

Digital Revolution in Infection Surveillance: The PDTA Model of the Provincial Health Authority of Ragusa

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ABSTRACT

Background: Healthcare-associated infections (HAIs) and multidrug-resistant organisms (MDROs) pose a significant threat to patient safety and healthcare system sustainability. Prevention requires integrated, realtime, multidisciplinary approaches. **Objective:** To describe the design, implementation, and preliminary evaluation of a digitalized DiagnosticTherapeutic-Assistance Pathway (PDTA) for direct surveillance of MDROs/alert organisms, integrating artificial intelligence, electronic health records, and mobile audit tools within a provincial hospital network.

Methods: The pathway was developed by the Hospital Infection Control Committee (CC-ICA) of the Provincial Health Authority of Ragusa (Italy), involving all clinical units, the microbiology laboratory, territorial services, and general practitioners. The PDTA includes: (1) admission risk stratification; (2) electronic prescription with clinical decision support; (3) automated laboratory alerts (MALDI-TOF, PCR); (4) real-time notification and isolation activation; (5) AI-assisted case analysis and contact tracing; (6) on-site verification with digital checklists; (7) post-discharge follow-up; and (8) monthly clinical audit. The system is supported by an integrated IT architecture (Modulab 2.0, ICA-Tracker Platform, Mobile Audit App, multi-channel alert system) with full GDPR compliance. Indicators were monitored from March 2025 to March 2026 across all 8 hospital units.

Results: During the 12-month observation period: mean laboratory-to-unit notification time decreased from 6.2 to 2.8 hours ($p < 0.001$); isolation compliance improved from 78% to 96%; the electronic alert registry reached 100% completeness; on-site verification was performed within 24 hours in 98% of cases; MDRO transmission rate decreased by 28% (from 3.2 to 2.3 episodes/1,000 patient-days; $p = 0.018$); broad-spectrum antibiotic consumption decreased by 22% ($p < 0.001$); and user satisfaction scored 4.3/5. The system adoption rate was 92%.

Conclusions: A digitalized, multidisciplinary PDTA significantly improves HAI surveillance, reduces MDRO transmission, enhances antimicrobial stewardship, and increases process compliance. This model is replicable and scalable in other regional and national healthcare settings.

1. INTRODUCTION

Healthcare-associated infections (HAIs) caused by multidrug-resistant organisms (MDROs) represent one of the main threats to patient safety and the economic sustainability of healthcare systems globally [1,2]. In Europe, MDROs are estimated to be responsible for over 30,000 attributable deaths each year, with considerable direct and indirect healthcare costs [3].

Traditional infection prevention and control (IPC) strategies, although effective in principle, often suffer from communication delays, fragmented pathways, suboptimal adherence, and lack of real-time data integration [4,5]. The COVID-19 pandemic further highlighted the need for agile surveillance systems, supported by digital tools, capable of ensuring rapid and coordinated responses [6].

Recently, substantial evidence has supported the use of structured diagnostic-therapeutic-assistance pathways (PDTAs) incorporating digital tools. Stone et al. (2022) demonstrated a 40% reduction

in hospital transmission and 35% reduction in MDRO-related mortality with structured pathways [7]. Huang et al. (2022) showed that universal digital screening reduces late-onset nosocomial infections by 30% [8]. Furthermore, predictive algorithms for MDRO risk have achieved AUC values > 0.85 , enabling targeted interventions [9].

In response to national and international recommendations - including the National Action Plan on Antimicrobial Resistance (PNCAR) 2022-2025 [10], ECDC guidelines on the alert-response approach [11], and WHO core components of IPC programs [12] - the Provincial Health Authority of southeastern Sicily designed and implemented an integrated digitalized PDTA for direct MDRO surveillance. The pathway involves all clinical units, the microbiology laboratory, territorial services, general practitioners, and the Hospital Infection Control Committee (CC-ICA).

This article describes the PDTA architecture, the implementation process, and the preliminary results



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obtained over a 12-month period, with the aim of providing a replicable model for other healthcare settings seeking to modernize their IPC strategies through digital transformation.

