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Optimizing Omnicell Automated Dispensing Cabinet Utilization Through Competency-Based Training to Strengthen Patient Safety Culture: A Quality Improvement Report, TVH, Qatar

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Abstract:
Background: *Automated Dispensing Cabinets (ADCs) are widely deployed in hospital settings to enhance medication safety and workflow efficiency. However, evidence on how system usability translates into improved patient safety culture remains limited, particularly regarding the role of staff training and competency.*
Aim: *This quality improvement (QI) initiative measured the direct and indirect relationships between perceived Omnicell ADC usability, training and competency effectiveness, and patient safety culture among nurses at a JCI-accredited tertiary hospital in Qatar, to generate evidence that informs targeted improvement interventions.*
Methods: *A service evaluation design was employed with a census of 206 nurses actively using the Omnicell system. Three validated measurement tools were administered: the Omnicell Usability Survey (SUS and UMUX-Lite subscales; α = .755), the Training and Competency Effectiveness Scale (α = .804), and an adapted 12-item Hospital Survey on Patient Safety Culture (HSOPSC; α = .898). Pearson correlation and hierarchical multiple linear regression were used to identify performance gaps and guide intervention priorities.*
Results: *Training and competency effectiveness was strongly correlated with patient safety culture ($r = .732$, $p < .001$), whereas Omnicell usability showed no significant direct association with safety culture ($r = .035$, $p = .621$). Hierarchical regression revealed that training effectiveness increased explained variance in safety culture from 0.1% to 55.9% ($R^2 = .559$, $F(2,203) = 128.467$, $p < .001$; $\beta = .770$).*
Conclusion and QI Implications: *Training and competency effectiveness, not system usability, was the strongest correlation of patient safety culture in this initiative. A structured, competency-based, cyclical training program represents the highest-priority improvement target for hospitals seeking to translate ADC technology into genuine patient safety gains. Seven KPIs were established for re-measurement at 6 and 12 months, including patient safety culture score (target ≥ 49.6; baseline moderate high: 94.6%), training effectiveness (target ≥ 97.6% sustained; baseline moderate high: 97.6%), competency pass rate (target ≥ 95%), barcode medication scanning compliance (target ≥ 95%; from 60% baseline), ADC-related medication error rate (target < 1%; from 3% baseline), nursing absenteeism rate (target ≤ 1%; from 3% baseline), and staffing adequacy (target ≥ 50%).*

Keywords: *Quality Improvement; Automated Dispensing Cabinets; Omnicell; Patient Safety Culture; Training Effectiveness; Nursing Competency; Medication Safety; Service Evaluation; Qatar*

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I. Background

Nurses are the primary professionals responsible for medication administration in inpatient settings. Their duties verifying prescriptions, selecting correct medications and dosages, administering on schedule, and completing documentation occur within high-pressure clinical environments characterized by heavy workloads, frequent interruptions, and cognitive demand. Medication errors, including omission errors, wrong-drug or wrong-dose events, and documentation failures, constitute a persistent patient safety challenge in acute care hospitals [1]. Contributing factors span both human dimensions fatigue, distraction, and cognitive overload and

system-level deficiencies, including disorganized medication storage, fragmented distribution, and inadequate real-time inventory control [2, 3].

Automated Dispensing Cabinets (ADCs) emerged as a technological response to these challenges. Contemporary systems incorporate patient-specific drawers, barcode verification, electronic health record (EHR) integration, and comprehensive audit trail capabilities designed to reduce medication administration errors, improve inventory accuracy, and support regulatory compliance [6, 7]. Evidence on ADC effectiveness is broadly positive but equivocal: while reductions in omission and wrong-drug errors have been documented, operational challenges — including workflow disruptions, technology malfunctions, and workarounds that circumvent safety safeguards — are also well-evidenced [8–10]. These findings consistently indicate that ADC safety benefits are not inherent to the technology itself but depend on contextual factors including user training, staffing adequacy, and system integration within broader safety frameworks [10].

The View Hospital (TVH), a JCI-accredited tertiary facility in Doha, Qatar (~240 beds), deployed the Omnicell ADC system across all clinical units. Following full deployment, internal observation and staff feedback identified variability in system utilization, persistent reports of drug misplacements and inventory discrepancies, and perceived gaps in training adequacy. These performance signals prompted this structured quality improvement initiative, designed within the hospital's clinical governance framework to measure current performance, identify root causes, and generate evidence for targeted interventions.

