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Implementation of intelligent pharmacy technologies in hospitals: A cross-sectional nationwide study

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A B S T R A C T

Background: Medication errors pose critical threat to patient safety. The implementation of intelligent pharmacy technologies demonstrate great potential to reduce medication risks. This study aimed to investigate the current status of intelligent pharmacy technology implementation in Chinese hospitals.
Methods: A nationwide survey was conducted from May 29 to June 10, 2025, covering 1,126 hospitals across China. Based on the intelligent pharmacy products (IPDs) identified through the Delphi method, this survey mainly collected data on current utilization rates of the identified IPD. Pearson's chi-square test was applied to compare usage rates across different hospital types.
Results: A total of 36 kinds of commonly used IPDs were identified and classified into six categories: intelligent drug supply (IDS), prescription review (IPR), drug preparation (IDP), drug distribution (IDD), medication consultation (IMC), and medication monitoring systems (IMM). Usage rates of these 6 types of systems varied significantly in hospital of different levels and number of beds ($P < 0.001$). Hospitals with a higher number of pharmacists per 100 beds (PPB ≥ 7) reported significantly lower utilization rates of IPR, IMC, and IMM systems ($P < 0.001$). Regionally, eastern coastal provinces such as Zhejiang, Jiangsu, and Shandong demonstrated higher levels of intelligent pharmacy implementation.
Conclusions: The implementation of intelligent pharmacy in China was uneven across regions, hospital levels, sizes, and pharmacist numbers. Future development should be supported by policy incentives and tailored to specific clinical needs, ensuring a balanced and sustainable advancement of intelligent pharmacy.

1. Background

Medication errors are crucial causes of potential avoidable disability or deaths in hospital settings. According to World Health Organization (WHO), there were approximately one-tenth of patients experienced harmful medical treatment, and more than 3 million patients dead due to inappropriate medication treatments.[1] Medication errors can cause direct economic losses of 42 billion and indirect healthcare costs of 140 billion annually.[2] In China, in 2023, there were nearly 30,000 cases of medication errors reported by only 439 medical institutions in 26 provinces, highlighting the crucial safety problems in drug utilization practices.[3]

Several evidence suggested that intelligent pharmacy technologies show great potential in improving work efficiency,[4] enhancing medication safety,[5] and reducing risk of manual error.[6] Intelligent pharmacy typically refers to the integration of advanced digital technologies, such as artificial intelligence (AI), big data, cloud computing, the internet of things (IoT), and automated devices, into hospital pharmacy practice.[7–9] It is valuable in optimizing the drug utilization workflows and providing opportunities for clinical pharmacists to transform from manual, repetitive tasks toward more clinical activities closely related to patient health.[10]

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Table 1
The characteristics of the hospitals and utilization rates of Intelligent pharmacy product (IPD) classified by workflow stages.

Characteristics	Number of hospitals (%)						
	Total	IDS	IPR	IDP	IDD	IMC	IMM
Total	1,126	745 (66.16)	935 (83.04)	698 (61.99)	982 (87.21)	500 (44.40)	232 (20.60)
Levels							
Tertiary	618 (54.88)	445 (72.01)[a]	570 (92.23)[a]	480 (77.67)[a]	563 (91.10)[a]	386 (62.46)[a]	193 (31.23)[a]
Secondary	422 (37.48)	245 (58.06)[b]	301 (71.33)[b]	173 (41.00)[b]	348 (82.46)[b]	90 (21.33)[b]	29 (6.87)[b]
Primary	86 (7.64)	55 (63.95)[a,b]	64 (74.42)[b]	45 (52.33)[b]	71 (82.56)[b]	24 (27.91)[b]	10 (11.63)[b]
P value	< 0.001**	< 0.001**	< 0.001**	< 0.001**	< 0.001**	< 0.001**	< 0.001**
Types							
General	936 (83.13)	623 (66.56)	782 (83.55)	592 (63.25)	822 (87.82)	425 (45.41)	196 (20.94)
Specialized	190 (16.87)	122 (64.21)	153 (80.53)	106 (55.79)	160 (84.21)	75 (39.47)	36 (18.95)
P value		0.533	0.312	0.053	0.174	0.133	0.536
Ownership							
Government	1,050 (93.25)	689 (65.62)[a]	872 (83.05)	654 (62.29)	917 (87.33)	471 (44.86)	214 (20.38)
Nonprofit	29 (2.58)	17 (58.62)[a,b]	24 (82.76)	17 (58.62)	27 (93.10)	10 (34.48)	9 (31.03)
For Profit	47 (4.17)	39 (82.98)[b]	39 (82.98)	27 (57.45)	38 (80.85)	19 (40.43)	9 (19.15)
P value		0.033	0.999	0.744	0.270	0.462	0.364
Number of Beds							
< 500	384 (34.10)	214 (55.73)[a]	255 (66.41)[a]	144 (37.5)[a]	310 (80.73)[a]	66 (17.19)[a]	15 (3.91)[a]
500–1000	334 (29.66)	223 (66.77)[b]	293 (87.72)[b]	207 (61.98)[b]	290 (86.83)[a]	148 (44.31)[b]	59 (17.66)[b]
≥ 1000	408 *36.23)	308 (75.49)[c]	387 (94.85)[c]	347 (85.05)[c]	382 (93.63)[b]	286 (70.10)[c]	158 (38.73)[c]
P value		< 0.001**	< 0.001**	< 0.001**	< 0.001**	< 0.001**	< 0.001**
Number of Pharmacists/100 Beds							
< 5	527 (46.80)	358 (67.93)	454 (86.15)[a]	340 (64.52)	451 (85.58)	261 (49.53)[a]	129 (24.48)[a]
5–7	317 (28.15)	206 (64.98)	261 (82.33)[a,b]	199 (62.78)	279 (88.01)	142 (44.79)[a]	66 (20.82)[a]
≥ 7	282 (25.04)	181 (64.18)	220 (78.01)[b]	159 (56.38)	252 (89.36)	97 (34.40)[b]	37 (13.12)[b]
P value		0.490	0.012**	0.072	0.271	< 0.001**	< 0.001**

