The rising value of IoT in pharmacy operations: The future starts today

Editorial Article

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Advancing technology is leading to profound changes in the healthcare sector. In the world of pharmacy, the Internet of Things (IoT) offers innovative solutions across a wide range of applications, from inventory management to patient monitoring systems. With smart sensors, automated processes, and real-time data analytics, pharmacy operations are becoming faster, more reliable, and more efficient. This rising value of IoT not only transforms pharmacy services but also lays the foundation for the future healthcare ecosystem. The future is no longer distant; it's happening today.

1. Digital transformation of pharmacy operations with IoT: IoT has become the cornerstone of digital transformation in pharmacy operations. By integrating physical processes with digital monitoring and control systems, IoT reduces manual workloads, enhances efficiency, and minimizes errors. For instance, instead of manually tracking medication inventory, IoT sensors automate this process, allowing pharmacists to focus on more critical tasks such as patient care.

2. Smart inventory management: IoT-powered smart inventory management enables the automatic monitoring of pharmacy stock. Sensors identify which medications are running low or nearing expiration, preventing stockouts or waste. For example, IoT devices placed on pharmacy shelves continuously track inventory levels. When a medication is low, the system automatically generates a purchase order or alerts the pharmacist, ensuring uninterrupted availability.

3. Temperature and humidity control: IoT devices monitor temperature and humidity levels to ensure that medications are stored under the right conditions. These systems alert pharmacists in case of any anomalies, preventing

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the degradation or loss of medication efficacy. For instance, vaccines requiring cold storage are maintained at optimal temperatures through IoT sensors, which immediately send an alarm if the temperature deviates, enabling prompt action.

4. Patient medication tracking and reminders: IoT devices simplify medication adherence by ensuring patients take their medicines on time and in the correct dosage. Smart pillboxes or mobile applications provide reminders and automatically track doses. This improves the effectiveness and consistency of treatment. For example, a patient using a smart pillbox receives alerts via light or sound to take their medicine. The system logs when the box is opened, and if the dose isn't taken, a notification is sent to the patient or their caregiver.

5. Enhancing customer experience: IoT technology improves customer experience in pharmacies through personalized services. Smart kiosks, mobile applications, and connected devices guide customers with medication information, potential side effects, and usage recommendations. For example, an IoT-enabled kiosk in a pharmacy provides detailed information about medications based on scanned prescriptions. It also displays alternative medications or promotions, boosting customer satisfaction.

6. Supply chain traceability: IoT allows real-time tracking of medications throughout the supply chain, from production to the pharmacy. This enhances drug safety, reduces counterfeiting risks, and ensures timely deliveries. For instance, a pharmacy using an IoT-based supply chain system can monitor the location and condition of medications, such as checking whether cold chain vaccines are stored under the correct temperature during transportation.

7. The future of IoT in pharmacies: The development of IoT promises faster, more reliable, and more personalized services in pharmacy operations. Combined with artificial intelligence and big data analytics, IoT enables the analysis of medication consumption habits, paving the way for more proactive healthcare services. In the future, IoT devices won't just manage stock but also analyze patients' health data to offer personalized health recommendations. For instance, a smart prescription system could optimize treatment plans based on a patient's past health records.

8. Conclusion: Smart transformation in pharmacies – the power of IoT: IoT plays a key role in the digital transformation of pharmacy operations. Smart technologies not only enhance operational efficiency but also deliver safer and more personalized services to customers. These innovations position pharmacies as a critical component of future healthcare services. For example, investing in IoT solutions doesn't just streamline processes but also improves customer satisfaction, contributing to long-term success.

Recent epidemiological reports indicate that nearly 80% of the global population incorporates complementary and alternative medicine into their healthcare practices. Herbs are frequently self-administered concurrently with therapeutic drugs. Consequently, clinicians are advised to proactively gather information regarding herb-drug combination in their patients and establish monitoring protocols, particularly for individuals with habitual and concurrent herbal consumption. Herbal products can competitively inhibit cytochrome P450 (CYP) isoenzymes, potentially elevating blood levels of prescription medications and exposing patients to the risk of adverse effects. Studies by Bailey et al. revealed the modification of felodipine biotransformation in the presence of grapefruit juice. Recent investigations further suggest that herbal products may induce both pharmacodynamic and pharmacokinetics interactions of pharmaceuticals.

The majority of drugs, herbal products, and food constituent undergo are metabolism mediated by CYP enzymes. Interactions between herbal product and prescription drugs, manifested as co-medication, encompass the inhibition or induction of metabolizing enzymes and drug efflux proteins, such as P-glicoprotein (P-gp) and multiple resistance proteins (MRPs). The chemical structure of active herbal ingredient significantly modulates drug efflux and metabolism. Adverse effects may arise from the concominant use of herbal products with therapeutic drugs, owing to the alteration of drug metabolism and efflux pathways. Numerous herbal products demonstrate the capacity to induce or inhibit CYP isoenzyme, thereby influencing the metabolism of a broad spectrum of drugs. Predominant among the isoenzymes responsible for the biotransformation of herbal products are CYP3A4/5 and CYP2D6. CYP3A4 metabolizes more than 50% of presently administered therapeutic drugs.

In the recent years, extensive investigation into herb-drug interaction have primarily concentrated on elucidating the pharmacokinetic and pharmacodynamic effects associated with anticancer, anti-HIV, cardiovascular, antidiabetic, antihypertensive, and neuropsychiatric medicines. However, there remains a substantial need for augmented data derived from comprehensive case reports, *in vitro* and *in vivo* studies as well as clinical trials, focusing on the coadministration of naturel products alongside conventional drugs. Moreover, the establishment of a phytovigilance database stands as a prospective initiative for systematically cataloging herb-drug interactions. Notably, the U.S. Federal Adverse Event Reporting System (FAERS) and the Center Adverse Event Reporting System (CAERS) emerge as pivotal conduits for sourcing critical information pertaining to herb-drug interactions.