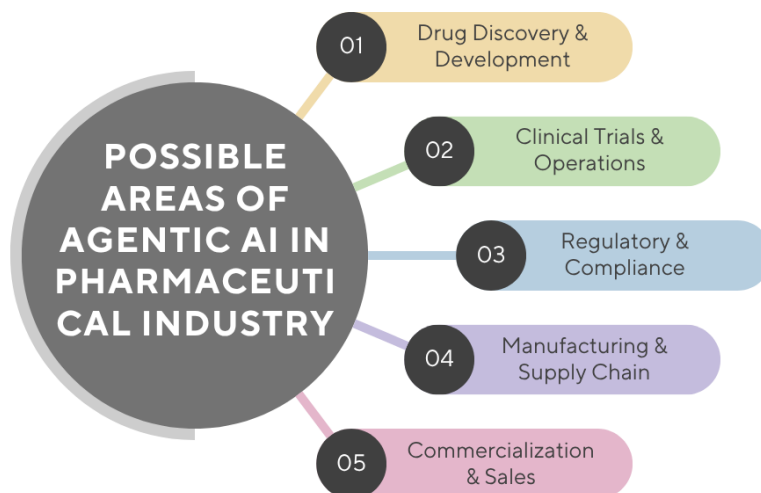


Fig-4-Possible areas of Agentic AI in Pharmaceutical Industry

Agentic AI playing the roles in supply chain management as cold chain management, autonomous demand planning, compliance management, inventory optimization, procurement and supplier management. In cold chain management, AI agents are continuously monitor the temperature of the shipment in real time, and automatically make changes the route or adjust logistics to prevent the product damage. For autonomous demand planning, multiple AI agents continuously track market conditions to make adjustment in production schedule that helps to reduction of storage capacity during the disruption [32], [35], [62]. AI agents help to automate the regulatory monitoring and documentations, and it helps to transform autonomous compliance from manual. Therefore, agentic AI also used in compliance management in terms of supply chain management in pharmaceutical industry. To optimize the inventory, agents are independently work together to control and manage inventory levels placed in different regions that confirm availability of high impact stock keeping units. AI based agents also help to optimize inventory by reducing waste. Autonomous AI agents are used in analysis of supplier performances, conditions of market, and facilitate to take faster decision. Therefore, Agentic AI is also useful in procurement and supplier management and it control and mange everywork regarding marketing strategies for the suppliers automatically.

Therefore, in pharmaceutical industries Agentic AI can play very vital role to manage the complex tasks of supply chain management because shipment of the drug related product is very crucial task in pharmaceutical industries [33], [36], [63]. Store keeping the medicine and prevent medicine to spoilage during shipment are very important and need to mange the store keeping and shipment very efficiently. AI agents do all these tasks very fast and efficiently. Technology work from the perception layer to

the AI agents layer and finally agentic AI act as the team leader to control and mange workflows automatically. IoT sensors are used in perception layers to collect real time data externally and that data passes through the brain as AI agents to develop decision making system.

7.0 CHALLENGES AND ISSUES IN AGENTIC AI IN PHARMACEUTICAL INDUSTRY

Artificial Intelligence (AI) is swiftly transforming the pharmaceutical industry from drug detection, clinical trials and to supply chain management with quite agreement in the most of the industries. In recent trends, AI activity of autonomous systems is capable of planning, reasoning and executing multi phenomenal tasks without the human adherence. It is the initial process to restructure pharmaceutical work flow at a deeper level. While the generating the potential for the AI integration is massive structure to bring these technologies together raises a complex issues and challenges that the industry must carefully directed as discusses in the following sections (please also refer Fig-5)

7.1 Data Quality, Integration, and Governance

One of the most fundamental challenges established in pharmaceutical industry with using the AI interface is the quality and accessibility of the data. Drug development engenders diverse datasets regarding the genomics, proteomics, electronic health records (EHRs), clinical trial results, and real-world suggestions obtained related to the developed drugs. Datasets that are obtained across different organizations, systems, and formats are to be assessed cautiously. AI models require massive data that is reliable only on the trained data, rather the inconsistent or incomplete datasets can result in the defective predictions and potentially dangerous outcomes. Agentic AI can handle the respective related challenges more significantly. Because agentic systems unconventionally retrieve, synthesize and perform based on the data across from

multiple sources [26], [45], [48]. A single corrupted or outdated data in the pipeline of the system can cascade into a series of inaccurate decisions central to in capability to catch the errors in real time. Establishing the robust data frameworks, standardized customization and interoperability protocols (such as FHIR and CDISC standards) becomes critically important in incorporation of AI across the pharma industries.