2. MATERIALS AND METHODS

2.1. Study Design and Setting

This is an observational, prospective implementation study conducted at the Provincial Health Authority of Ragusa, which includes:

- 8 hospital units (acute care, long-term care, hospice) distributed across four hospital sites: PO Giovanni Paolo II in Ragusa, PO Guzzardi in Vittoria, PO R. Margherita in Comiso, PO N. Baglieri in Modica;
- 3 microbiology laboratories;
- Territorial health services;
- Approximately 1,200 beds and 4,500 healthcare workers.

The implementation period was March 2024 - February 2025 (12 months), with data collection extended to March 2026 for outcome evaluation.

2.2. PDTA Development and Governance

The PDTA was developed by the CC-ICA, a multidisciplinary committee composed of:

- Infection control specialists
- Infectious disease physicians
- Microbiologists
- Hospital pharmacists
- Nurses and nursing coordinators
- Risk managers and quality officers
- ICT specialists
- Representatives from each clinical unit

The committee followed a structured methodology based on:

- Systematic review of guidelines and scientific evidence (2021-2024);
- Gap analysis of existing workflows;
- Co-design with end-users (clinicians, nurses, laboratory

staff);

- Iterative prototyping of digital tools.

Governance included monthly performance reviews, root cause analysis for non-conformities, algorithm updates based on new evidence, and quarterly reporting to the General Directorate.

2.3. PDTA Workflow: Eight Phases

The pathway consists of eight sequential and interconnected phases, with responsibilities defined by a RACI matrix (Responsible, Accountable, Consulted, Informed).

Phase 0 - Admission Screening and Risk Stratification

Within 1 hour of admission, a digital questionnaire is completed (triage or scheduled admission). An automatic algorithm stratifies patients as low/medium/high risk for MDRO colonization, guiding diagnostic priority. This phase is based on evidence from Huang et al. [8].

Phase 1 - Microbiological Test Prescription

Using the Modulab 2.0 electronic prescription system with integrated clinical decision support (CDSS), the attending physician selects the appropriate sample type and microbiological panel. The CDSS suggests optimal profiles based on symptoms, risk score, and local epidemiology. This step is completed within 24 hours of admission or symptom onset [13].

Phase 2 - Laboratory Execution and Advanced Reporting

The microbiology laboratory uses automated systems (MALDI-TOF, multiplex PCR, automated blood cultures). When results become available:

- The LIS (Laboratory Information System) generates automatic alerts;
- Results are classified by a predictive risk algorithm (high/medium/low);
- Notifications are sent to the ICA-Tracker Platform and the clinical unit via the Clinical Information System (CCE).

Response times: molecular results within 2-4 hours; cultures within 24-48 hours (priority).

Phase 3 - Rapid Unit Response and Isolation Activation

After notification, the clinical unit activates a visual alert system (infobox at the patient's bedside, flag in the CCE) and a digital isolation kit containing:



- Video procedures for PPE use;
- Printable signage templates;
- Digital verification checklists.

Isolation is activated within 2 hours of notification, with real-time compliance monitoring.

Phase 4 - AI-Assisted Case Analysis

The ICA-Tracker Platform automatically extracts:

- Data from the electronic health record;
- Calculates transmission risk;
- Identifies potential contacts;
- Suggests additional measures;
- Populates the electronic alert registry with epidemiological mapping.

This analysis is completed within 6 hours, with dashboard access for the CC-ICA.

Phase 5 - On-Site Verification with Digital Tools

An infection control nurse performs an on-site verification within 24 hours using a Mobile Audit App with:

- Guided digital checklists (bundle adherence, environmental cleaning);
- Photo/voice note upload;
- Real-time synchronization.

An automatic report is generated and sent to the unit and CC-ICA.

Phase 6 - Epidemiological Surveillance and Predictive Analysis

The system performs:

- Automatic cluster detection;
- Geographic heat mapping;
- Anomaly trend alerts;
- Dashboard visualization of real-time and historical indicators.

The CC-ICA reviews data within 48-72 hours and generates automatic reports for health authorities.

Phase 7 - Post-Discharge Follow-up

Upon discharge, an automatic alert is sent to the patient's general practitioner (GP) or pediatrician. Digital follow-up questionnaires are sent at 7, 30, and 90 days. A reminder system prompts microbiological checks if needed. This phase was

added based on preliminary data showing a 25% reduction in HAI-related readmissions.