QI Objectives

This initiative aimed to: (1) measure the current levels of Omnicell ADC usability, training and competency effectiveness, and patient safety culture among nursing staff; (2) quantify the relationships between these dimensions to identify the highest-leverage improvement target; and (3) use these findings to inform a structured, evidence-based intervention plan aligned with the hospital's patient safety priorities.

QI Questions

Q1: What is the current level of perceived Omnicell usability, training effectiveness, and patient safety culture among nurses?
Q2: Is there a significant association between Omnicell usability and patient safety culture?
Q3: Is there a significant association between training and competency effectiveness and patient safety culture?
Q4: Does training and competency effectiveness mediate the relationship between Omnicell usability and patient safety culture?

II. Methods

QI Design and Setting

This initiative used a service evaluation design a systematic measurement of current performance against defined quality standards conducted at The View Hospital, Doha, Qatar. TVH is a JCI-accredited tertiary hospital with approximately 240 beds, providing emergencies, ICU, cardiac catheterization, endoscopy, obstetrics and gynecology, pediatrics, and ambulatory services. The Omnicell ADC system is deployed across all clinical units as part of the hospital's medication management infrastructure.

Participants

A census approach targeted all eligible nursing staff (n = 206) meeting the following criteria: (1) active clinical practice involving direct Omnicell ADC use; (2) minimum six months of Omnicell experience in daily workflow; and (3) basic system proficiency acquired through formal orientation, structured training, or supervised on-the-job experience. Nurses with less than six months of Omnicell exposure were excluded to ensure adequate system familiarity. Participation was entirely voluntary.

Measurement Tools

Tool I: Omnicell Usability Survey: Developed and validated by Eap and Ben Ramadan (2022), this 19-item questionnaire measures nurses' perceptions of Omnicell ADC usability and satisfaction [16]. Usability items draw from two validated scales: the System Usability Scale (SUS; 10 items) and the Usability Metric for User Experience – Lite (UMUX-Lite; 2 items), both rated on a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). Three open-ended items elicit qualitative feedback on system strengths, inconveniences, and persistent operational gaps. Internal consistency was acceptable (Cronbach's $\alpha = .755$).

Tool II: Training and Competency Effectiveness Scale: A composite instrument comprising two parts. Part 1 is an 8-item Training Effectiveness Subscale structured across four dimensions based on Omer's (2021) empirical training effectiveness framework trainer performance, training design, training needs determination, and trainee performance expanding two validated items from Zaidan et al. (2016) as employed by Alomair et al.

(2024) [17–20]. Scores range from 8–40, with thresholds of 32–40 (high), 20–31 (moderate), and < 20 (low, requiring intervention). Part 2 is the 16-item Healthcare Providers' Competency Scale a structured observational tool developed by TVH's Learning and Development Team assessing performance across medication safety, infection control, documentation, and Omnicell device handling, scored as Done (1) or Not Done (0). Overall reliability was good (Cronbach's α = .804).

Tool III: Adapted HSOPSC: A 12-item version of the Hospital Survey on Patient Safety Culture (Sorra & Nieva, 2004; AHRQ), adapted to three dimensions relevant to ADC medication management: Staffing and Workflow Adequacy (4 items), Frequency of Events Reported (4 items), and Communication Openness (4 items). Items are rated on a five-point Likert scale; total scores range from 12–60 with higher scores indicating stronger safety culture. Reliability was excellent in this initiative (Cronbach's α = .898) [20].

Data Collection

An anonymous self-administered survey incorporating all three tools was distributed to all eligible nursing staff over a six-week period, facilitated by unit-level charge nurses. Open-ended qualitative responses were analyzed thematically to triangulate and contextualize quantitative findings. The response rate was 100%, reflecting the census approach and institutional endorsement of the initiative.

Governance and Ethical Considerations

This initiative was conducted as a service evaluation within TVH's clinical governance and quality improvement framework, consistent with the hospital's JCI accreditation standards for internal performance measurement. The initiative was reviewed and approved by the Chief Nursing Officer (CNO). No patient data was collected; measurement was limited to de-identified, voluntary, anonymous staff perceptions. No formal ethics committee review was required under the hospital's governance policy for QI and service evaluation activities. All principles of the Declaration of Helsinki were observed with respect to voluntary participation, anonymity, and confidentiality.

