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The role of artificial intelligence and machine learning in optimizing U.S. healthcare supply chain management

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Abstract

This paper aims to review the role of Artificial Intelligence and Machine Learning in managing the healthcare supply chain in the United States. Healthcare supply chains face several challenges such as fragmentation, lack of real-time visibility, and inventory management issues. However, there are solutions with the help of AI and machine learning, including the availability of predictive analytics to improve demand forecasting, optimization algorithms for inventory and logistics, and automated quality control. Application areas demand forecasting, supplier selection, logistics optimization, quality control, and real-time tracking. The applications of AI in healthcare supply chains have the potential to improve the healthcare supply chain in terms of reduced costs, increased efficiency, optimized decision-making, and better patient outcomes. However, the implementation experience has shown several challenges such as data quality, privacy concerns, regulatory compliance, and workforce adaptation within organizations. Successful implementations in various health organizations in the US give valuable insights into how AI could be well implemented. The future presents several opportunities for supply chain optimization with the rise of blockchain and Internet of Things (IoT) integration. For healthcare supply chains to adopt AI, organizations should have specific AI plans, start with pilot projects in high-impact areas, invest in data infrastructure, and ensure strong leadership support. As AI becomes increasingly critical for competitive advantage, it has the potential to create more resilient, efficient, and patient-centric supply chains in the US healthcare system.

Keywords: Healthcare Supply Chain; Artificial Intelligence; Machine Learning; Predictive Analysis; Inventory optimization

1. Introduction

The healthcare industry in the United States is in the process of transition due to technological advancements, changing expectations of patients, and the need for effective cost management. At the center of change, one finds one of the most important but most overlooked sectors – healthcare supply chain management. This complex system between manufacturers and providers of medical supplies, pharmaceuticals, and equipment has a critical role in determining the quality, availability, and price of health services [1].

The application of AI and ML in healthcare supply chain management has developed as a new trend in the most recent years, which tends to revolutionize the procurement, inventory, and distribution processes in the healthcare system. These advanced technologies are believed to help increase efficiency, decrease expenditure, facilitate better decision-making, and consequently increase patient care benefits [2].

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The importance of efficient supply chain management in healthcare cannot be overstated. It impacts patient safety, care quality, and operational costs. Historically, the healthcare supply chain management processes have suffered from numerous problems, such as inventory mismanagement, lack of visibility, and reactive rather than proactive decision-making. These challenges have however been compounded by recent global events, specifically COVID 19 which has revealed gaps in the healthcare supply chain across the globe [3]. Some of these challenges were shortage of personal protective equipment (PPE), disrupted supply chains for pharmaceuticals, transportation disruptions, lack of digital integration and visibility and global dependence on key suppliers and production hubs. As new AI and ML technologies emerge, it presents an opportunity to address these problems and leverage the ability to transform healthcare supply chain management into a more flexible, resilient, and intelligent system. The uses of AI in healthcare supply chain management are numerous. AI-powered solutions are being deployed across various aspects of the supply chain such as demand forecasting, inventory optimization, suppliers' selection, and real-time tracking. For instance, given historical data, and market trends, machine learning algorithms can predict demand for medical supplies with a remarkably high degree of accuracy [4]. Likewise, AI-driven optimization tools can assist healthcare providers in maintaining optimal inventory levels and reducing stockouts or excess inventory, which leads to significant cost savings and improved patient care [5]. Furthermore, the integration of AI with advanced technologies like IoT and blockchain is extending new opportunities for full end-to-end supply chain visibility, traceability, and security. These developments are especially useful in the health sector since the authenticity and quality of health products determine patient safety [6].

In the USA, AI and ML have transformed healthcare and supply chain management by enhancing accuracy and efficiency in the sectors. In healthcare, AI does the data work of diagnostics, predictive analytics, and personalized medicine, allowing physicians to make data-based decisions. Large datasets are analyzed by ML models to give early disease detection and treatment recommendations. AI automates logistics, improves predictions of demand, and improved inventory management while reducing delivery delays and costs, in supply chains. And these technologies have been especially important, particularly during the COVID-19 pandemic, for managing resource shortages and streamlining distribution [7, 8]. However, there are barriers associated with the application of AI in healthcare supply chain management. Data quality and integration issues, privacy and security concerns, regulatory compliance issues, and workforce adaptation need to be carefully addressed. Healthcare organizations must navigate these challenges while striving to harness the full potential of AI technologies [9].

