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BLUEPRINT FOR PREDICTIVE CONTROL: LEVERAGING RETROSPECTIVE HAI DATA TO ARCHITECT AI-READY INFECTION SURVEILLANCE IN A RESOURCE-CONSTRAINED TEACHING HOSPITAL

Hospital Administration

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ABSTRACT

Healthcare-associated infections (HAIs) such as CAUTI, SSI, and VAP remain a persistent challenge in low- and middle-income countries (LMICs), with prevalence rates as high as 15% among hospitalized patients. Traditional surveillance systems are delayed and reactive, limiting their capacity for early intervention. **Objective:** To evaluate the effectiveness of HAI Shield, a zero-budget digital surveillance system, and outline a feasible pathway toward AI-driven predictive infection control within resource constraints. **Methods:** Implemented in January 2025 at a 1,050-bed teaching hospital in rural Telangana, HAI Shield utilized Microsoft Excel for daily risk scoring and Google Sheets for dashboards and automated alerts. HAI data from July 2024 to June 2025 were retrospectively and prospectively compared. Staff feedback and operational workflows were reviewed. **Results:** Overall HAIs fell by 40% (from 10 to 6 cases). CAUTI was completely eliminated; SSI dropped by 20%; VAP remained stable. Early alerts enabled timely intervention in 5 out of 7 flagged high-risk cases. ICN rounds became approximately 35% more efficient, and staff compliance with infection control protocols improved. **Conclusion:** HAI Shield demonstrates that frugal digital tools can deliver measurable infection control benefits. The model is AI-ready, scalable across hospital domains, and offers a low-cost blueprint for transforming hospital safety practices.

KEYWORDS

HAI, digital surveillance, infection control, frugal innovation, AI-ready framework, teaching hospital

INTRODUCTION :

Hospital-acquired infections (HAIs) such as catheter-associated urinary tract infections (CAUTI), surgical site infections (SSI), and ventilator-associated pneumonia (VAP) are significant contributors to morbidity, mortality, and escalating healthcare costs, particularly in Indian teaching hospitals. Recent surveillance data indicate up to 15% HAI prevalence in LMIC hospitals, with ICU settings in India reporting CAUTI rates between 1.7–2.8 per 1,000 catheter-days and CLABSI up to 12.1 per 1,000 line-days [1, 3]. One five-year ICU study reported an HAI incidence rate of 31.7%, doubling length of stay and markedly increasing mortality risk [4]. ICMR data further indicate SSI rates of 5.2% in Indian surgical patients , higher than the 1.2–5.2% range observed in high-income settings [5].

These elevated rates, compounded by rising antimicrobial resistance, underscore the urgency of proactive surveillance systems. Traditional infection prevention and control (IPC) systems in Indian hospitals rely on retrospective microbiology data and manual audits, which fail to provide early warning. With health spending around 1.3% of GDP, investment in hospital information systems (HIS) remains uncommon and often prohibitively expensive, especially in rural or semi-urban regions [2].

Kamineni Institute of Medical Sciences identified recurring HAIs between July and December 2024 through conventional ICC reporting. Recognising the need for proactive intervention, the infection control team implemented HAI Shield in January 2025 , a rule-based, digital surveillance platform leveraging Microsoft Excel and Google Sheets. The system enabled daily risk scoring, ward-level heatmaps, alert-driven rounds, and weekly dashboards. This paper evaluates the system's clinical impact over 12 months and proposes methods to scale it toward AI-driven predictive surveillance.

AIM:

To assess the effectiveness of HAI Shield, a zero-budget digital surveillance system, in reducing HAIs and improving infection control workflows in a resource-constrained teaching hospital.

OBJECTIVES:

1. Quantify baseline HAI incidence between July and December 2024.
2. Implement HAI Shield in January 2025.
3. Compare HAI trends before and after the intervention.
4. Document operational improvements and staff adoption.
5. Propose scalable expansion to other hospital functions and outline a low-budget AI integration roadmap.

METHODOLOGY

Study Design and Setting:

A retrospective–prospective observational study conducted at a 1,050-bed teaching hospital in rural Telangana, India.

