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PHARMACY AUTOMATION: A SCIENTIFIC REVIEW OF TECHNOLOGIES, BENEFITS AND CHALLENGES

Eng. Hosaam Ali AlShaikh[1], Dr. Mohammad Ismail AlAmr*[2]

[1]Gulf Medical Company

[2]Affiliation (Dr. Sulaiman AlHabib Medical Group).

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***Corresponding Author: Dr. Mohammad Ismail AlAmr**
Affiliation (Dr. Sulaiman AlHabib Medical Group).
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ABSTRACT

This paper reviews recent evidence on the impact of pharmacy automation on dispensing errors, efficiency, cost and user satisfaction. It draws on eleven sources published between 2016 and 2026: four systematic reviews, a scoping review, a narrative review, two Saudi implementation studies, a Qatari study, a French study, and a trade article from the UAE. Robots and automated dispensing cabinets consistently reduce dispensing errors in hospitals, with a pooled standardized difference of −3.89 across 23 studies, but the effect on dispensing time is inconclusive. The initial investment is large, heterogeneity between studies approaches 100% in most analyses, and evidence outside hospitals is sparse. Artificial intelligence is so far limited to workflow support, with limited evidence. The paper concludes that integration with prescribing and inventory systems, together with training, are the conditions for realizing the benefits.

KEYWORDS: Pharmacy automation, automated dispensing, dispensing errors, medication safety, artificial intelligence.

INTRODUCTION

Dispensing errors are among the most prominent medication-safety risks in hospitals and pharmacies. The review by Alshmemri et al. (2026) reports an estimate that about 1.6% of dispensed medications are affected by an error, and that the proportion reaches 33.5% in some settings.

Pharmacy automation here means the use of automated or digital systems in dispensing and preparation steps: central robots, automated dispensing cabinets (ADC), unit-dose systems, intravenous compounding robots, and verification software. The stated goals are to reduce human error, raise productivity, and free pharmacist time for clinical work.

Despite the spread of these systems, the evidence remains scattered. The review by Batson et al. found that studies differ in design and in how outcomes are reported, and more than half of the studies in the Alshmemri et al. (2026) review were quasi-experimental before/after studies (12 of 23). This paper therefore poses the following questions:

1. What are the main pharmacy automation technologies, and where are they used?
2. What is their effect on dispensing errors, efficiency, cost and user satisfaction?
3. What are the main challenges that limit their benefits?
4. Where does artificial intelligence stand within this ecosystem today?

Conceptual Framework: The Medication Use Cycle

This section is a general explanation of concepts that prepares for the findings; it is not a result taken from the reviewed sources.

Within a hospital, a medication passes through a chain of linked steps known as the medication use cycle. The path begins with the physician prescribing the drug, then the pharmacist reviews the prescription, prepares and dispenses the drug, and it ends with administration to the patient and monitoring of its effects. An error can occur at any link, and can pass from one link to the next if it is not detected.

Stages of the Cycle

- Prescribing: The physician writes the prescription; electronic systems (CPOE) replace the paper prescription.
- Review and verification: The pharmacist checks the dose, drug interactions and allergies before dispensing.
- Preparation and dispensing: The drug is picked from the shelf, packaged and labeled with the patient's name; this is where robots and cabinets operate.
- Administration: The nurse gives the drug to the patient and records it; this is where the electronic medication administration record (eMAR) operates.
- Monitoring: The patient's response and side effects are observed.

Research Methodology

This is a rapid narrative review, not a systematic review following PRISMA. The search was conducted on 10 October 2026 using a web search engine, and the original publisher pages were then opened to read abstracts and full texts where possible.

Eleven sources published between 2016 and 2026 were used: four systematic reviews (two with pooled quantitative analysis), a scoping review, a narrative review, two field implementation studies from Saudi Arabia, a Qatari study, a French study whose reading was limited to the abstract, and a UAE trade article. The selection covered hospitals, outpatient clinics and artificial intelligence.

This approach has limits. Some PubMed Central pages blocked automated access, so I did not rely on them; I did not assess the quality of the primary studies myself but relayed the reviews' assessments; and the figures are reported as they appear in their sources.