7.2 Regulatory Compliance and Validation

The pharmaceutical sector is the most profoundly regulated industries in the world. Regulatory bodies such as FDA, EMA, and CDSCO superintend the quality in the drug development or tools used for the patient care must be thoroughly validated and traceable. Traditional software validation backgrounds were not designed in AI algorithms to handle it to the agentic AI. AI models are characteristically probabilistic and can be result in outputs that can be swiftly learnt or retrained. Agentic AI can indulge even more complex regulatory problems that an autonomous agent generates a decision that can influence clinical trial strategy, dosage recommendation and regulatory submissions which determining the accountability of the drugs. The lack of clear regulatory guidelines for AI-driven pharmaceutical processes creates a definite uncertainty and decelerates the adoption of AI systems.

7.3 Explainability and Transparency

Deep learning models are the pillar support for most of the pharmaceutical AI applications that are disreputably difficult to understand. In pharma industry, every decision must be scientifically justified and should be reproducible. The inability to explain a model prediction for a certain drug target interaction or recognition on a patient can lead to high risks and obstacles. For agentic AI, the decisions of machine learning models have more critical challenges. Agentic systems repeatedly execute long chains of reasoning and actions to trace the logical path that results to a specific outcome which is technically challenging and may not always be feasible. This in flexibility destabilizes the trust of doctors, regulators and patients those require a clear validation for critical medical pronouncements [39], [49].

7.4 Ethical and Bias-Related Concerns

AI systems trained on the past pharmaceutical data available on the pre conceptions from the drug users. Clinical trials have factually understated the women, aged patients and minority ethnic groups. The AI models built on this uncertain data may generate predictions that are less accurate or even harmful for these inhabitants. Agentic AI operating autonomously in drug adapting system, patient enrolment or suggesting the personalized medicine could unintentionally perpetuate or amplify the disparities at large scale, where the human oversight can detect these differences. Ensuring algorithmic impartiality, fairness, and insertion is the main moral obligation and a growing regulatory requirement that the industry is to address methodically.

7.5 Cybersecurity and Intellectual Property Risks

Pharmaceutical companies capitalize higher investments in R&D development including trademarked composite libraries, experimental results and formulation patents that represents enormous competitive and monetary value. The disposition of AI and agentic systems is that progress, access and transmit sensitive data across cloud platforms. External APIs intensely enlarges the cybersecurity attack surfaces. Agentic AI systems have designed to higher access permissions and autonomous action capabilities in making them high value targets for argumentative attacks, data poisoning and prompt injection that's pitefully instructs the manipulate agent behavior [34], [51]. A compromised agentic system can outflow the trade secrets, alter experimental data and disrupt manufacturing processes with wide ranging consequences.

7.6 Workforce Disruption and Change Management

AI adoption in pharmaceutical management is redesigning the job roles across the drug research, clinical processes, regulatory activities and supply chains. While AI enhances the productivity and it also transfers the routine reasoning tasks which creates the apprehension among the workforce. Agentic AI is also capable of independently managing the workflows such as literature reviews, contrary event monitoring and vendor communications that accelerates the interruption. Pharmaceutical organizations must show attention in capitalizing the re-skilling programs and to cultivate AI literacy among employees that reshape workflows. The position human interference is seen as a strategic supervisor rather than the task organizers. Resistance to change particularly the extremely credentialed and process activity cultures should remain a significant organizational blockade.

7.7 Clinical Trial Design and Patient Safety

AI is progressively used to increase the clinical trial design, identifying the patient allies and the coincidental in forecasting the adverse effects. However, agentic AI systems autonomously regulating trial limitations or patient stratification approaches to introduce substantial patient safety risks [52], [60]. A misclassified patient allies if not carefully controlled or an autonomously revised endpoint could nullify a trial or led to worsen or expose the participants to impairment. Robust interface of human in the loop system (HITL) mechanism clearly defines the agent action the boundaries and safe condition protocols that are essential, but technically and structurally difficult to implement at a scale. Overall, the integration of AI and agentic AI hold a transformative potential for the pharmaceutical industry in accelerating the drug discovery, improving the clinical outcomes, and enhancing the operational efficiency of the drug industries. However, the challenges related to the data governance, regulatory uncertainty, explainability, ethical prejudice, cybersecurity, workforce enthusiasm and patient safety are significant and interconnected. Successful implementation of these technologies requires not only technical innovation but also strong policy outlines, different sectors collaboration and a profoundly ethical approach to autonomous decision making in one of the world's most significant industries [57], [58].