Analysis

Data was analyzed using IBM SPSS Statistics Version 29. Descriptive statistics (frequencies, percentages, means, standard deviations) were computed for all variables. Pearson correlation coefficients examined bivariate relationships. Hierarchical multiple linear regression was conducted in two steps: Model 1 entered Omnicell usability as the sole predictor of patient safety culture; Model 2 added training effectiveness to test its incremental contribution and mediating role. Statistical significance was set at $p \leq .05$.

III. Results: Performance Measurement

Workforce Profile

The census comprised 206 nurses. The majority (72.3%, n = 149) were aged 30–<40 years, with a mean nursing experience of 9.46 ± 5.12 years. Female nurses constituted 70.9% (n = 146) of the workforce. Mean Omnicell familiarity was 1.85 ± 0.833. Table 1 presents the full demographic distribution.

Table 1. Workforce profile of participating nurses (n = 206)

Characteristic	Category	n	%
Age (years)	20–30	38	18.4
	30–<40	149	72.3
	40–<50	19	9.2
Gender	Male	60	29.1
	Female	146	70.9
Nursing Experience (years)	1–5	53	25.7
	5–<10	16	7.7
	10–<15	96	46.6
	≥ 15	41	19.9
Mean ± SD [9.46 ± 5.12]			
Omnicell Familiarity	Mean ± SD [1.85 ± 0.833]		

Current Performance Levels

Table 2 presents the measured performance levels for each QI dimension. Overall Omnicell usability was moderate for the majority (68.9%; Mean = 43.70 ± 5.85). A notable divergence emerged between subscales: 72.8% scored at a moderate level on the SUS (Mean = 35.27 ± 5.25), while 89.8% scored high on the

UMUX-Lite (Mean = 8.42 ± 1.07), indicating that nurses perceive the system as meeting their needs in principle while experiencing day-to-day operational friction.

Training effectiveness was high for 57.8% (Mean = 29.78 ± 4.58). Trainee Performance was the strongest subscale (66.5% high), while Training Design had the highest rate of low scores (7.3%), signaling that individual nurses perform adequately post-training, but the structural design of training programmed requires improvement.

Patient safety culture was high for 48.5% (Mean = 43.14 ± 8.99). Communication Openness was the strongest dimension (62.1% high; Mean = 15.13 ± 3.63). Staffing and Workflow Adequacy was the most critical performance gap, with only 30.1% scoring at a high level (Mean = 13.25 ± 2.93) and the majority (63.6%) at a moderate level.

Table 2. Performance measurement across QI dimensions (n = 206)

Dimension	Low n (%)	Moderate n (%)	High n (%)	Mean ± SD
Omnicell Usability (Total)	—	142 (68.9)	64 (31.1)	43.70 ± 5.85
SUS Subscale	—	150 (72.8)	56 (27.2)	35.27 ± 5.25
UMUX-Lite Subscale	—	21 (10.2)	185 (89.8)	8.42 ± 1.07
Training Effectiveness (Total)	5 (2.4)	82 (39.8)	119 (57.8)	29.78 ± 4.58
Trainer Performance	5 (2.4)	86 (41.7)	115 (55.8)	7.50 ± 1.29
Training Design	15 (7.3)	82 (39.8)	109 (52.9)	7.21 ± 1.76
Training Needs Determination	11 (5.3)	83 (40.3)	112 (54.4)	7.24 ± 1.64
Trainee Performance	0 (0.0)	69 (33.5)	137 (66.5)	7.81 ± 1.01
Patient Safety Culture (Total)	11 (5.3)	95 (46.1)	100 (48.5)	43.14 ± 8.99
Staffing & Workflow Adequacy	13 (6.3)	131 (63.6)	62 (30.1)	13.25 ± 2.93
Frequency of Events Reported	13 (6.3)	73 (35.4)	120 (58.3)	14.75 ± 3.50
Communication Openness	12 (5.8)	66 (32.0)	128 (62.1)	15.13 ± 3.63

Correlation Analysis: Identifying the Primary Improvement Lever

Table 3 presents Pearson correlation coefficients. Training effectiveness demonstrated a strong positive correlation with patient safety culture ($r = .732$, $p < .001$), identifying it as the dominant performance lever for safety culture improvement. Omnicell usability showed a weak but significant correlation with training effectiveness ($r = .246$, $p < .001$). Critically, Omnicell usability showed no significant direct association with patient safety culture ($r = .035$, $p = .621$), confirming that technology deployment alone does not drive safety culture outcomes.