Pharmacy Automation Technologies

The technologies are distributed across the stages of the medication cycle, and most of the published evidence comes from hospital dispensing. The table summarizes each technology with one numerical example from the evidence.

Technology	What it does	Where it is used	Example from the evidence	Source
Central dispensing robots	Store packages and pick medication automatically	Central hospital pharmacy and outpatient clinics	Prescription dispensing time fell from 60 to 23 seconds, and dispensing error from 0.204% to 0.044% (Japanese study)	Alshmemri 2026
Automated dispensing cabinets (ADC)	Keep medication near the patient and control access to it	Hospital wards, emergency and intensive care	Medication selection and preparation error fell from 1.96% to 0.69% in an Australian emergency department	Alshmemri 2026
Unit-dose dispensing systems (UDDS)	Pack doses into individual labeled packages	Inpatient wards	Ward medication handling time fell from 4.52 to 1.67 minutes per patient per day (German hospital)	Alshmemri 2026
IV and chemotherapy compounding robots	Prepare doses automatically	Oncology pharmacies	85 doses (1.2%) of 7,384 fell outside the ±4% accuracy range at a US cancer center, and a first-generation robot recorded high failure rates in dose accuracy	Shbaily 2025
Outpatient and community pharmacy automation	Dispense and pack original packages automatically	Outpatient clinics and community pharmacies	Reported medication-related incidents fell by up to 37%, and productivity rose by about 4 items per person per hour	Sng 2019
Electronic prescribing and records (CPOE and eMAR)	Digitize prescribing and administration recording	Hospitals	Administration-recording error rate fell from 48.0% to 36.9% after eMAR	Shbaily 2025
Artificial intelligence (machine learning)	Flags prescriptions needing pharmacist intervention and supports screening and analysis	Community pharmacies and hospitals	Of 560 studies, only 7 met the review criteria, all using machine learning, and 4 of them identified prescriptions needing intervention	Scoping review 2024

The figures come from different studies with different definitions of error, so they should not be compared directly across rows.

A Brief Description of Each Technology

The following paragraphs are a general explanation of the technologies; the figures come from the table above and from the later case studies.

Central dispensing robots: These are enclosed cabinets that hold original medication packages in a storage area organized by the system. When a prescription arrives, a robotic arm picks the requested package and delivers it to the dispensing window. Accuracy depends on linking the system to the inventory and prescription databases. In the Dammam study presented later, each unit held about 12,500 packages.

Automated dispensing cabinets (ADC): These cabinets are placed in wards, emergency departments and intensive care units, and keep medication near the patient. Only an authorized user can open the cabinet, and the system records every withdrawal. They reduce waiting for medication from the central pharmacy, but they need periodic restocking by a pharmacist or technician.

Unit-dose dispensing systems (UDDS): These divide medication into individual doses packaged and labeled with the patient's name. This reduces the nurse's work in preparing doses on the ward.

IV and chemotherapy compounding robots: These prepare sterile medications given by injection or infusion. This category is sensitive to dose accuracy, so its accuracy is measured against a defined tolerance range, as in the table's data.

Outpatient and community pharmacies: These dispense original packages to visiting patients, so the effect of automation there relates to waiting time and the number of prescriptions per pharmacist. The evidence there is thinner than in hospitals, according to the review by Sng et al.