Note:* Test level: $P < 0.05$;.
**Bonferroni adjustment method, adjust the test level to α', $\alpha' = \alpha/m$, $m = k/(k\text{-}1)/2$, k represents the number of multiple independent samples. The difference between the frequency distribution of the three samples, the test level $\alpha = 0.05$, $m = 3$, $\alpha' = 0.0167$. intelligent drug supply (IDS), prescription review (IPR), drug preparation (IDP), drug distribution (IDD), medication consultation (IMC), and medication monitoring systems (IMM).
[a,b]:There was no statistical difference between the two groups with the same superscript letter.

The development of intelligent pharmacy requires continuous investment in advanced products, including automated and information systems.[11] Such investments must be strategically allocated based on comprehensive assessments of hospital-specific conditions, including current infrastructure maturity and operational needs. Currently, there are few studies conducting large-scale investigations on the overall picture of the implementation of intelligent pharmaceutical products in Chinese hospitals. Therefore, we conducted a nationwide research aiming to explore the current status of implementation of intelligent pharmacy in China and provide evidence for the balanced, sustainable and healthy development of intelligent pharmacy.

2. Methods

2.1. Study design

Our study was a cross-sectional survey of hospital pharmacy departments across China from May 29 to June 10, 2025. We used convenience sampling to recruit pharmacy directors from hospitals in 31 provincial administrative regions (except of Macao, Hong Kong, and Taiwan) of China.[12] We developed the questionnaire via an online survey platform in China and distributed the questionnaire link via social platform (Wechat) or email to pharmacy directors recruited.

2.2. Questionnaire

The questionnaire was developed following multiple stages. (1) policy file collection and review: (2) expert discussion; (3) pilot research. We searched on the official websites of national and local administrative departments for policy files related to the guidance, development plans, specific development actions, management measures, or evaluation measures for intelligent pharmacy in hospitals. The websites searched for policy files included the national and local Health Commission, Administration of Traditional Chinese Medicine, Health Security Administration, and Medical Product Administration. We used the following search terms: Intelligent pharmacy, automated pharmacy and intelligent pharmaceutical science. We also used combinations of these terms. The date of the last search was September 10, 2025.

The drafted items went through two rounds of delphi methods with senior hospital pharmacists and artificial intelligence specialists. After that, an investigation table was generated and a pilot test was then conducted in 10 hospitals to test question clarity and estimate completion time. Based on pilot feedback, the questionnaire is appropriate and the estimated completion time was around 20–45 min. The final questionnaire comprised 48 questions covering three domains: (1) hospital characteristics (level, type, ownership, location, number of beds, pharmacy staff size); (2) current utilization of intelligent pharmacy products (IPDs); and (3) Supplement the IPDs not mentioned in the questionnaire and describe their usage. The whole investigation questionnaire is provided in the supplementary material.

2.3. Data collection

The online platform automatically recorded timestamps and prevented multiple submissions from the same account. After survey closure, data were exported to Microsoft Excel for cleaning and coding. We checked for missing values, logical inconsistencies, and outliers; records failing quality checks were excluded as described above. Key derived variables (region, hospital bed category, pharmacy staffing category) were generated prior to analysis. Exclusion criteria: (1) implausible or extreme completion times based on pilot estimates (responses completed in < 10 min or > 60 min); (2) missing key data (e.g., hospital bed count or region); (3) duplicate responses from the same hospital; (4) internally inconsistent or clearly erroneous data (for example, classification mismatches such as a primary hospital reporting ≥ 1,000 beds). Duplicate and inconsistent responses were resolved by checking reported hospital identifiers and contacting respondents for verification.

2.4. Statistical analysis

Hospitals were classified by number of beds into three categories: ≥ 1,000, 500–999, and < 500. The number of pharmacists per 100 beds (PPB) were calculated by formula as follows: PPB = (N_pharmacists/N_beds) × 100. Where N_pharmacists is the number of full - time pharmacists in the hospital pharmacy department in 2024, and N_beds is the number of open beds during the same period. The comparisons of the rates were performed using Pearson's chi-squared test. Statistical significance was set at two-sided $p < 0.05$. Confidence intervals were calculated for key proportions where appropriate. Statistical analyses were performed using SPSS version 26.0. Data visualization was produced in R (version 4.4.3) using the ggplot2, hchinamap, and fmsb packages.

3. Results

In total, 1,653 questionnaires were collected from 1,653 hospitals across 31 provincial administrative regions in China. After excluding 538 questionnaires, 1,126 questionnaires were finally included for analysis. The basic characteristics of the hospitals were shown in Table 1. Approximately, 54.88% of the hospitals were tertiary hospitals, 83.13% were general hospitals, and 93.25% were public hospitals.

3.1. Identifications and classifications of IPDs

Through literature research and Delphi method, we identified that 36 kinds of IPDs are currently utilized in China. The IPDs covered six stages of pharmaceutical practices in hospitals: intelligent drug supply (IDS), intelligent prescription review (IPR), intelligent drug preparation (IDP), intelligent drug dispensing (IDD), intelligent medication consultation (IMC), and intelligent medication monitoring (IMM). The names and classifications of the IPDs were shown in Fig. 1. The explanations of the IPDs were shown in Supplementary Table.