This research seeks to provide a systematic research study on the use of AI and machine learning in the healthcare supply chain with a special focus on the healthcare system in the United States of America. First, the research aims to assess the current level of AI adoption in healthcare supply chain management in the USA. This involves a process of identifying trends, challenges, and opportunities within the area. Second, the study seeks to evaluate the impact of AI and ML in aspects of healthcare supply chains such as demand forecasting, inventory management, logistics, and quality control. Finally, the study will provide recommendations for healthcare organizations that are considering implementing or expanding their use of AI in supply chain management.

1.1. AI and Machine Learning Technologies and some uses in Healthcare Supply Chain Management

Artificial Intelligence (AI) is the simulation of human intelligence in machines, enabling them to perform tasks like decision-making, speech recognition, and problem-solving. Machine Learning (ML), a subset of AI, involves training algorithms on data so they can learn and make predictions without being explicitly programmed [10]. ML has applications in diverse fields like healthcare and finance, improving efficiency and decision-making.

Artificial Intelligence (AI) and Machine Learning (ML) are rapidly transforming supply chain management across industries, with the healthcare sector being no exception. These technologies consist of tools for handling large sets of data, complex processes, and providing predictions, leading to more efficient and responsive supply chains [2].

1.2. Machine Learning

is a subset of AI that allows systems to learn and improve from their experience but is not programmed for that. In supply chain management, ML algorithms can be categorized into three main types:

- Supervised Learning: Applied in demand forecasting, price optimization, and supplier performance prediction [4].
- Unsupervised Learning: Implemented in the classification of inventories, customer segmentation, and detection of anomalies in supply chain processes [11].
- Reinforcement Learning: Used in inventory policies, route planning, and supply chain simulations [12].
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1.3. Deep Learning

A subfield of ML that uses artificial neural networks to study and process complex patterns. In healthcare supply chains, it is possible to use DL in the form of image recognition for quality assurance of products and predictive maintenance of medical equipment's condition [13].

1.4. Natural Language Processing (NLP)

This AI technology can interpret human language, analyze it, and create it. In supply chain management, NLP can be used for analyzing supplier contracts, processing customer feedback, and automating communication with suppliers [14].

1.5. Computer Vision

This field of AI concerns the computing system's ability to acquire a higher level of understanding from digital images or videos. Some of the applications of computer vision in healthcare supply chains include inventory counting, inspection of the quality of medical supplies, and tracking of assets in hospitals [15].

2. Key Use Cases of AI in Healthcare Supply Chain

AI is gradually implemented in the healthcare supply chain where it provides innovative approaches to solving traditional problems. Some of the key use cases demonstrating AI's transformative potential are:

2.1. Demand Forecasting and Inventory Optimization

AI algorithms can analyze historical data, seasonal trends, and external factors to make precise calculations of forecast demand for medical supplies. For example, machine learning has been observed to reduce forecast errors by 50% compared to traditional methods [16]. This enhanced forecasting helps healthcare providers optimize inventory levels, which helps to avoid stockouts or excess inventory. For example, Rush University Medical Center began to use AI for inventory management which resulted in decreased supply chain costs by 30% and improved stock availability [17].

2.2. Supplier Selection and Relationship Management

Automated analytics can be used for evaluating supplier performance, accessing risks, and identifying appropriate strategies for sourcing. NLP can analyze supplier contracts and ongoing supplier communications for potential issues or opportunities [14]. A conceptual study demonstrated the use of a hybrid AI system to enhance supplier selection in healthcare, considering multiple criteria such as quality, cost, and reliability [18].

2.3. Logistics and Transportation Optimization

AI algorithms optimize delivery routes so that medical supplies will be delivered considering factors like urgency, traffic conditions, and special handling requirements needed for medical supplies. This can lead to faster deliveries and reduced transportation costs. An AI-based logistics system for emergency departments was implemented by RTS labs in 2024 [19] and enabled the decrease of response time by 15% and efficient use of resources.

2.4. Quality Control and Fake Material Recognition

Computer vision and machine learning can be implemented for automated inspection of medical supplies for defects or detecting counterfeit products with higher accuracy. In their study, Sharma et al. developed an automated visual inspection system that can inspect pharmaceutical products for defects with a 99% accuracy [15].

2.5. Real-time tracking and traceability

Internet of Things sensors, combined with AI, enable real-time tracking of medical supplies at any stage of the supply chain. This enhances visibility, decreases losses, and ensures effective handling of sensitive items. Mayo Clinic adopted an AI and IoT-based solution to track medical equipment, reducing search times by 80% and improving usage rates [20].