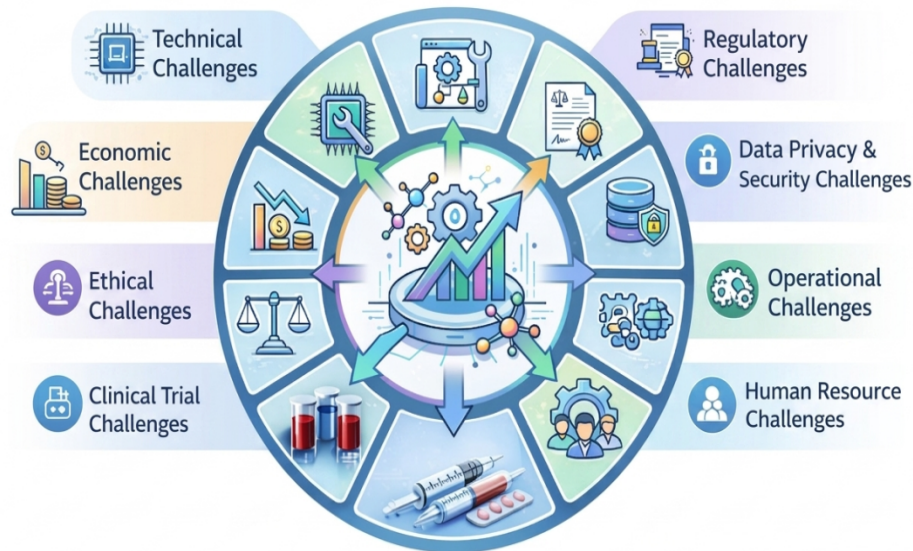


Figure: 5 Some challenges and issues Agentic AI in pharmaceutical industry.

8.0 FUTURE ROADMAP AND POTENTIALITY OF AGENTIC AI IN PHARMACEUTICAL INDUSTRY

Compared to traditional forms of AI, which perform very limited tasks as they were previously designed, agentic AI offers many benefits, including adaptive reasoning and autonomous operation. These characteristics make it uniquely suited to support and operate within highly dynamic and complex industries, such as the pharmaceutical industry [1]. The future roadmap for pharmaceutical sector applications of agent-based AI begins with the use of agent-based AI across all stages of the drug life cycle, from drug discovery through post-market surveillance. A promising application area is drug discovery and development. Drug discovery and development is traditionally a long and expensive process that takes longer than 10 years. The time required to perform drug discovery and development can be considerably reduced using agent-based systems. Such agent-based systems can quickly analyze large amounts of data, identify possible drug candidates, and predict how well they may function. Agent-based systems can also simulate how biological components interact, optimize chemical structures, and provide suggestions on how to create new compounds with a high probability of success.

Clinical Trials are another significant area of benefit for agentic AI systems. The processes of conducting clinical trials have been plagued with problems, including recruiting patients, managing large amounts of data, and monitoring trials. Agentic AI systems can utilize wearable technology and electronic health records (EHRs) to continuously monitor a patient's health because of their ability to review patient medical histories, select appropriate subjects, and promote diversity among participants in clinical trials. Early detection of potential

side effects and improved patient safety occur when continuous monitoring is used. As this field evolves, it is expected that many clinical trials will be conducted in a decentralized manner via virtual platforms utilizing agentic AI systems, which will allow clinical trials to be conducted in an efficient and cost-effective manner [55], [62]. The potential of agentic AI is significant in the manufacture and quality inspection of drugs. The manufacturing of drug products requires a high level of accuracy and specific quality requirements. Using agentic AI in a production process allows for the monitoring of each production step in real-time, recognition of abnormalities, and automatic changes to ensure consistency in final product quality and reduce waste. Additionally, predictive maintenance, using agentic A.I., can detect impending mechanical failure prior to its occurrence, thereby reducing or eliminating lost production due to mechanical downtime and increasing overall plant efficiency. Future plans include the creation of fully automated smartfactories that utilize A.I. agents to oversee all aspects of production, including quality control and procurement.

The use of agent AI in supply chains and inventory management has many potential advantages. A pharmaceutical supply chain is a very complex system that requires careful planning to maintain medicine availability. An agent-based (agentic) AI may forecast drug demand, determine the optimal quantity of items that should be held in inventory, and facilitate the most efficient flow through the distribution network. In addition, an agentic AI may be able to quickly respond to disruptions (such as a pandemic or disaster) by adapting the supply strategy on the fly. Therefore, AI-driven supply chains will be better able to withstand disruption, have

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greater transparency, and be far more efficient than current systems for delivering drugs to patients.