3.2. Utilization rates of IPDs

Among the 1,126 hospitals, there were 745 (66.16%), 935 (83.04%), 698 (61.99%), 982 (87.21%), 500 (44.40%), and 232 (20.60%) hospitals were equipped with IDS, IPR, IDP, IDD, IMC and IMM systems respectively (Table 1). The most used IPDs were the barcode management system (81.26%), antibiotic monitoring and management system (67.7%), and drug inventory system (52.4%) (Table 2). The least used were patient medication compliance monitoring equipment (2.8%), AI pharmacist intelligent agent (3.0%) and TDM monitoring result automatic interpretation system (3.6%) (Table 2).

Among the IPDs for IDS, the pharmaceutical inventory system (PIS) was the most used (52.4%), while the supplier management and evaluation system (SMES) was the least used (7.9%) (Table 2, Fig. 2). The

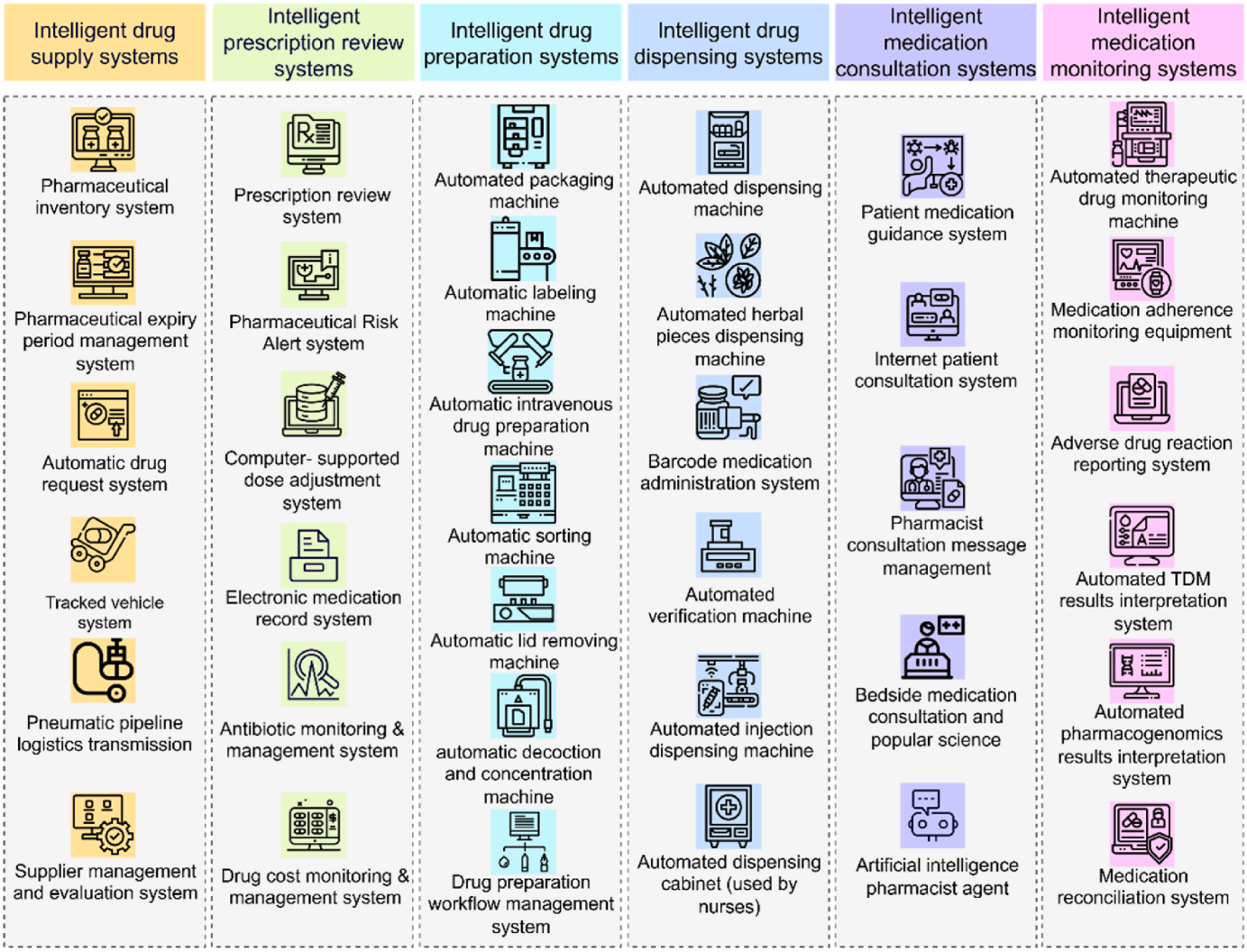


Fig. 1. The classifications of the IPDs included in the study.

Table 2
The utilization rates of IPDs in hospitals of different levels.