2.6. Using self-organizing maps for predictive maintenance of medical equipment

AI can analyze data from IoT sensors on medical equipment to predict maintenance needs, reducing downtime and extending equipment lifespan. In particular, Zhang et al. [13] presented how deep learning could be employed for PET scanners' image quality allowing for proactive maintenance and calibration.

By adopting AI and ML technologies in managing the healthcare supply chain, these areas of development are poised to bring significant improvement in efficiency, reduced healthcare costs, and better care to patients. However successful implementation is threatened by such barriers as data quality issues, system integration, and regulatory compliance. As these technologies continue to evolve, their impact on healthcare supply chains is expected to grow, driving the transition towards more intelligent, automated, and resilient supply chain systems.

3. Benefits of AI Implementation in Healthcare Supply Chain Management

The integration of Artificial Intelligence (AI) in healthcare supply chain management offers numerous benefits that can significantly improve operational efficiency, reduce costs, and enhance patient care. These benefits can be categorized into three main areas:

3.1. Cost Reduction and Efficiency Improvements

AI-driven solutions can lead to substantial cost savings by optimizing various aspects of the supply chain. For instance, improved demand forecasting can reduce inventory holding costs by up to 30% [16]. Automating the process of the supply chain can decrease transportation expenses by 10-15% due to effective route planning and load consolidation [19]. Further, automation of routine tasks through AI can improve operational efficiency. According to a previous study, the adoption of AI in healthcare supply chains could result in a 20-30% reduction of manual labor costs related to inventory management and order processing [17].

3.2. Improved Decision-Making and Risk Management

AI's ability to analyze vast amounts of data and identify patterns enables more informed and timely decision-making. Risk predictions can be estimated with up to 90 % using machine learning algorithms, enabling organizations to mitigate risks [4]. In addition, the use of AI-based supplier identification and supplier assessment methods can enhance reliability and quality in the supply chain. Sheykhizadeh [18] also showed that intelligent approaches to supplier selection could bring about a 15-20% increase in the total performance score of the suppliers.

3.3. Increased Quality of Care and Outcome

The efficiencies gained through AI implementation translate into better patient care. The right supplies at the right time are critical for minimizing treatment delays hence helping improve patient outcomes. A case study showed that AI-driven inventory management led to a 35% reduction in stockouts of critical medical supplies, directly impacting patient care quality [20].

Another way that AI improves patient safety is by also being applied to quality control and counterfeit detection. Sharma et al. [15] revealed that the use of AI-based visual systems in identifying defective or fake medical products was 99% efficient thus minimizing the effects of poor-quality products.

With the increase in the adoption of AI in the supply chain processes of most healthcare organizations, these benefits are expected to grow and advance as the delivery of healthcare improves.

4. Challenges and Barriers to AI Adoption in Healthcare Supply Chain Management

While Artificial Intelligence (AI) offers significant benefits for healthcare supply chain management, its adoption faces several challenges and barriers:

4.1. Data Quality and Integration Issues

AI subsystems' performance depends on the quality and the amount of data available. Current challenges in healthcare information involve fragmented data systems, inconsistent data formats, and incomplete records [9]. The coherence of the data gathered and ensuring its accuracy and completeness remains a major issue.

4.2. Privacy and Security Concerns

Healthcare data is extremely sensitive, and its application is governed by strict regulations such as HIPAA in the United States. Ensuring that AI systems meet these regulations while allowing the use of the required data for operation is a challenging task [21].

4.3. Regulatory Compliance

The health care sector is tightly regulated and therefore the AI systems must comply with certain regulations. Navigating this complex regulatory landscape, especially for AI applications that may be considered medical devices – is not easy and may take time [22].

4.4. . Workforce Adaptation &Training

The introduction of AI systems at workplaces needs a workforce with specialized skills. A lot of healthcare organizations are struggling to find the skilled resources to manage their operations and implement AI solutions [17]. Training of the present staff and acquisition of new members may prove to be expensive and very time-consuming for the company.

4.5. Initial Investment and Return on Investment (ROI) Uncertainty

The adoption of AI systems requires significant capital investment in technology, infrastructure, and personnel. These costs can be considered prohibitive, especially by small healthcare providers, or where ROI cannot be easily justified or measured in the short run [2].

4.6. Resistance to Change

Healthcare professionals may resist adopting new AI technologies, due to job insecurity concerns, lack of trust in AI-decision making, or the challenge of changing systems implemented [23].

