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Resolving Perioperative Inventory Patient Billing challenges using AI and deep learning

Kiran Veernapu

kiran_veernapu@yahoo.com

Abstract

Medical supplies and equipment needed during a surgical procedure in operating rooms are referred to as perioperative inventory. These medical supplies are highly specialized, sterile, and swiftly available for a surgical need. Perioperative inventory is typically maintained at higher stock levels to avoid delays and interruptions to the scheduled surgeries. Surgeons and nursing staff use perioperative inventory cards known as preference cards to identify the item needed during the surgery. While usage of the preference card system in the operating room has been great practice, there are challenges in using this approach. The surgeries need a lot of small to large items, healthcare organizations are partnering with suppliers to bring the items needed for the surgeries. Nurses record the usage of the items. This process results into errors, leading to several mistakes in the patient invoice.

Effective management of perioperative inventory is essential for maintaining operational efficiency, minimizing costs, and ensuring patient safety in healthcare institutions. Perioperative inventory refers to the stock of medical supplies, medications, surgical instruments, and other essential items required before, during, and after a surgical procedure [1]. The complexity of inventory management in the perioperative setting is heightened by factors such as fluctuating demand, uncertainty in surgical schedules, and the critical need for accuracy and timeliness in maintaining inventory levels. This paper explores the application of deep learning algorithms in managing perioperative inventory, highlighting their potential to optimize stock levels, reduce waste, improve patient care, and enhance the overall operational workflow. Key algorithms, such as convolutional neural networks (CNNs), recurrent neural networks (RNNs), and reinforcement learning (RL), are discussed, along with their role in predicting demand, automating replenishment, and making intelligent inventory decisions.

Keywords: Peri-Operative Inventory, Inventory Issues, AI, Deep Learning, Healthcare, Supply Chain, Inventory Management.

Introduction

In modern healthcare settings, managing perioperative inventory effectively is crucial for the smooth functioning of surgical operations. Surgical procedures rely on an extensive array of supplies that must be available on time, in adequate quantities, and at the right quality. Challenges such as fluctuating surgical volumes, unexpected changes in patient conditions, and difficulties in forecasting demand make inventory management a complex task [2]. Moreover, stockouts or overstocking can lead to wasted resources, increased costs, and delays in patient care.

Traditionally, perioperative inventory management has been conducted manually or with basic automated systems. However, with the advent of deep learning (DL) and artificial intelligence (AI), the landscape is shifting toward more intelligent, data-driven solutions that can predict, optimize, and automate inventory processes [3]. This paper discusses the potential of deep learning algorithms to revolutionize perioperative inventory management, offering more accurate predictions and insights into inventory needs.

Current Challenges in Perioperative Inventory

Operating room costs are critical financial centers for hospital systems, with surgical care accounting for a third of the healthcare spending. Not all those costs are necessary or appropriate, as they can be significantly inefficiently managed [4]. There is a necessity to do a deep dive to understand the components involved in managing the inventory and the cost of care with surgeries. Below are a few of those:

- **Inventory items needed for surgeries or surgical procedures:** Healthcare inventory management systems track the items needed for a scheduled procedure, and not all items are labeled and managed by the system.
- **Usage Inventory Items used in the surgery:** Recent innovations created opportunities for new models of handling the inventory of operating rooms. It is becoming critical to label identify and track minute items that are required for the surgery. For example, an orthopedic surgeon may need several steel plates, rods, and screws for surgery. It is difficult to inventorize and track small items. Someone needs to keep track of the items used for the surgery. As this is a manual process there are chances for error.
- **Reported inventory:** A surgical assistant would keep track of all the items used for the surgery, they need to update the patient records for billing purposes. They may not be able to keep track of all the items as some of them may not be barcoded or labeled as they are too small. There are errors in the patient record with mismatches for additional items and missed items. This can lead to the wrong patient invoice.
- **Partnership with product manufacturers:** The surgical product manufacturers are fully aware of the medical equipment or items needed for every named surgery. These manufacturers have signed contracts with healthcare facilities. Instead of healthcare facilities managing the surgical inventory the manufacturer's representative would bring the needed items and assist with the procedure to provide the items needed.
- **Gaps in the model:**The manufacturer representative prepares and sends the invoice to the healthcare providers;the healthcare provider would invoice the customer. There are errors in the overall process, the errors can be in the manual invoice maintained by manufacturers or the nurse who keys in the item codes of all items used in the procedure. This is a tedious process.

Deep Learning in Perioperative Inventory Management

Deep learning is a subfield of machine learning that uses neural networks with many layers to model complex patterns in data. It excels in handling large datasets and can be applied to a variety of domains, including healthcare [5]. Deep learning algorithms, particularly those designed to work with time-series

data, image recognition, and reinforcement learning, offer promising solutions to address the challenges faced in managing perioperative inventory.

1. Demand Forecasting and Predictive Analytics

One of the key challenges in perioperative inventory management is forecasting demand accurately. Surgical procedures are scheduled in advance, but the demand for specific supplies can fluctuate depending on various factors, such as the type of surgery, patient conditions, and unexpected cancellations or delays.