IPDs	Number of hospitals (%)				*P* value
	Total	Tertiary	Secondary	Primary	
Barcode Medication Administration System (BCMA)	915 (81.26)	506 (81.88)	339 (80.33)	70 (81.40)	0.821
Antibiotic Monitoring and Management System (AMMS)	762 (67.7)	467 (75.6)[a]	247 (58.5)[b]	48 (55.8)[b]	< 0.001*
Pharmaceutical Inventory System (PIS)	590 (52.4)	330 (41.3)	214 (34.6)	46 (38.4)	0.68
Electronic Medication Record System (EMRS)	512 (45.5)	347 (56.1)[a]	134 (31.8)[b]	31 (36.0)[b]	< 0.001*
Prescription Review System (PRS)	509 (45.2)	377 (61.0)[a]	106 (25.1)[b]	26 (30.2)[b]	< 0.001*
Drug Cost Monitoring and Management System (DCMMS)	451 (40.1)	300 (48.5)[a]	127 (30.1)[b]	24 (27.9)[b]	< 0.001*
Automatic Decoction and Concentration Machine (ADCM)	442 (39.3)	287 (46.4)[a]	124 (29.4)[b]	31 (36.0)[a,b]	0.001*
Pharmaceutical Expiry Period Management System (PEPMS)	434 (38.5)	255 (41.3)	146 (34.6)	33 (38.4)	0.095
Automatic Packaging Machine (APM)	429 (38.1)	350 (56.6)[a]	57 (13.5)[b]	22 (25.6)[c]	< 0.001*
Automatic dispensing machine (ADM)	375 (33.3)	299 (48.4)[a]	57 (13.5)[b]	19 (22.1)[b]	< 0.001*
Internet Patient Consultation System (IPCS)	296 (26.3)	246 (39.8)[a]	36 (8.5)[b]	14 (16.3)[b]	< 0.001*
Pharmacist Consultation Message Management System (PCMMS)	250 (22.2)	200 (32.4)[a]	40 (18.0)[b]	10 (11.6)[b]	< 0.001*
Automatic Drug Request System (ADRS)	229 (20.3)	169 (27.3)[a]	43 (10.2)[b]	17 (19.8)[a]	< 0.001*
Patient Medication Guidance System (PMGS)	220 (19.5)	176 (28.5)[a]	35 (8.3)[b]	9 (10.5)[b]	< 0.001*
Computer-Supported Dose Adjustment System (CSDAS)	198 (17.6)	153 (24.8)[a]	37 (8.8)[b]	8 (9.3)[b]	< 0.001*
Automatic Labeling Machine (ALM)	174 (15.5)	154 (24.9)[a]	15 (3.6)[b]	5 (5.8)[b]	< 0.001*
Pharmaceutical Risk Alert System (PRAS)	156 (13.9)	125 (20.2)[a]	26 (6.2)[b]	5 (5.8)[b]	< 0.001*
Pneumatic Pipeline Logistics Transmission (PPLT)	150 (13.3)	126 (20.4)[a]	18 (4.3)[b]	6 (7.0)[b]	< 0.001*
Automatic Sorting Machine (ASM)	145 (12.9)	128 (20.7)[a]	12 (2.8)[b]	5 (5.8)[b]	< 0.001*
Adverse Drug Reaction Reporting System (ADRRS)	134 (11.9)	108 (17.5)[a]	20 (4.7)[b]	6 (7.0)[b]	< 0.001*
Tracked Vehicle System (TVS)	121 (10.7)	100 (16.2)[a]	15 (3.6)[b]	6 (7.0)[a,b]	< 0.001*
Drug Preparation Workflow Management System (DPWMS)	120 (10.7)	99 (16.0)[a]	16 (3.8)[b]	5 (5.8)[b]	< 0.001*
Supplier Management and Evaluation System (SMES)	89 (7.9)	67 (10.8)[a]	15 (3.6)[b]	7 (8.1)[a,b]	< 0.001*
Automated Therapeutic Drug Monitoring Machine (ATDMM)	80 (7.1)	76 (12.3)[a]	1 (0.2)[b]	3 (3.5)[c]	< 0.001*
Automatic Verification Machine (AVM)	71 (6.3)	63 (10.2)[a]	5 (1.2)[b]	3 (3.5)[c]	< 0.001*
Automated Herbal Pieces Dispensing Machine (AHPDM)	67 (6.1)	53 (8.6)[a]	14 (3.3)[b]	0 (0)[b]	0.001*
Automatic Lid Removing Machine (ALRM)	65 (5.8)	55 (8.9)[a]	9 (2.1)[b]	1 (1.2)[b]	< 0.001*
Automatic Intravenous Drug Preparation Machine (AIDPM)	65 (5.8)	58 (9.4)[a]	4 (0.9)[b]	3 (3.5)[a,b]	< 0.001*
Medication Reconciliation System (MRS)	65 (5.8)	60 (9.7)[a]	4 (0.9)[b]	1 (1.2)[b]	< 0.001*
Automatic Dispensing Cabinet (used by nurses) (ADC)	62 (5.5)	55 (8.9)[a]	4 (0.9)[b]	3 (3.5)[ab]	0.001*
Bedside Medication Consultation and Popular Science (BMCPS)	53 (4.7)	41 (6.6)[a]	10 (2.4)[b]	2 (2.3)[a,b]	0.003*
Automatic Injection Dispensing Machine (AIDM)	47 (4.17)	38 (6.15)	8 (1.90)	1 (1.16)	
Automated Pharmacogenomics Results Interpretation System (APRIS)	42 (3.7)	35 (5.7)[a]	5 (1.2)[b]	2 (2.3)[a,b]	0.001*
Automated Therapeutic Drug Monitoring Results Interpretation System (ATRIS)	40 (3.6)	34 (5.5)[a]	4 (0.9)[b]	2 (2.3)[a,b]	< 0.001*
Artificial Intelligence Pharmacist Agent (AIPA)	34 (3.0)	32 (5.2)[a]	2 (0.5)[b]	(0)[a,b]	< 0.001*
Medication Adherence Monitoring Equipment (MAME)	31 (2.8)	26 (4.2)[a]	4 (0.9)[b]	1 (1.2)[a,b]	0.004*

Note: Bonferroni adjustment method, adjust the test level to α', $\alpha' = \alpha/m$, $m = k/(k-1)/2$, k represents the number of multiple independent samples. The difference between the frequency distribution of the three samples, the test level $\alpha = 0.05$, $m = 3$, $\alpha' = 0.0167$.
[a,b]:There was no statistical difference between the two groups with the same superscript letter.

most used IPD for IPR was the antibiotic monitoring and management system (AMMS) (67.7%), while the pharmaceutical risk alert system (PRAS) (13.9%) was the least used. Among the IDP systems, the automatic decoction and concentration machine (ADCM) (39.3%) had the highest utilization rate, while the automatic intravenous drug preparation machine (AIDPM) had the lowest utilization rate (5.8%). Among the IPDs for IDD, the barcode medication administration system (BCMA) had the highest utilization rate (81.26%), while the automatic injection dispensing machine (AIDM) had the lowest (3.6%). In the IMC stage, the Internet patient consultation system (IPCS) (26.3%) had the highest usage rate while the AI pharmacist agent (AIPA) had the lowest (3.0%). Among the IPDs for drug monitoring, the adverse drug reaction reporting system (ADRRS) had the highest utilization rate (11.9%) while the medication adherence monitoring equipment had the lowest (2.8%).