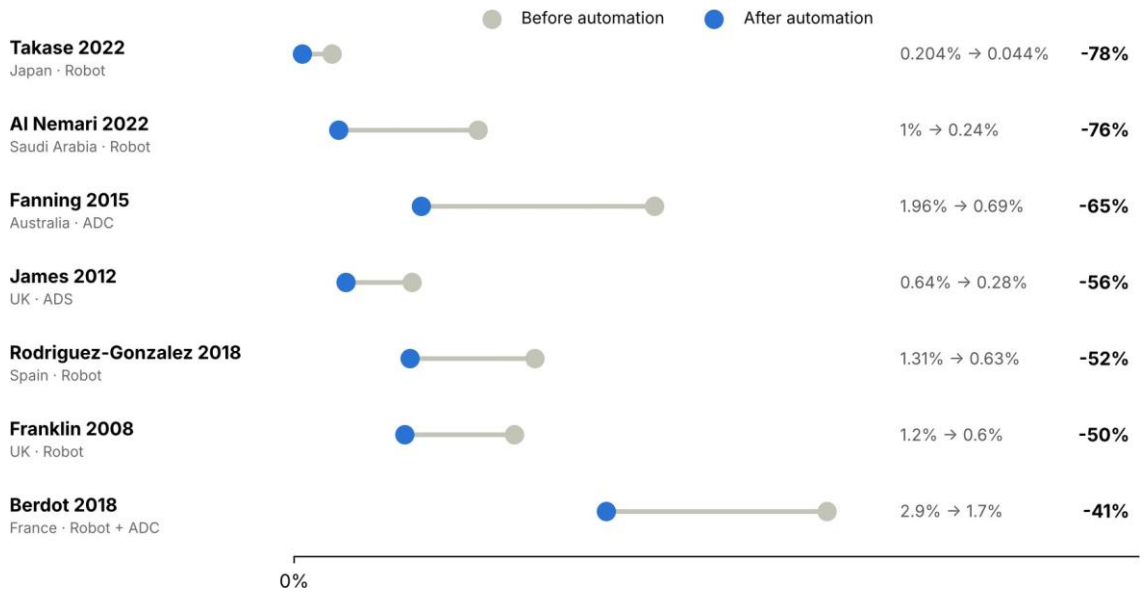
Digital systems and artificial intelligence: These include computerized prescribing (CPOE), the electronic medication administration record (eMAR), and prescription-screening software. Machine-learning models add an alert layer that flags prescriptions needing pharmacist review, without replacing the pharmacist.

Evidence and Findings

The reviews agree that automation reduces dispensing errors in hospitals, but the size of the effect varies widely, and it does not appear on every time measure.

Dispensing Errors

The review by Alshmemri et al. (2026) pooled 23 studies from 10 countries. The dispensing error rate fell with a pooled standardized difference of −3.89 (95% confidence interval: −4.53 to −3.26), and the effect was clearer with robots (−4.44) than with automated dispensing cabinets (−3.31). The review by Batson et al. found, across 48 publications, reductions in medication errors, administration time and cost.



Dispensing errors fell by 41% to 78% after automation in seven studies. Dispensing error rate (%) in each study. From the tables of Alshmemri et al. (2026) and Shbaily et al. (2025); the percentage reduction is calculated from the reported figures. Error definitions and measurement methods differ between studies, so comparison between rows is approximate.

Errors fell in every study, and the reduction was larger in the Japanese and Saudi studies than in the French one, with differences in setting and error definition between studies.

Efficiency and Time

Medication administration time fell with a standardized difference of −4.35 (p = 0.01) in four studies. Dispensing time itself (two studies) did not differ significantly (−5.38; p = 0.19), nor did the patient's time within the dispensing system. In outpatient pharmacies, waiting and prescription-filling time fell by 17–20 seconds, but staff did not feel a reduction in workload, according to Sng et al.

In an implementation study at a private facility in Saudi Arabia, Momattin et al. (2021) recorded, after 10 months, a 53% reduction in average waiting time, a 33% increase in pharmacist productivity, and a 22% rise in overall satisfaction, with zero reported dispensing errors. This is a single-site before/after study, and the Alshmemri review classified it as having moderate risk of bias.

Cost

The initial investment is large, but Shbaily et al. (2025) conclude that operating costs are lower in the long run thanks to reduced labor and medication waste. A financial analysis of surgical intensive care units showed a positive net present value. Batson et al., however, consider that return-on-investment recommendations need larger studies that measure clinical outcomes.

User Satisfaction

Seven studies in the Alshmemri review reported higher satisfaction after automation, but nurse satisfaction was lower at first in one study and then improved over time. In outpatient pharmacies, job satisfaction did not change, according to Sng et al.

Limits of Confidence in Pooled Figures

Heterogeneity between studies (IZ) reached 100% in most pooled analyses in Alshmemri, and 99.76% in Shbaily. In Shbaily's table, two studies have confidence intervals tens of thousands wide, which weakens the pooled mean (0.505). The same review also gives a negative effect for one Saudi study, while its descriptive table says the study showed a reduction in errors, an internal inconsistency in reporting. The pooled figures therefore indicate direction, not an effect size that can be generalized.