Table 3. Correlation matrix: Omnicell usability, training effectiveness, and patient safety culture (n = 206) ** p < .001

Variable	1. Omnicell Usability	2. Training Effectiveness	3. Patient Safety Culture
1. Omnicell Usability	—		
2. Training Effectiveness	r = .246** p < .001	—	
3. Patient Safety Culture	r = .035 p = .621	r = .732** p < .001	—

Regression Analysis: Quantifying the Training–Safety Culture Pathway

Hierarchical multiple regression tested the mediating role of training effectiveness. Model 1 (Omnicell usability alone) was not significant ($F(1, 204) = .245$, $p = .621$; $R^2 = .001$), confirming the absence of a direct usability-to-safety-culture effect. Model 2 adding training effectiveness was highly significant ($F(2, 203) = 128.467$, $p < .001$) and explained 55.9% of variance in patient safety culture ($R^2 = .559$, Adjusted $R^2 = .554$). Training effectiveness was the dominant positive predictor ($B = 1.511$, $\beta = .770$, $p < .001$): each one-unit increase in training effectiveness corresponded to a 1.511-unit increase in safety culture score. Notably, Omnicell usability became a statistically significant negative predictor when controlling for training ($B = -.237$, $\beta = -.155$, $p = .002$), suggesting a suppressor effect usability perception without structured competency development may not improve and can detract from safety culture, consistent with automation complacency phenomena documented in the patient safety literature [8, 10]. Table 4 presents full regression output.

Table 4. Hierarchical regression predicting patient safety culture (n = 206)

Parameter	Model 1 (Usability only)	Model 2 (Usability + Training)
R	.035	.747
R^2	.001	.559
Adjusted R^2	−.004	.554
Std. Error of Estimate	9.010	6.004
F	.245	128.467
Sig.	.621	< .001
Constant (B)	40.822 (p < .001)	8.526 (p = .024)

Omnicell Usability (B; β)	.053; β = .035 (p = .621)	−.237; β = −.155 (p = .002)
Training Effectiveness (B; β)	—	1.511; β = .770 (p < .001)

IV. Discussion: Interpreting Performance Gaps

Omnicell Usability: Conceptual Acceptance, Operational Friction

The finding that most nurses (68.9%) demonstrated a moderate level of overall Omnicell usability, with a divergence between the UMUX-Lite (89.8% high) and SUS (72.8% moderate), reflects a pattern consistent with ADC implementation literature: nurses accept the system's value in principle while experiencing friction in day-to-day use [17]. Qualitative responses confirmed these nurses valued medication error prevention, organized dispensing, and inventory tracking, while identifying slow system response times, login delays, barcode scanner malfunctions, and stock visibility gaps as recurring operational barriers. These barriers are well-documented in ADC safety literature and represent actionable targets for technical improvement [10].

Technology Alone Does Not Drive Safety Culture

The absence of a significant direct relationship between Omnicell usability and patient safety culture ($r = .035$, $p = .621$; $R^2 = .001$) is the most operationally significant performance measurement finding of this initiative. It directly challenges the assumption common in technology procurement decisions that a more usable system will straightforwardly produce stronger safety culture. Abdelwanis et al. [14] similarly found that safety benefits of healthcare technology adoption depend on organizational readiness and workforce preparedness rather than on system features per se. Nurses who expressed satisfaction with Omnicell did not automatically report stronger safety culture; rather, they cited staffing shortfalls, residual human error, and training gaps as persistent barriers to safe medication management despite the system's safeguards.

Training is the Highest-Leverage QI Target

Training and competency effectiveness emerged as the dominant performance driver in this initiative, consistent with QI objectives Q3 and Q4. The correlation between training effectiveness and patient safety culture ($r = .732$) is among the strongest bivariate associations reported in comparable ADC evaluations. The regression findings are even more compelling: adding training effectiveness to the model increased explained variance from 0.1% to 55.9%, with each unit improvement in training effectiveness corresponding to a 1.511-unit increase in safety culture scores ($\beta = .770$, $p < .001$). This finding is consistent with Ibrahim et al. [12], who identified training-related variables as pivotal mediators of patient safety competency and safety outcomes.