3.3. Discrepancies in utilization of IPDs

After classified by workflow stages, the utilization rates of IPD for all workflow stages in tertiary hospitals were significantly higher than those in secondary and primary hospitals (Table 1). Moreover, the utilization rates of hospitals with $\geq$ 1000 beds were significantly higher than those of hospitals with 500–1000 beds, and higher than those of hospitals with $<$ 500 beds. The usage rates of IPR, IMC, and IMM systems in hospitals with $\geq$ 7 PPBs were significantly lower than those in hospitals with 5–7 and $\leq$ 5 PPBs (Table 1).

Specifically regarding the products, the usage rates of almost all IPDs were significantly related with the level of the hospitals except for the PIS and PEPMS. The usage rates of IPDs in tertiary hospitals were significantly higher than those in secondary or primary hospitals (Table 2).

Fig. 2 illustrated the differences in implementation patterns of IPDs in hospitals with different number of beds. The usage patterns were basically the same for IDS, IPR, IMC, and IMM systems. In the IDP stage, the gap in the ADCM usage rate among hospitals of different sizes is relatively small, but there are significant differences in APM. APM has the highest usage rate in hospitals with $\geq$ 1000 beds, while it is a weak item with a low usage rate in hospitals with $<$ 500 beds. In the IDD stage, ADM is a relatively popular product in hospitals with $\geq$ 1000 beds, with a usage rate of over half, but its usage rate is less than a quarter in hospitals with $<$ 500 beds. In contrast, the promotion rate of BCMA is relatively similar among hospitals of different sizes.

In terms of the regional distribution, we observed higher rates of implementation of IPDs for drug supply in the southeast regions of China, especially in Zhejiang (93.94%) (Table 3). On the contrary, the implementation rates in the central region were relatively low, especially in Guizhou (41.67%). The implementation of IPR systems were well carried out in most parts of the country, with the highest in Shandong (100%) and slight deficiencies in some parts of the southwest and northeast like Xizang Autonomous Region (60%). The provinces with highest rates for implementation of IDP systems were Zhejiang (90.91%) and Chongqing (89.47%), while the provinces with poor construction include Xizang Autonomous Region (20%) and Guizhou (29.17%). The