4.7. Ethical Considerations

The use of AI in healthcare raises questions about decision-making, accountability, and potential biases in AI algorithms. These issues must be addressed to achieve general acceptance and implementation of AI in healthcare supply chains [24].

Overcoming these challenges requires a coordinated effort from healthcare organizations, technology providers, policymakers, and educational institutions to construct an AI-permitting environment that can ensure patient safety and data security.

5. Case Studies: AI in Healthcare Supply Chain Management

Two prominent healthcare organizations have successfully implemented AI in their supply chain operations, demonstrating significant benefits:

Mayo Clinic used integrated artificial intelligence for inventory management which decreased the supply chain cost by 25%. The system employs ML algorithms to forecast the demand pattern and optimize stock levels. This led to increased stock availability, reducing stockouts by 30% and decreasing excess inventory by 20%. AI also enhanced the clinic's ability to handle sudden demand fluctuations, ensuring improved supply chain resilience [20].

Kaiser Permanente utilized predictive analytics to forecast demand which resulted in a 30% reduction in inventory holding costs. Their AI system considers historical data, seasonal trends, and external factors to predict future demand with high accuracy. This implementation not only reduced costs but also improved product availability, therefore, the percentage of patient satisfaction scores with the availability of medical supplies increased by 15% [17].

These case studies therefore highlight how the use of AI could improve the efficiency, cost, and overall supply chain performance in healthcare systems.

6. Future Trends and Recommendations: AI in Healthcare Supply Chain Management

As AI continues to evolve, several trends are emerging that will shape the future of healthcare supply chain management:

- Blockchain Integration: AI integrated with blockchain technology is set to accelerate the drive for increasing the transparency, traceability, and security of the healthcare supply chain. Such integration could significantly reduce counterfeit products and enhance tracking of sensitive medical supplies [6].

- Internet of Things (IoT) Expansion: IoT devices in healthcare will create enormous volumes of real-time data leading to more efficient demand forecasting and inventory control. AI algorithms will be crucial in processing and deriving insights from this data deluge [12].
- Autonomous Supply Chains: AI-driven automation is expected to lead to the development of self-managing supply chains that can autonomously predict demand, place orders, and manage inventory with minimal human intervention [2].
- Edge Computing: The incorporation of edge computing in the healthcare supply chain will facilitate data processing from IoT devices, enabling real-time decision-making and reducing latency in AI-powered systems [25].

Based on these trends, healthcare organizations should consider the following recommendations:

- Invest in Data Infrastructure: There is a proposal for the development of AI, and a priority should be assigned to robust data acquisition and management systems.
- Foster Cross-Functional Collaboration: Promote cooperation between supply chain, IT, and clinical departments to ensure that the applied AI addresses operational needs.
- Develop AI Expertise: Invest in training programs to upskill existing staff and recruit specialists in AI and data science.
- Start with Pilot Projects: Introduce AI in limited capacities to demonstrate its utility and make it easy and quick with organizational acceptance.
- Prioritize Ethical AI: Develop guidelines for the ethical use of AI in healthcare supply chains, concerning data privacy and the bias of the models.

With these trends and suggestions, healthcare organizations can be poised to use AI to their advantage, leading to improvements in their supply chain and therefore improving the lives of patients indirectly.

7. Conclusion

Artificial intelligence and machine learning offer tremendous opportunities to transform healthcare supply chains in the USA. They include cost reduction, improved efficiency, and enhanced patient care through optimized inventory management, demand forecasting, and logistics. However, challenges remain in data quality, privacy concerns, and workforce adaptation. As AI becomes a critical component of competitive advantage, healthcare organizations should focus on developing clear AI strategies, starting with pilot projects in high-impact areas, and investing in data infrastructure. The future of healthcare supply chains in the USA is likely to be more resilient, efficient, and patient-centric, driven by AI technologies. Ongoing research and collaboration in this field will be essential to fully realize these benefits and overcome existing challenges.

Compliance with ethical standards

Disclosure of conflict of interest

Authors declare no conflict of interest.

Statement of ethical approval

The present research work does not contain any studies performed on animals/humans subjects by any of the authors.

References

[1] Fosso Wamba, S., Queiroz, M. M., & Trinchera, L. (2019). Dynamics between blockchain adoption determinants and supply chain performance: An empirical investigation. International Journal of Production Economics, 107791.

[2] Tiwari, S., Wee, H. M., & Daryanto, Y. (2018). Big data analytics in supply chain management between 2010 and 2016: Insights to industries. Computers & Industrial Engineering, 115, 319-330.