Case Study: Two Dispensing Robots in an Outpatient Pharmacy in Dammam

The study by Momattin et al. (2021) is one of the most detailed sources in this review, because it describes implementation and results at a single site. The study took place in an outpatient pharmacy at Al Mouwasat Hospital, a private facility in Dammam in northeastern Saudi Arabia. The pharmacy operates around the clock, and peak crowding runs from 9:30 to 12:30 and from 4:00 to 10:00 p.m.

Technology and Implementation

The facility installed two Rowa Vmax 160 robots from Becton, Dickinson and Company (BD), each holding about 12,500 packages. Packages reach ten dispensing windows via conveyor belts and spiral tubes. The team linked the two robots to the existing health information system — appointments, medical records and prescriptions — through the HL7 standard. The study lasted 21 months, from September 2018 to June 2020, with live operation starting in August 2019. Pre-operation data covered 11 months, and results were published after 10 months of operation.

Results as Reported in the Study

Measure	Before robot	After robot
Average waiting time	15 minutes	7.9 minutes
Dispensing errors per 1,000 items	1.50	0.01
Prescriptions per pharmacist per day	43.5	60
Prescriptions dispensed per month	About 8,728	About 13,588
Satisfaction with waiting time	58.67%	89%
Overall satisfaction	62%	88%

The number of full-time-equivalent (FTE) staff did not change during the study. The time freed for patient medication education was estimated at about five minutes per patient, but it was measured only after operation began, so there is no before comparison.

A Critical Reading of the Figures

These results must be interpreted with caution for three reasons. First, the percentages in the abstract do not match the tables. The abstract reports a 20% rise in satisfaction with waiting time and 22% in overall satisfaction, while the table values give differences of 30.3 and 26 percentage points. By my calculation from the figures reported above, waiting time fell 47%, not 53%, and daily pharmacist prescriptions rose about 38%, not 33%. The difference may stem from a different calculation method, and I could not verify this.

Second, the study is single-site, and its text reports no statistical significance tests for the before/after comparisons. Third, there is a conflict of interest: two of the authors work for BD, the manufacturer of the system, and the company provided support for publication. The study acknowledges other limits: the system does not dispense unit-dose packages and does not relabel or split packages, and its benefits may not transfer to facilities without an integrated health information system.

Automated Dispensing Cabinet Implementation Study at a Hospital in Al-Ahsa

A recent qualitative study from Saudi Arabia gives a different picture, because it asks staff about their experience rather than about performance indicators. Al Mutair et al. (2025) conducted interviews at Al Moosa Specialist Hospital in Al-Ahsa, a 460-bed facility. The cabinets were introduced in September 2021, with 25 cabinets operating in 20 units. Before that, the hospital relied on manual ward stock and medication carts carrying a 24-hour supply.

Method

The study used a qualitative design with semi-structured interviews of 30 to 40 minutes each, audio-recorded, transcribed and analyzed thematically using the Braun and Clarke method. Participants were purposively selected from pharmacists, informatics pharmacists and nursing managers, including staff in emergency and intensive care, and interviews continued until saturation. Two researchers attended each interview.

Benefits Reported by Staff

- Time saving: Nurses no longer spent long periods requesting and counting stock, and avoided waiting 30 to 60 minutes for new medications to be dispensed from the pharmacy.
- Fewer errors: The cabinets display the exact quantity required and warn of dose mismatch, which eased staff stress with high-risk medications.
- Traceability and accountability: Discrepancy reports and user-behavior data support accountability and reduce the

need for auditing.

- Inventory: Manual counting almost disappeared.

Barriers

- Training: Training began with a course from the supplier, then sessions led by experienced users and the informatics team, and a need for retraining remained after cases of misuse.
- Technical problems and medication management: The link to the resource-planning system failed, the network went down, double deduction recurred after outages, and different batches were mixed in the same container. One case was reported in which an error nearly occurred between two similar inhaled medications in the emergency department because of a hazardous override of an alert.
- Cabinet design: Narrow spacing between free zones and indicator lights confused users.
- Workload: Pharmacists faced a heavy morning restocking burden and were overwhelmed by alerts from all departments.