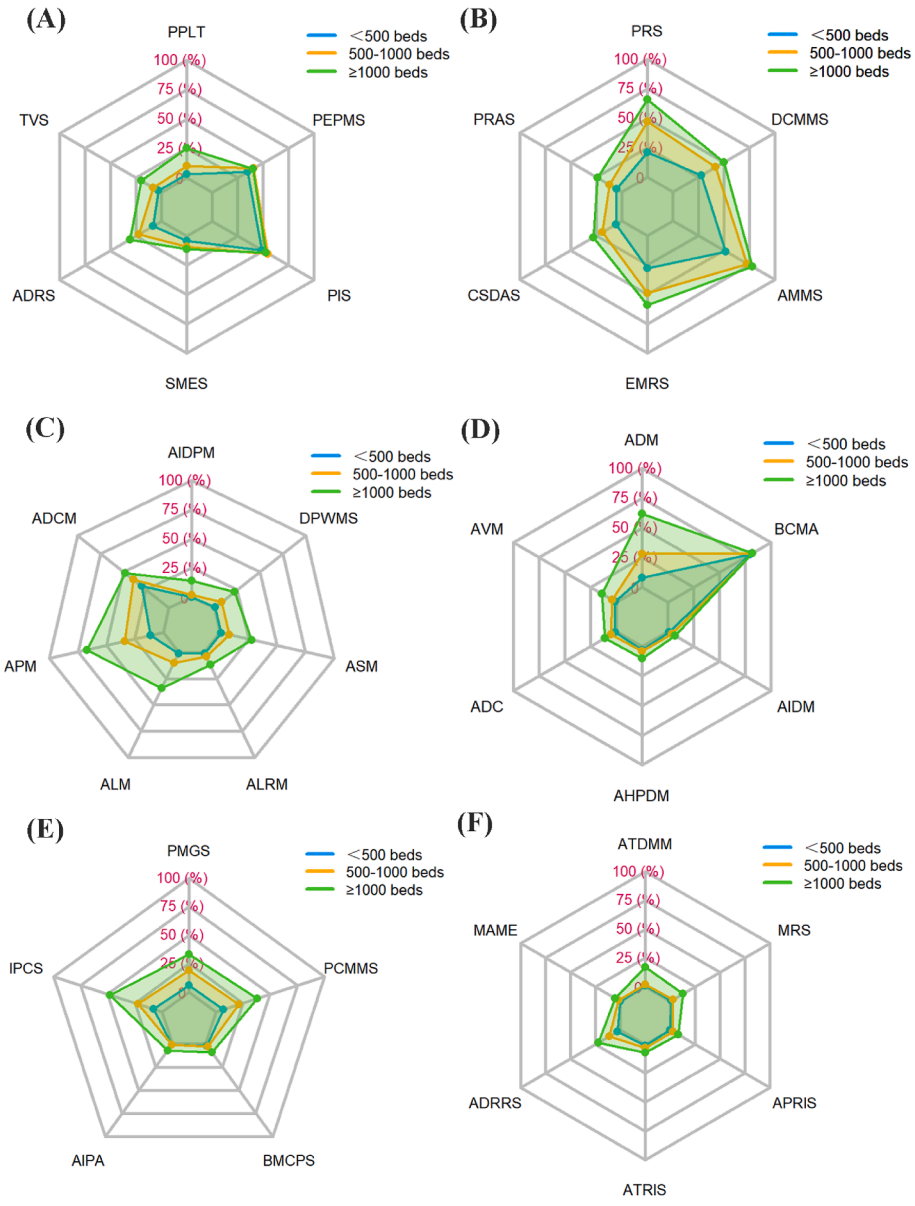


Fig. 2. The discrepancies in IPD utilization rates among hospitals with different number of beds (A: Intelligent systems for drug supply (IDS), B: Intelligent systems for prescription review (IPR), C: Intelligent drug preparation (IDP), D: Intelligent drug dispensing (IDD), E: Intelligent medication consultation (IMC), F: Intelligent medication monitoring (IMM)).

Note: PIS: Pharmaceutical Inventory System; PEPMS: Pharmaceutical Expiry Period Management System; ADRS: Automatic Drug Request System; TVS: Tracked Vehicle System; PPLT: Pneumatic Pipeline Logistics Transmission; SMES: Supplier Management and Evaluation System; PRS: Prescription Review System; PRAS: Pharmaceutical Risk Alert System; CSDAS: Computer-Supported Dose Adjustment System; EMRS: Electronic Medication Record System; AMMS: Antibiotic Monitoring and Management System; DCMMS: Drug Cost Monitoring and Management System; APM: Automatic Packaging Machine; ALM: Automatic Labeling Machine; AIDPM: Automatic Intravenous Drug Preparation Machine; ASM: Automatic Sorting Machine; ALRM: Automatic Lid Removing Machine; ADCM: Automatic Decoction and Concentration Machine; DPWMS: Drug Preparation Workflow Management System; ADM: Automatic Dispensing Machine; AHPDM: Automated Herbal Pieces Dispensing Machine; BCMA: Barcode Medication Administration System; AVM: Automated Verification Machine; AIDM: Automated Injection Dispensing Machine; ADC: Automated Dispensing Cabinet (used by nurses); PMGS: Patient Medication Guidance System; IPCS: Internet Patient Consultation system; PCMMS: Pharmacist Consultation Message Management System; BMCPS: Bedside Medication Consultation and Popular Science; AIPA: Artificial Intelligence Pharmacist Agent; MAME: Medication Adherence Monitoring Equipment; ADRRS: Adverse drug reaction reporting system; ATRIS: Automated Therapeutic Drug Monitoring Results Interpretation System; APRIS: Automated Pharmacogenomics Results Interpretation System; MRS: Medication Reconciliation System; ATDMM: Automated Therapeutic Drug Monitoring Machine.

areas with higher implementation rates of IDD systems were mainly located in the eastern coastal areas, and the best were Tianjin, Jiangsu and Guangdong (100%). Similarly, the implementation situation of IMC systems in the eastern coastal areas were better, like Shandong (80.77%) and Zhejiang (78.79%) while the construction situation in the southwest and northeast regions was relatively poor. In terms of IMM systems, the implementation rates in the southeastern areas is still a little better, and the implementation rate in Hunan is the best (50%), while the construction situation in the southwest and northeast regions is poor. Overall, the development of intelligent pharmacy is relatively better in the southeast of China than in the northwest and northeast.

4. Discussion

This nationwide survey including 1,126 hospitals from 31 provincial administration regions across China investigated the current status of the implementation of intelligent pharmacy technologies in hospitals. Our results highlight an uneven development pattern of intelligent pharmacy in China, suggesting that regional resources, institutional capacities, and workforce distribution may play critical roles in shaping implementation of the intelligent pharmacy technologies. Importantly, this study provides empirical evidence to inform policymakers in designing targeted strategies to promote more balanced and equitable development of intelligent pharmacy in the future.

The development of intelligent pharmacy was uneven and the level of the hospital and the number of beds are important factors affecting the implementation of intelligent pharmacy. The utilization rates of IPDs in tertiary hospitals were significantly higher than those in secondary and primary hospitals, because tertiary hospitals typically had more financial investment, scientific research funding, information investment and technology procurement capabilities to purchase complex intelligent pharmacy systems. Similarly, hospitals with $\geq$ 1000 beds exhibited significantly higher implementation rates than those with fewer beds, particularly for complex systems such as APM and ADM. Interestingly, however, the usage rates of IPR, IMC, and IMM systems were relatively lower in hospitals with a larger number of pharmacists