Another important use of agentic AI is personalized healthcare or medicine. By analyzing an individual's medical history and genetic makeup, as well as their personal health habits (i.e., diet and exercise), agentic AI can provide individualized recommendations on how to best treat a specific condition. Thus, there will be less harm from treatments with personalized medicine using AI [16], [29]. In addition, through personalized medicine, AI could help doctors choose the most effective medications and appropriate doses for each patient. Personalized medicine with AI support will become common place, which should lead to improved healthcare. Pharmacovigilance and drug safety monitoring, which are important functions for the post-market surveillance of drugs, could be expanded by the capacity of agentic AI. There are many ways that AI systems can monitor the safety of drugs once they have been approved and placed on the market. Data from patients, social media, and various other data sources, such as electronic medical records, can be used to determine whether there has been an adverse reaction to a particular drug. Additionally, once an adverse drug reaction is identified by an agentic AI system, it can alert healthcare professionals in a timely manner and assist with regulatory decisions about drugs. As a result of advancements in technology and increased use of agentic AI in this field, public health will benefit from improved drug safety [6], [39]. Although agentic AI has many advantages, there are several hurdles for its development and use in the pharmaceutical industry. One of the most significant hurdles is protecting patient privacy with respect to personal health care-related data (in addition to other types of sensitive data). Ensuring the secure collection, transmission, and storage of this type of data, as well as ensuring regulatory compliance, will likely require considerable investment. A second hurdle is the need to address several ethical issues related to the use of AI in drug development, such as transparency regarding how the AI system made its recommendations or decisions; responsibility (accountability) if the AI system recommends or suggests an incorrect treatment option; and fairness/bias in making those recommendations. Compliance with regulations is also important. Pharmaceuticals are very heavily regulated; as such, it is imperative that all uses of artificial intelligence (AI) comply with those regulatory requirements [53], [65]. For regulatory authorities, there is a need to develop standards by which they can evaluate and approve the use of artificial intelligence-based systems. Similarly, there is a great need for trained professionals (s) who are capable of developing, managing, and maintaining agentic AI systems. Education/training is essential for the successful integration of this technology into our daily lives. The future roadmap for agential intelligence also involves developing cooperative multiple agent systems in which multiple AI agents collaborate to achieve a variety of complex goals. In addition, integration with emerging technologies, including Internet of Things (IoT) technology, blockchain, and cloud computing, will further

develop its capacity. For example, IoT devices are capable of providing real-time data, and blockchain is capable of ensuring that the data has been secured and transparently recorded.

9.0 CONCLUDING REMARKS

The pharmaceutical industry is rapidly changing because of the integration of artificial intelligence. In the last few years, an enhanced version of artificial intelligence, referred to as "agentic" AI, has developed into one of the most effective methods for enhancing decision making and automation in the pharmaceutical industry. The term 'agentic' describes intelligent systems that are able to operate independently, provide their own solutions based on available data, and interact or cooperate with each other to reach established objectives. Operational practice is one of the challenges for the pharmaceutical industry. For the implementation of the whole system, it is necessary to invest high cost. The maintenance of the system also involves a higher level of cost. It is necessary to create a stable infrastructure for the operation of the whole system. It is necessary to ensure high development cost that creates an economic burden for the organization. It is also tough to adapt to market conditions. It is necessary to invest in technological and infrastructure up gradation. Licensing and software costs also create a financial burden for the organization. Pharmaceutical companies invest a very low amount of cost in AI-based projects. The system is very difficult to scale up and maintain under competitive pressure. It is also challenging to get efficient human resources for the operation of the system. It is very tough to find proper AI-skilled professionals. There is a shortage of properly skilled persons from interdisciplinary fields. It finds a lack of awareness about Agentic AI among people. It is difficult to up-skill employees to adopt the system. There is also a skill mismatch among employees. It lacks expert knowledge in the system among those who understand both Agentic AI-based systems and the pharmaceutical system. It is very challenging to create highly complex biological systems. It is found that there is very limited availability of high-quality biological data, which may generate inadequate performance. It is very challenging to test the results in real-time scenarios. It creates a major issue in implementing theoretical data in practical scenarios. It is very difficult to identify targets. It is necessary to test the Agentic AI-generated results in real-time cases. So, it generates a higher failure rate. Clinical trial issues also create a big concern for the system. It may have biased clinical data. Agentic AI-generated results may fail in real-time clinical testing. There is a lack of transparency in real data and trial decisions. There is no regulatory authority that ensures the reliability of the whole system. Ethical challenges are very difficult for system design. There may be a lack of transparency in the dataset. The dataset may be biased, so the results and decision-making may be wrong. With a wrong dataset, it produces incorrect automatic decisions. It is very difficult to establish human-AI collaboration. It is possible to misuse artificial intelligence and Agentic AI technologies.

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