The suppressor effect for Omnicell usability in Model 2 ($\beta = -.155$, $p = .002$) is a clinically important finding: when nurses perceive the system as highly usable without receiving structured competency development, they may develop automation complacency bypassing safety verification steps such as barcode checking and double-checking documentation [8, 10]. This risk is amplified in the ADC context by the high-stakes nature of controlled substance dispensing. Qualitative data reinforced the centrality of training — nurses most frequently requested routine refresher training, narcotics management modules, one-on-one instruction, and accessible quick-reference guides. The finding that Training Design was the weakest subscale (7.3% low) while Trainee Performance was the strongest (66.5% high) indicates a structural gap: individual nurses perform adequately but the architecture of training programmed needs assessment, design, and sequencing requires targeted redesign [18, 19].

Staffing is a Critical Systemic Gap

Staffing and Workflow Adequacy was the most critical performance gap in patient safety culture (30.1% high; Mean = 13.25 ± 2.93), with most nurses (63.6%) scoring at a moderate level. Qualitative responses confirmed this with urgency: nurses described difficulty obtaining witness signatures during understaffed shifts, recommended additional ADC units per floor, and specifically identified the shared-cabinet model as a source of dispensing errors and delays. Hariyati et al. [2] identified workload as the most important contributing factor to medication errors by nurses a conclusion that resonates directly with the TVH performance data. Technology deployment without commensurate investment in human resources can paradoxically increase patient safety risk rather than mitigate it [5, 8].

Communication Openness as a Strength to Leverage

Communication Openness (62.1% high; Mean = 15.13 ± 3.63) and Frequency of Events Reported (58.3% high; Mean = 14.75 ± 3.50) were the strongest safety culture dimensions, reflecting the reporting-positive culture associated with TVH's JCI accreditation. The qualitative responses further demonstrated by these nurses offered specific, actionable recommendations rather than general dissatisfaction, indicating a workforce engaged with improvement. Mistri et al. [15] identified communication openness and event reporting as active drivers of safety improvement when supported by institutional feedback mechanisms. Establishing

structured reporting and review cycles for ADC-related events represents a high-yield, low-cost intervention that capitalizes on this existing cultural strength.

V. QI Interventions: PDCA Framework

The performance measurement findings directly informed of a structured improvement plan implemented using the Plan-Do-Check-Act (PDCA) cycle. The following summarizes each phase. A detailed PDCA project report has been separately prepared for clinical governance submission.

PLAN: Root Cause Analysis and Improvement Priorities

Root cause analysis identified five primary gap categories: (1) Training and competency : single-event onboarding, no refresher cycle, gaps in narcotics protocols; (2) Equipment reliability : scanner malfunctions, slow system response, stock visibility discrepancies; (3) Staffing and workflow :insufficient nurse-to-cabinet ratios, shared-cabinet design, difficulty obtaining witnesses during high-acuity periods; (4) Communication and reporting :inconsistent near-miss documentation, no formal ADC-specific feedback loop; (5) Training programmed design " inadequate needs assessment, poorly sequenced content, absence of controlled substance competency modules.

DO: Interventions Implemented

Four parallel interventions were initiated. First, a structured competency-based training program was developed using Kirkpatrick's Four-Level Evaluation Model, incorporating: mandatory one-on-one orientation before independent ADC access, biannual unit-based refresher sessions, a targeted narcotics management and override protocol module, and laminated quick-reference guides posted at each ADC station. Second, a preventive maintenance protocol for barcode scanners was established (monthly inspection, quarterly calibration) with a defined escalation pathway for system failures. Third, a briefing was delivered to nursing leadership presenting the Staffing and Workflow Adequacy performance gap data, with a structured proposal for flexible staffing during high-acuity hours.