Table 3
The utilization rates of IPDs in different regions in China

Provinces	IDS	IPR	IDP	IDD	IMC	IMM
Anhui	67.27%	85.45%	76.36%	90.91%	54.55%	23.64%
Beijing	63.83%	82.98%	76.60%	93.62%	40.43%	21.28%
Fujian	60.00%	66.67%	46.67%	73.33%	20.00%	13.33%
Gansu	64.52%	83.87%	61.29%	83.87%	35.48%	12.90%
Guangdong	72.41%	86.21%	58.62%	100.00%	41.38%	13.79%
Guangxi	60.87%	95.65%	65.22%	82.61%	43.48%	34.78%
Guizhou	41.67%	83.33%	29.17%	83.33%	37.50%	12.50%
Hainan	50.00%	68.75%	56.25%	87.50%	25.00%	9.38%
Hebei	66.67%	92.98%	50.88%	89.47%	28.07%	10.53%
Henan	70.31%	93.75%	75.00%	95.31%	57.81%	39.06%
Heilongjiang	71.43%	77.14%	54.29%	94.29%	42.86%	14.29%
Hubei	65.22%	88.41%	68.12%	71.01%	47.83%	23.19%
Hunan	75.00%	95.00%	70.00%	55.00%	60.00%	50.00%
Jilin	73.17%	73.17%	46.34%	73.17%	29.27%	7.32%
Jiangsu	82.76%	96.55%	82.76%	100.00%	68.97%	37.93%
Jiangxi	68.75%	90.63%	65.63%	87.50%	46.88%	21.88%
Liaoning	73.77%	78.69%	52.46%	93.44%	45.90%	19.67%
Inner Mongolia	47.06%	94.12%	58.82%	70.59%	35.29%	17.65%
Ningxia	69.57%	73.91%	39.13%	86.96%	43.48%	13.04%
Qinghai	75.00%	87.50%	37.50%	62.50%	50.00%	0.00%
Shandong	76.92%	100.00%	80.77%	92.31%	80.77%	42.31%
Shanxi	59.18%	64.29%	39.80%	88.78%	15.31%	9.18%
Shaanxi	53.85%	82.05%	64.10%	89.74%	38.46%	25.64%
Shanghai	51.72%	75.86%	58.62%	93.10%	51.72%	17.24%
Sichuan	62.86%	82.86%	62.86%	85.71%	60.00%	8.57%
Tianjin	75.00%	79.17%	70.83%	100.00%	50.00%	16.67%
Xizang	80.00%	60.00%	20.00%	50.00%	0.00%	0.00%
Xinjiang	78.26%	89.13%	58.70%	91.30%	50.00%	19.57%
Yunnan	44.74%	71.05%	76.32%	76.32%	39.47%	21.05%
Zhejiang	93.94%	93.94%	90.91%	96.97%	78.79%	36.36%
Chongqing	65.79%	89.47%	89.47%	94.74%	71.05%	34.21%

($\geq$ 7 PPBs). These systems were all for medication medication processes which need more professional knowledge. The hospitals with more pharmacists may have developed a habitual work pattern, thus reducing their acceptance of innovative technologies. On the contrary, hospitals with lesser pharmacists have a heavier workload, and pharmacists lack the time and energy to engage in patient health-related work. Therefore, they are more eager to use technological innovation to streamline work processes.

Hospitals in the eastern coastal regions, particularly Zhejiang, Jiangsu, and Guangdong, demonstrated markedly higher adoption rates in multiple types of IPDs. The development of intelligent pharmacy is closely related to the economic development.[13] Disparities in the advancement of intelligent pharmacy across regions can often be attributed to varying economic conditions.[14] Additionally, policy initiatives play a crucial role in driving the disparities of intelligent pharmacy implementation. For instance, provinces including Jiangsu, Zhejiang, Shanghai, and Anhui have introduced an evaluation criteria for intelligent pharmacy systems.[15] This focus underscores their commitment to advancing intelligent pharmacy infrastructure, thereby accelerating its development in these regions.

Notably, the BCMA system within IDS systems was the most commonly used product (81.26%), followed closely behind by AMMS with a high implementation rate of 67.7%. These phenomena can be primarily attributed to recent national policies. The National Health Commission of China encouraged that hospitals of all levels should improve the clinical management of antimicrobial agents and promote rational utilization of antibiotics through systematic monitoring. Moreover, the National Healthcare Security Administration the nationwide regulatory application of drug traceability codes started in March 2025 to ensure the safety and authority of the drugs, and mandates that all medical institutions fully collect and upload drug traceability codes by January 1, 2026.[16–18] The results of this survey, concluded by June 2025, demonstrate that BCMA systems have already been widely implemented in most Chinese hospitals, aligning with these national directives.

In comparison with the most recent survey by the American Society of Health-System Pharmacists (ASHP) in 2023,[19] this study reveals distinct national patterns in the implementation of intelligent pharmacy technologies. In China, more than 60% of large hospitals equipped with ADM in central pharmacies, while the reported utilization rate of ADC in the wards was only 5.5%. By contrast, the ASHP 2023 survey showed that 86.1% of U.S. hospitals employed ADC in clinical units, while only 2.0% relied primarily on centralized ADM. Chinese hospitals face extremely high outpatient volumes and central pharmacy dispensing pressure,[20] which makes ADM a strategic choice for improving bulk dispensing efficiency. In the U.S., however, the hospital system places greater emphasis on point-of-care safety and timeliness for inpatients, leading to widespread adoption of ADC. This demonstrates that the integration of intelligent pharmacy equipment is not merely a matter of technology transfer but rather a context-specific decision influenced by workflow demands, cost-effectiveness, and patient service models.

With regard to other technologies, the adoption of AIDPM was relatively similar (5.8% in China vs. 3.7% in the U.S.). Moreover, BCMA has already become routine in both countries (81.3% in China vs. 73.6% in the U.S.), reflecting a shared recognition of its value for medication safety. Taken together, these findings suggest that while certain technologies demonstrate global consensus, others evolve along divergent pathways shaped by national healthcare environments. Future development of intelligent pharmacy should therefore consider not only technological advancement but also alignment with local clinical needs, patient care models, and system-level resource allocation.

There are several limitations that cannot be ignored. First, the present cross-sectional design only reflects the status of intelligent pharmacy technology utilization at one time point instead of temporal trends or causal relationships. Future researches can use longitudinal or repeated survey designs to track dynamic trends and policy impacts. Second, convenience sampling was adopted to recruit respondents, primarily through professional academic WeChat groups. This approach may limit the representativeness of the findings. However, the sample

size of this study was large (> 1000) and the characteristics of the samples were clearly illustrated suggesting that the findings retain substantial reference value.[21] Finally, although the questionnaire was developed through two rounds of Delphi methods and a pilot testing, it may not cover all the types of intelligent pharmacy technologies. Future researches regarding of International experiences may be needed to further inform strategies to optimize intelligent pharmacy development in hospitals.