Phase 8 - Clinical Audit and Complex Case Review

Monthly CC-ICA meetings with each clinical unit to review complex or sentinel cases. An AI-supported clinical audit platform facilitates root cause analysis. "Lessons learned" are disseminated to all staff. This has resulted in a 30% improvement in quality scores [internal audit].

2.4. IT Architecture

The PDTA is supported by an integrated, GDPR-compliant digital ecosystem:

1. **Modulab 2.0** - electronic prescribing with CDSS, integrated with patient history and the Regional Electronic Health Record (FSE).
2. **ICA-Tracker Platform** - central surveillance platform with workflow automation, electronic alert registry, and dashboards.
3. **Mobile Audit App** - for on-site inspections with checklists, multimedia upload, and real-time synchronization.
4. **Intelligent Notification System** - multichannel alerts (CCE, email, SMS, internal app).

Data security includes end-to-end encryption, role-based access control (RBAC), complete access/modification traceability, daily backups, semi-annual disaster recovery testing, and a Data Protection Impact Assessment (DPIA) for each module.

2.5. Training and Implementation Strategy

A phased training program was delivered:

- **Pre-implementation (2 months):** mandatory 4-hour e-learning course on "Digital PDTA and HAI management"; interactive workshops for "Clinical Champions" per clinical unit.
- **Go-live (1 month):** on-site training in each unit with simulations; video tutorials on app/platform use.
- **Maintenance (ongoing):** semi-annual updates on scientific and technological developments.





Training resources included a corporate Moodle-based platform and a digital library of guidelines, procedures, and videos.

2.6. Indicators and Data Collection

The following performance indicators were monitored (Table 1).

Table 1. Process and Clinical Indicators Monitored

Indicator	Target	Frequency	Pre-implementation Result	Postimplementation Result (12 months)	Significance (p-value)
Laboratory-to-unit notification time	< 4 hours	Daily	6.2 hours	2.8 hours	p < 0.001
Isolation compliance	> 95%	Weekly	78%	96%	N/A
Alarm registry completeness	100%	Daily	N/A	100%	N/A
On-site verification (within 24h)	100%	Daily	N/A	98%	N/A
MDRO transmission rate (episodes/1,000 patient-days)	-30% in 12 months	Monthly	3.2	2.3	p = 0.018
Broad-spectrum antibiotic consumption (DDD/100 patientdays)	-20% in 6 months	Monthly	N/A	-22%	p < 0.001
Environmental contamination rate	< 5%	Monthly	12%	4.2%	N/A
30-day readmission rate (HAI-related)	N/A	Monthly	6.7%	5.1%	p = 0.04

2.7. Statistical Analysis

Statistical analyses were performed using SPSS version 26.0. Paired-sample Student’s t-tests were used to compare pre- and post-implementation means for continuous variables (e.g., notification times, antibiotic consumption). The chi-square test was used for categorical variables (e.g., isolation compliance). A p-value < 0.05 was considered statistically significant. Temporal trends were analyzed using linear regression.

3. RESULTS

3.1. Process Indicators

During the 12-month observation period (March 2025 - March 2026), all 8 clinical units and the microbiology laboratory fully adopted the digitalized PDTA.

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- **Mean laboratory-to-unit notification time:** decreased from 6.2 hours (pre-implementation) to 2.8 hours (p < 0.001), well below the 4-hour target.
- **Isolation compliance:** improved from 78% to 96% (target >95%).
- **Electronic alert registry completeness:** reached 100%, with automatic validation.
- **On-site verification:** performed within 24 hours in 98% of cases.



- **System adoption rate among healthcare workers:** 92% at 12 months.
- **User satisfaction:** score of 4.3 out of 5 in the quarterly digital survey (n=320 respondents).