CHECK: Monitoring and KPIs

Key performance indicators were established for measurement at 6 and 12 months post-intervention. Primary KPIs include: (1) overall patient safety culture score: target ≥ 15% improvement from baseline (≥ 49.6); (2) Staffing and Workflow Adequacy high-level rate: target ≥ 50% (from 30.1% baseline); (3) training effectiveness high or moderate rate: target ≥ 97.6% sustained (from 97.6% baseline); (4) competency assessment pass rate: target ≥ 95% post-training; (5) ADC-related medication error rate: target < 1%, providing an outcome-level indicator of the training intervention's downstream impact on safe medication administration; (6) barcode medication scanning compliance: target ≥ 95% (from 60% institutional baseline), directly measuring reduction in the automation complacency behaviors identified as a safety risk in Section 4.3; and (7) nursing absenteeism rate: target ≤ 1% (from 3% institutional baseline), as a measurable proxy for the Staffing and Workflow Adequacy gap identified as the most critical performance gap in patient safety culture.

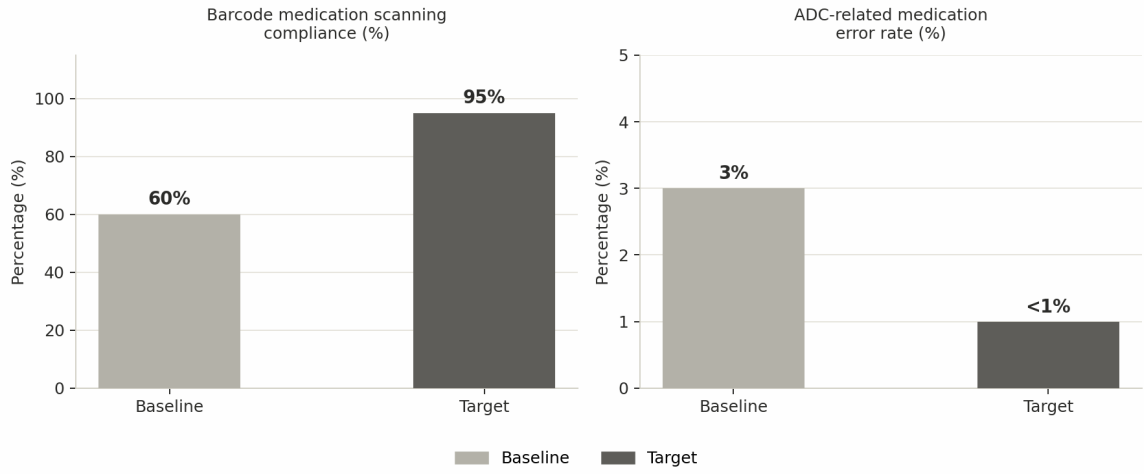

Figure 1. Baseline vs. target KPI comparison: barcode medication scanning compliance and ADC-related medication error rate.

ACT: Standardization and Next Cycle

Successful interventions will be standardized into TVH's annual Nursing Education Calendar and incorporated into the nursing performance appraisal framework. Findings have been submitted to the Nursing Knowledge, Innovation and Improvement (NKI&I) Committee and the Evidence-Based Practice and Research (EPP) Committee for governance review and institutional endorsement. A second PDCA cycle has been planned to address: dedicated Omnicell units per clinical unit (replacing the shared-cabinet model), real-time inventory synchronization with pharmacy systems, and a longitudinal digital competency dashboard for ongoing monitoring.

VI. Conclusion

This quality improvement initiative provides robust measurement evidence that training and competency effectiveness not Omnicell system usability is the primary driver of patient safety culture among nurses using automated dispensing cabinets. With training effectiveness accounting for 55.9% of variance in safety culture scores and a standardized effect of $\beta = .770$, the operational implication is clear: investment in structured, sustained, competency-based training programmed is the highest-yield strategy for translating ADC technology into genuine patient safety gains. Staffing adequacy emerged as a systemic performance gap requiring urgent leadership attention, while the high communication openness scores offer a cultural foundation on which structured reporting and improvement cycles can be built. These findings have been used to develop and implement a PDCA-structured improvement plan, with formal re-measurement planned at 6 and 12 months post-intervention.

VII. Limitations

This initiative was conducted at a single JCI-accredited tertiary hospital in Qatar, limiting generalizability to other settings, cultural contexts, or ADC platforms. The service evaluation design does not permit causal inference, and self-report bias may have influenced usability and safety culture scores. Open-ended qualitative responses were variable in depth and length, limiting systematic thematic analysis. Future evaluations should incorporate longitudinal measurement, multi-site designs, and objective performance metrics including dispensing error rates and near-miss logs to strengthen causal attribution.

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Conflict of Interest: The authors declare no conflict of interest.

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