Economics and Return on Investment

The economic evidence appears scattered and varied. We saw that Shbaily et al. conclude that operating costs fall in the long run, and that Momattin et al. estimate payback after 3.5 years. But a French study gives a less optimistic picture.

Berdot et al. (2019) evaluated a central dispensing robot in a French teaching hospital eight years after it began operating and after its upgrade. The researchers found a slight return on investment (+1.86%), and the payback period lengthened by about three years. At the same time, dispensing errors fell from 2.9% to 1.7% ($p < 0.001$), and staff rated the robot at an average of 5.52 out of 7. The authors conclude that these systems are a worthwhile investment that improves the quality and safety of the medication process. I could not access the full text because the page is for subscribers only, so I relied on the abstract, and I do not report cost or time figures from it.

These studies agree that financial return is not guaranteed and that it is affected by the cost of upgrades and maintenance and by the number of staff whose time can be dispensed with. Justifying the investment by improved safety alone may therefore be stronger than justifying it by financial savings.

The Situation in Saudi Arabia and the Gulf States

This paper focuses on Saudi Arabia and the Arab Gulf states. The available evidence comes from three countries — Saudi Arabia, Qatar and the UAE — with large variation in source type and quality. In my search I did not find sources from Kuwait, Oman or Bahrain.

Saudi Arabia

This review includes three Saudi sources. The first is the Dammam study on two dispensing robots in an outpatient pharmacy. The second is the Al-Ahsa qualitative study on automated dispensing cabinets. The third is a study relayed by the Alshmemri review and shown in the figure above (Al Nemari 2022), in which the error fell from 1 to 0.24 in the relayed table, about 76%. All are from a single site, and one of them has a declared conflict of interest, as we saw.

Qatar

Zaidan et al. (2016) conducted a survey of nurses at the Heart Hospital and the National Center for Cancer Care and Research in Qatar, both part of Hamad Medical Corporation. Automated dispensing cabinets were launched at the two

sites in 2010 and 2012, and the study was carried out by electronic questionnaire in May and November 2012. 403 nurses of 503 invited responded (80%). 94% agreed that the system makes their work safer, 90% said they wait less time for medication from the pharmacy, 87% agreed they administer medication more efficiently, and overall satisfaction was 91%. These are impressions, not measurements of errors.

United Arab Emirates

An article by Ministry of Health and Community Prevention staff (2020) describes a comparison between two outpatient pharmacies over twelve months in 2018, one conventional and the other automated. The automated one dispensed 37,754 prescriptions for 12,739 patients, and the conventional one 33,782 prescriptions for 11,646 patients. The article states that the automated pharmacy dispensed about 11.8% more prescriptions, outperformed by 28.8% in prescriptions dispensed correctly, and cut the time between receiving and completing a prescription by about 95.7%. But these are self-reported figures from a piece in a trade magazine, not a peer-reviewed journal, written by the staff of the same body; the page does not mention independent verification, and it contains a promotional video for BD. I therefore treat it as a preliminary indicator, not as evidence.

What This Evidence Means for the Gulf

First, all the Gulf studies I opened come from a single site or institution, so they cannot support an estimate of effect at regional level. Second, the Dammam study is tied to the interests of a manufacturer, and the UAE reports were published in a trade publication. Third, the Qatar and Al-Ahsa studies focus on staff experience rather than error measurement. Fourth, the survey of pharmacists in the Middle East and North Africa relayed by the review by Alam et al. shows that concern about the absence of legal frameworks, privacy and cybersecurity tops staff worries about artificial intelligence. What is needed, then, is independent multi-site evaluation and clear regulation of artificial intelligence, not the purchase of technology alone.

Challenges and Limitations

The reviews show that most barriers relate to how the technology is implemented, not to the technology itself.