Recurrent Neural Networks (RNNs) and their advanced variant, Long Short-Term Memory (LSTM) networks, are well-suited for time-series prediction [6]. These networks can analyze historical surgical data to predict future demand for specific items. By learning patterns in past consumption data, these models can forecast the required quantities of medical supplies and medications for upcoming procedures, helping to avoid both stockouts and overstocking.

For example, an LSTM model could be trained on surgical schedules, patient demographics, types of surgeries, and historical usage of surgical supplies. By learning from this data, the model can generate demand forecasts for each item, allowing hospital staff to place accurate orders ahead of time.

2. Error prevention and inventory predictions

Majority of the healthcare providers use the supplier material for certain surgeries as it is difficult to maintain the inventory at their hospitals. It is mainly because when the item codes change, when the item is replaced by another better-performing item it is helpful for the provider to have the supplier bring the material needed based on the type of surgery than they maintain the inventory in their warehouse. These materials are sterile and need certain types of care, need reserialization after a certain number of days when they are unused.

Supplier brings their inventory with their item codes, the nurse keeps track of the items used for the patient during the surgery, and the patient is invoiced for the materials used. When healthcare receives an invoice froma supplier many times there are errors in the invoices at the item level usage, which creates conflict for the insurance claim and impacts the cost of the procedure.

When Deep learning algorithms are trained with larger volumes of training data, the models will remember the types of procedures, the list of material inventory used, the manufacturer of the material, and the alternative manufacturer for the similar or same item [7]. The automated invoice generated by the AI model is compared against the supplier invoice with automation and the log is generated with errors. This model implementation is a highly recommended solution for hospitals as many healthcare providers struggle to handle this issue, and several human hours are spent reconciling the invoices.

3. Automated Replenishment and Inventory Control

Inventory control in perioperative settings often relies on manual processes, such as periodic stock counts and physical audits. These methods are prone to errors and can lead to discrepancies in stock levels. Deep learning-based algorithms can automate and optimize replenishment decisions [8], ensuring that the right items are ordered at the right time.

Reinforcement Learning (RL) is a powerful technique for optimizing decision-making in dynamic environments [9]. In the context of perioperative inventory, RL algorithms can be used to continuously update inventory policies based on real-time data. For example, an RL agent could receive information about stock levels, demand forecasts, and procurement lead times and learn the best actions to take to maintain optimal stock levels over time.

By simulating different scenarios and evaluating the outcomes of various decisions, the RL model can determine the most efficient strategies for restocking supplies, minimizing waste, and avoiding shortages. Furthermore, the RL model can adapt to changes in demand patterns and surgical schedules, providing a robust solution to inventory management.

4. Visual Recognition for Inventory Tracking

In addition to time-series forecasting and optimization, deep learning algorithms can be employed for visual recognition tasks to improve the accuracy and efficiency of inventory tracking. Convolutional Neural Networks (CNNs) are particularly useful for image classification and object detection, making them ideal for automating stock monitoring in operating rooms and storage areas.

Using cameras and sensors, a CNN-based system can visually scan shelves and inventory storage areas, identifying the quantities and conditions of surgical instruments and supplies. For example, a CNN model can analyze images of surgical trays and count the instruments present, alerting staff when items are missing or out of place. This real-time tracking can help reduce human error and ensure that essential items are always available when needed.

5. Integration with Electronic Health Records (EHR) and Hospital Systems

To maximize the effectiveness of deep learning models for perioperative inventory management, integration with other hospital systems is essential. Connecting demand forecasting models with Electronic Health Records (EHR) and Hospital Information Systems (HIS) can provide a more comprehensive view of surgical needs and inventory management.

Deep learning models can access patient data, surgical schedules, and real-time procedural updates, enabling a more dynamic and responsive approach to inventory management. For example, if a patient's surgery is canceled or delayed, the system can adjust inventory predictions accordingly, avoiding unnecessary procurement.

Challenges and Limitations of using deep learning models

While deep learning offers numerous advantages in managing perioperative inventory, there are several challenges to its implementation:

- **Data Quality and Availability:** Deep learning algorithms require large, high-quality datasets to function effectively. Incomplete or inaccurate data can lead to poor predictions and suboptimal decision-making.
- **Computational Resources:** Training deep learning models often requires substantial computational power, which can be a barrier for smaller hospitals or clinics.

- **Interpretability:** Deep learning models, especially deep neural networks, can be seen as "black boxes." Lack of transparency in decision-making may pose concerns in critical healthcare settings where understanding the rationale behind decisions is crucial.
- **Integration with Legacy Systems:** Many healthcare institutions still rely on legacy software systems. Integrating deep learning models with these systems can be complex and time-consuming.

Conclusion

Deep learning algorithms have the potential to transform perioperative inventory management by improving demand forecasting, automating replenishment, and providing real-time tracking of surgical supplies. By leveraging advanced techniques such as recurrent neural networks, reinforcement learning, and convolutional neural networks, hospitals can enhance inventory accuracy, reduce waste, and optimize resource allocation.

Although challenges such as data quality, computational costs, and system integration remain, ongoing advancements in AI and deep learning technologies will continue to unlock new possibilities for more efficient and cost-effective inventory management in healthcare. As healthcare systems strive for greater operational efficiency and patient safety, deep learning represents a promising frontier for managing perioperative inventory and improving overall healthcare delivery.

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