3.2. Clinical Outcomes

- **MDRO transmission rate:** decreased by 28%, from 3.2 to 2.3 episodes per 1,000 patient-days ($p = 0.018$), approaching the -30% target.
- **Broad-spectrum antibiotic consumption (DDD/100 patient-days):** decreased by 22% in 6 months ($p < 0.001$), achieving the -20% target.
- **Environmental contamination rate (surface swabs):** decreased from 12% to 4.2% (target <5%).
- **30-day HAI-related readmission rate:** decreased by 24% (from 6.7% to 5.1%; $p = 0.04$).

3.3. Economic Impact

A preliminary cost analysis, based on the methodology of Gharbi et al. [17], estimated a return on investment of approximately 4.2 for every 1 invested in the digitalized PDTA, driven by reduced length of stay, fewer readmissions, and lower antibiotic consumption.

3.4. User Feedback

Qualitative feedback from 120 staff interviews highlighted:

- **Positive aspects:** improved communication, faster decision-making, reduced bureaucracy, greater empowerment.
- **Critical issues:** initial learning curve, need for ongoing technical support, occasional “alert fatigue.”

4. DISCUSSION

This study demonstrates that a comprehensive digitalized PDTA for MDRO surveillance and HAI prevention can be successfully implemented in a multi-site hospital network, achieving substantial improvements in process efficiency, clinical outcomes, and staff satisfaction.

4.1. Comparison with Existing Evidence

Our findings are consistent with and extend previous studies. Stone et al. [7] reported a 40% reduction in MDRO transmission with structured

pathways; we observed a 28% reduction, likely due to the shorter follow-up period and the inclusion of all clinical units, not just high-risk areas. The reduction in broadspectrum antibiotic consumption (-22%) is consistent with the 20-40% reported in antimicrobial stewardship programs integrated with CDSS [15,16].

The rapid laboratory notification (2.8 hours) exceeds the 4-hour target and outperforms traditional phone/fax-based systems, corroborating Vlek et al. [18] on the impact of MALDI-TOF. The high isolation compliance (96%) and environmental cleanliness (4.2%) reflect the effectiveness of digital checklists and real-time feedback, as demonstrated by Morgan et al. [19].

4.2. Strengths of the Digitalized PDTA

Key strengths include:

- Comprehensive integration between hospital, laboratory, and community care.
- Real-time automation that reduces delays and human errors.
- AI-assisted analysis that supports proactive rather than reactive management.
- Multichannel alerts ensuring no notification is missed.
- GDPR-compliant design with robust data governance.
- Continuous training and audit promoting a culture of safety.

4.3. Limitations

Several limitations must be acknowledged:

- This is a single-province study; generalizability to other regions or countries requires validation.
- The pre-post design without a concurrent control group may be subject to temporal trends.
- Some outcomes (e.g., MDRO transmission) may be influenced by concomitant interventions (e.g., hand hygiene campaigns).
- Long-term sustainability and cost-effectiveness beyond 12 months require further evaluation.
- Alert fatigue and digital overload remain potential risks requiring ongoing monitoring.



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4.4. Lessons Learned and Recommendations

From our experience, we derive the following recommendations for similar implementations:

1. Engage end-users early in co-design to ensure usability and acceptance.
2. Provide robust training with ongoing support, including super-users in each clinical unit.
3. Start with a pilot project in 2-3 units before scaling up.
4. Integrate with existing hospital information systems rather than creating standalone systems.
5. Monitor both process and outcome indicators to guide iterative improvements.
6. Address privacy and security from the outset to build trust.

4.5. Future Developments

Planned developments include:

- Integration of whole-genome sequencing data for outbreak tracing;

- Machine learning models to predict individual patient colonization risk;
- Expansion to outpatient and long-term care settings;
- Inter-regional data sharing for national surveillance;
- Patient-facing portal for self-monitoring and education.

5. CONCLUSIONS

The implementation of an integrated digitalized PDTA for MDRO surveillance and HAI prevention at the Provincial Health Authority of Ragusa has led to significant improvements in notification times, isolation compliance, MDRO transmission, antimicrobial stewardship, and staff satisfaction. The model is feasible, acceptable, and effective in a real-world hospital network. It provides a scalable template for other healthcare systems seeking to leverage digital health to combat antimicrobial resistance and improve patient safety.

Further research with longer follow-up, controlled designs, and multi-center collaborations is needed to confirm these findings and refine the approach.

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