Study Period:

- Pre-intervention: 01 July – 31 December 2024
- Post-intervention: 01 January – 30 June 2025

Data Sources:

ICC-confirmed cases of CAUTI, SSI, and VAP; device usage logs; nursing notes; and ward cluster history.

HAI Shield Implementation Protocol:

1. Daily Risk Scoring: Excel-based patient-level data entry capturing duration of admission (>48 hours), device use, comorbidities, and ward cluster history. The system automatically computed risk scores (0–5) using conditional formatting , green (low), yellow (moderate), red (high).
2. Dashboards and Alerts: Weekly pivot-table reports generated and shared via Google Sheets; automatic email triggers for red-flag cases.
3. Response SOPs: Standardised workflows triggered by high-risk flags, including catheter and wound care review, antibiotic reassessment, and hand hygiene enforcement.
4. Staff Training and Monitoring: Short orientation sessions conducted; monthly ICC reviews held to assess trends and collect feedback.

DATA ANALYSIS:

Quantitative comparison of HAI incidence across two six-month periods. Qualitative summary of staff experiences and workflow changes.

RESULTS:

TABLE 1 : Pre- and Post-Intervention HAI Incidence

Period	CAUTI	SSI	VAP	TOTAL HAIs
July-December 2024	3	5	2	10
January-June 2025	0	4	2	6

- Overall HAIs decreased by 40%.
- CAUTI was completely eliminated.
- SSI reduced by 20%.
- VAP remained stable; however, earlier flagging of high-risk patients provided precursors for timely intervention.

OPERATIONAL PERFORMANCE:

- **Alert Effectiveness:** 7 patients were flagged as high-risk; 5 received targeted interventions that prevented progression to confirmed infection.
- **Efficiency:** ICN rounds became more targeted, with time reduced by approximately 35%; staff effort was concentrated on flagged wards.
- **Staff Feedback:** Users reported that dashboards were intuitive and improved compliance and accountability.

Qualitative Insights:

- Visual cues emphasised catheter and wound care interventions.
- Documentation accuracy improved across wards.
- Hospital leadership endorsed data-driven decision-making as a result of visible outcomes.

DISCUSSION:

Frugal Digital Innovation: HAI Shield demonstrates that hospitals can achieve significant infection reduction using freely available tools. Risk identification and early response transformed the infection control culture from reactive to predictive without new software, hardware, or capital expenditure. This finding is particularly significant for LMICs, where resource constraints often preclude investment in proprietary HIS or commercial surveillance platforms.

Transferable Framework: The same architecture is easily replicable across other hospital management domains, including bed utilisation monitoring, OT scheduling conflict detection, biomedical waste fill-level alerts, equipment maintenance tracking, discharge delay flagging, and patient feedback sentiment dashboards.

Policy Alignment: The model aligns with NABH audit requirements, national infection control policies, and WHO recommendations to gradually adopt intelligent surveillance in LMIC hospitals [1, 4].

Limitations:

- Single-centre scope with a limited number of HAI events
- Manual data entry carries risk of transcription error
- No formal cost-effectiveness analysis conducted
- No EHR integration at present

Despite these constraints, HAI Shield provides a clear, replicable model for building AI-ready hospital infrastructure in resource-limited settings.

CONCLUSION:

This study illustrates how rule-based, frugal digital tools can dramatically reduce HAI rates and strengthen infection control protocols in resource-limited settings. HAI Shield achieved a 40% reduction in total HAIs, eliminated CAUTIs entirely, and enhanced staff responsiveness and workflow efficiency ,all without new expenditures.Critically, the system is designed for AI evolution, with a low-budget upgrade path to predictive surveillance, NLP-based alerts, and analytics dashboards. Hospitals can start safe today with tools they already have, then progressively scale toward smart systems.

By sharing this Blueprint for Predictive Control, we propose a replicable, policy-aligned pathway for transforming hospital operations, from infection control to discharge planning and beyond ,through intelligence layering upon frugal infrastructure.

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