- Cost: The initial investment is large, and return-on-investment studies are still few (Shbaily 2025, Batson).
- Operational readiness: A failure mode and effects analysis (FMEA) at a Gulf hospital highlighted training problems, breakdowns and weak communication, and a first-generation chemotherapy compounding robot recorded high failure rates in dose accuracy (as relayed from Shbaily 2025).
- Integration and supply chain: Momattin et al. concluded that success requires a strong supply chain and full integration with appointment, medical record and prescription systems.
- The human element: Productivity was initially disrupted in an Australian study and then improved, and a Canadian study reported delays in preparing and administering doses, with 48% dissatisfaction (as relayed from Alshmemri 2026).
- Quality of evidence: Near-complete heterogeneity between studies, and little evidence in outpatient and community pharmacies, which Sng et al. described as scattered.
- Artificial intelligence: In a survey of pharmacists in the Middle East and North Africa relayed by Alam et al. (2025), 67.0% expressed concern about the absence of legal frameworks, 62.9% about job loss, and 58.9% about privacy and cybersecurity.

Future Directions and Recommendations

Artificial intelligence is the next layer above mechanical automation, but its evidence in pharmacy remains limited. Of 560 studies in the scoping review, only 7 met the inclusion criteria, and they focused on workflow and productivity more than on patient outcomes. The review by Alam et al. (2025) lists broader uses, including clinical decision support, inventory forecasting and prescription screening, with reservations about privacy, bias and integration with existing systems.

The following recommendations are drawn from the sources and are not text quoted from them:

1. Link the robot or cabinet to the prescribing and inventory system before go-live, as the experience of Momattin et al. indicates.
2. Give training, technical support and post-go-live follow-up a fixed place in the budget (Shbaily 2025).
3. Measure dispensing errors per 1,000 prescriptions and waiting time before and after implementation, as Momattin et al. did.
4. Future research needs cost-benefit studies, standardized outcome measurement, long-term follow-up, and assessment of staff satisfaction (Alshmemri 2026, Batson).
5. When introducing artificial intelligence, models must be validated and final oversight kept in the pharmacist's hands (Alam et al.).

Implementation Readiness Checklist

This checklist is my own distillation of the reviewed studies and is not a peer-validated tool. It is a suitable starting point for team discussion before purchasing any system.

Domain	Verification question	Basis in the sources
Integration	Does the device connect to the electronic prescription, inventory and appointment systems?	Momattin et al., Al Mutair et al.
Training	Is there a plan for initial training, refresher training and a permanent support team?	Al Mutair et al., Shbaily et al.
Operational continuity	What is the plan when the network goes down or the device breaks down?	Al Mutair et al.
Workflow	Who restocks the cabinets, and how is the load distributed among pharmacists?	Al Mutair et al.
Usability design	Have look-alike medications, indicator lights and alerts been taken into account?	Al Mutair et al.
Measurement	Were errors and waiting time measured before go-live?	Momattin et al.
Financial feasibility	Was payback calculated with a discount rate and upgrade and maintenance costs?	Momattin et al., Berdot et al.
Impartiality	Is the impact evaluated by a body independent of the supplier?	Conflict of interest in the Momattin study

DISCUSSION

Question Two: What Is the Effect?

The clearest result is the reduction in dispensing errors. They fell by between 41% and 78% in the seven studies shown in the figure, and in the pooled review by a standardized difference of −3.89. For time, the picture is less decisive: administration time fell, and dispensing time did not change significantly. Satisfaction results vary between staff groups and between implementation phases. As for cost, the evidence ranges from a positive net present value to a slight return after a robot upgrade.

Question Four: Where Does Artificial Intelligence Stand?

Artificial intelligence in pharmacy is still at an early stage of proof. Only 7 of 560 studies met the scoping review's criteria, and pharmacists' concern about the legal framework and privacy appeared in the regional survey. It is therefore advisable to trial it under pharmacist supervision rather than as a replacement for the pharmacist.

CONCLUSION

The available evidence indicates that dispensing automation reduces dispensing errors in hospitals and improves some measures of time and satisfaction, in exchange for a large initial investment. However, the heterogeneity of the studies, the scarcity of evidence outside hospitals, and the weak measurement of cost and clinical outcomes prevent generalizing the size of the effect. The success of implementation remains dependent on integration with prescribing and inventory systems, and on training and follow-up. Artificial intelligence is promising but at the start of its path to proof.

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