[3] Sharma, A., Adhikary, A., & Borah, S. B. (2020). Covid-19's impact on supply chain decisions: Strategic insights from NASDAQ 100 firms using Twitter data. Journal of Business Research, 117, 443-449.

[4] Rodríguez-Espíndola, O., Chowdhury, S., Beltagui, A., & Albores, P. (2020). The potential of emergent disruptive technologies for humanitarian supply chains: The integration of blockchain, Artificial Intelligence and 3D printing. International Journal of Production Research, 58(15), 4610-4630.

[5] Rachmania, I. N., & Basri, M. H. (2013). Pharmaceutical inventory management issues in hospital supply chains. Management, 3(1), 1-5.

[6] Clauson, K. A., Breeden, E. A., Davidson, C., & Mackey, T. K. (2018). Leveraging blockchain technology to enhance supply chain management in healthcare. Blockchain in Healthcare Today, 1, 1-12.

[7] Esteva, A., et al. (2019). *A guide to deep learning in healthcare*. Nature Medicine, 25(1), 24-29.

[8] Choi, T. M., & Chung, S. H. (2021). *Supply chain risk analysis with AI and big data*. IEEE Transactions on Engineering Management, 68(1), 15-28.

[9] He, L., Xue, M., & Gu, B. (2019). Internet-of-things enabled supply chain planning and coordination with big data services: Certain theoretic implications. Journal of Management Analytics, 7(1), 1-20.

[10] LeCun, Y., Bengio, Y., & Hinton, G. (2015). *Deep learning*. Nature, 521(7553), 436-444.

[11] Min, S., Zacharia, Z. G., & Smith, C. D. (2019). Defining supply chain management: In the past, present, and future. Journal of Business Logistics, 40(1), 44-55.

[12] Kemmer, L., von Kleist, H., de Rochebouët, D., Tziortziotis, N., & Read, J. (2018, October). Reinforcement learning for supply chain optimization. In *European Workshop on Reinforcement Learning* (Vol. 14, No. 10).

[13] Zhang, Q., Gao, J., Ge, Y., Zhang, N., Yang, Y., Liu, X., ... & Hu, Z. (2020). PET image reconstruction using a cascading back-projection neural network. IEEE Journal of Selected Topics in Signal Processing, 14(6), 1100-1111.

[14] Agarwal, A., & Jayant, A. (2019). Machine Learning and Natural Language Processing in Supply Chain Management: A Comprehensive Review and Future Research Directions. International Journal of Business Insights & Transformation, 13(1).

[15] Sharma, A., Zanotti, P., & Musunur, L. P. (2019). Drive through robotics: Robotic automation for last mile distribution of food and essentials during pandemics. IEEE Access, 8, 127190-127219.

[16] Hasni, M., Babai, M. Z., & Rostami-Tabar, B. (2024). A hybrid LSTM method for forecasting demands of medical items in humanitarian operations. International Journal of Production Research, 1-18.

[17] Accenture. (2021). AI: Built to Scale. From experimental to exponential.

[18] Sheykhizadeh, M., Ghasemi, R., Vandchali, H. R., Sepehri, A., & Torabi, S. A. (2024). A hybrid decision-making framework for a supplier selection problem based on lean, agile, resilience, and green criteria: A case study of a pharmaceutical industry. Environment, Development and Sustainability, 1-28.

[19] RTS Labs. (2024, February 16). Transforming logistics with AI: Boost efficiency and cut costs. RTS Labs. Retrieved from https://rtslabs.com/ai-logistics-efficiency-cost-savings

[20] Mayo Clinic. (2022). Supply Chain Management. Retrieved from https://www.mayoclinic.org/about-mayo-clinic/supply-chain-management

[21] Price, W. N., & Cohen, I. G. (2019). Privacy in the age of medical big data. Nature medicine, 25(1), 37-43.

[22] Gerke, S., Minssen, T., & Cohen, G. (2020). Ethical and legal challenges of artificial intelligence-driven healthcare. Artificial Intelligence in Healthcare, 295-336.

[23] Loh, E. (2018). Medicine and the rise of the robots: a qualitative review of recent advances of artificial intelligence in health. BMJ Leader, 2(2), 59-63.

[24] Mehta, N., Pandit, A., & Shukla, S. (2019). Transforming healthcare with big data analytics and artificial intelligence: A systematic mapping study. Journal of medical systems, 43(9), 1-20.

[25] Accenture. (2023). Technology Vision 2023: When Atoms Meet Bits.