5. Conclusion

This study reveals the national patterns of the implementation of intelligent pharmacy technologies in China, reflecting an uneven landscape with clear variations by region, hospital levels, size and pharmacist numbers. BCMA and ADM systems have already been widely implemented in most Chinese hospitals while little hospitals have implemented ADC systems in wards. the integration of intelligent pharmacy equipment is not merely a matter of technology transfer but rather a context-specific decision influenced by workflow demands, and patient service models.

CRediT authorship contribution statement

Wenshuo Jiang: Writing – original draft, Methodology, Investigation, Data curation. **Yuntian Wang:** Writing – review & editing, Validation, Methodology, Formal analysis. **Weizhong Shi:** Writing – review & editing, Validation, Investigation, Data curation. **Cao Li:** Visualization, Software, Formal analysis, Data curation. **Yongqiang Tang:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Zhengzhong Xu:** Writing – review & editing, Visualization, Validation, Supervision, Conceptualization. **Zhigang Zhao:** Writing – review & editing, Supervision, Methodology, Data curation, Conceptualization. **Xiaolin Yue:** Writing – review & editing, Supervision, Methodology, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Given his role as the Editor-in-Chief of the journal, Zhigang Zhao had no involvement in the peer review of this article and had no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to another journal editor. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ipha.2026.05.001.

Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

References

1. Slawomirski L. *The Economics of Patient Safety: From Analysis to Action*. 2024. Paris: Organisation for Economic Co-operation and Development; 2020.
2. Tariq RA, Vashisht R, Sinha A, Scherbak Y. *Medication Dispensing Errors and Prevention*. 2025.
3. Zhang QX, Bai XR, Wang ZM, Yan SY, Wang YQ. Annual report of national monitoring network for clinical safe medication. *Adverse Drug React J*. 2023;26:390–398.
4. Bagattini AM, Borges JLA, Riera R, de Carvalho DCMF. Automation of a tertiary hospital pharmacy drug dispensing system in a lower-middle-income country: a case study and preliminary results. *Explor Res Clin Soc Pharm*. 2022;6:100151.
5. Alanazi MF, Shahein MI, Alsharif HM, et al. Impact of automated drug dispensing system on patient safety. *Pharm Pract*. 2022;20(4):2744.
6. Lin G, Huang R, Zhang J, Li G, Chen L, Xi X. Clinical and economic outcomes of hospital pharmaceutical care: a systematic review and meta-analysis. *BMC Health Serv Res*. 2020;20(1):487.
7. Li C, Jiang W, Shen A, et al. *International expert consensus on hospital intelligent pharmacy*. *Intelligent Pharmacy*. 2025.
8. Li X, Tan B, Zheng J, Xu X, Xiao J, Liu Y. The intervention of data mining in the allocation efficiency of multiple intelligent devices in intelligent pharmacy. *Comput Intell Neurosci*. 2022;2022:5371575.
9. Zhang L, Liu W, Zhang Y. Application of intelligent intravenous drug dispensing robot in clinical nursing. *Contrast Media Mol Imaging*. 2022;2022:4769883.
10. Fernández De Gamarra-Martínez E, Tortajada-Goitia B, Corte-García JJ, et al. Hospital pharmacy towards 2030. *Farm Hosp*. 2024;48(Suppl 1):S52–S58.
11. Hanninen K, Ahtiainen HK, Suvikas-Peltonen EM, Totterman AM. Automated unit dose dispensing systems producing individually packaged and labelled drugs for inpatients: a systematic review. *Eur J Hosp Pharm*. 2023;30(3):127–135.
12. Biroudian S, Jabari K, Mirzaei P, Eskandari S, Roostaei D, Delpasand K. Evaluation of adherence to the patients' bill of rights charter in pharmacies in Iran: a descriptive-correlational study. *BMC Health Serv Res*. 2025;25(1):1148.
13. Angaran DM. Telemedicine and telepharmacy: current status and future implications. *Am J Health Syst Pharm*. 1999;56(14):1405–1426.
14. Meng F, Song F, Guo M, et al. Status and influential factors of intelligent healthcare in nursing homes in China. *Comput Inform Nurs*. 2021;39(5):265–272.
15. Shen A, Li M, Zhou W, et al. *Intelligent Pharmacy Evaluation System*. 2025. 2022.
16. National Health Commission of the People's Republic of China. *Notice of the General Office of the National Health Commission on Issuing the Monitoring Indicators for the Implementation of Core Medical Quality and Safety Systems*. 2025 Edition 2025. 2025.
17. National Healthcare Security Administration. *2025, the Supervision of Medical Insurance Funds Using Drug Traceability Codes will Come to the Forefront*. 2025. 2025.
18. Zhao Z, Wang H, Zhai J, Wang Z. Comprehensive promotion of drug traceability codes in China in 2025: challenges and solutions for tertiary outpatient pharmacists. *Front Pharmacol*. 2025;16:1619916.
19. Schneider PJ, Pedersen CA, Ganio MC, Scheckelhoff DJ. ASHP national survey of pharmacy practice in hospital settings: operations and technology - 2023. *Am J Health Syst Pharm*. 2024;81(16):684–705.
20. Gao Y, Lv Y, Wang S, et al. Implementation and evaluation of whole-course-based internet hospital outpatient pharmacy services: a cross-sectional study in western China. *Front Public Health*. 2024;12:1448471.
21. Andrade C. The inconvenient truth about convenience and purposive samples. *Indian J Psychol Med*. 2021;43(1):86–88.