

Effectiveness of Technology-Assisted Hand Hygiene Monitoring in Reducing Multidrug-Resistant Organisms in Tertiary Hospitals

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Abstract

Background: Hospital-acquired infections (HAIs) caused by multidrug-resistant organisms (MDROs) remain a significant challenge in healthcare. Hand hygiene is critical in preventing HAIs, but compliance is often suboptimal. This study evaluates the effectiveness of a technology-assisted hand hygiene monitoring system (THHMS) in improving compliance and reducing MDRO prevalence in a tertiary hospital.

Methods: A quasi-experimental study was conducted over 12 months, involving the implementation of a THHMS across selected hospital units. Hand hygiene compliance was measured before and after the intervention, and MDRO prevalence was assessed through microbiological screening. Staff perceptions of the system were also analyzed.

Results: Compliance rates improved significantly from 52% pre-intervention to 83% post-intervention ($p < 0.01$). MDRO prevalence decreased from 15% to 9%, with notable reductions in MRSA and CRE rates. While staff feedback was largely positive, 45% of participants expressed concerns about privacy.

Conclusion: The THHMS effectively improved hand hygiene compliance and reduced MDRO prevalence. Addressing privacy concerns and ensuring cost-effectiveness will be critical for broader adoption in healthcare settings.

Keywords: Hand Hygiene, Multidrug-Resistant Organisms, Hospital-Acquired Infections, Electronic Monitoring, Infection Control, Compliance Improvement.

Introduction

Hospital-acquired infections (HAIs) caused by multidrug-resistant organisms (MDROs) are a pressing issue in healthcare settings worldwide, particularly in tertiary hospitals. Hand hygiene is a cornerstone of infection prevention, as proper handwashing significantly reduces the transmission of MDROs. Despite its proven effectiveness, adherence to hand hygiene protocols remains inconsistent, creating critical gaps in infection control (Allegranzi et al., 2009).

Advancements in technology have introduced innovative tools to monitor and promote hand hygiene compliance. Electronic monitoring systems and automated feedback mechanisms have been increasingly adopted to track compliance rates and provide real-time data to healthcare teams. Studies have shown that these technologies improve adherence rates and subsequently reduce the prevalence of HAIs (Srigley et al.,

2014; Boyce, 2017). For instance, electronic systems that monitor hand hygiene moments can provide detailed compliance reports, enabling targeted interventions and fostering a culture of accountability among healthcare workers (Farmani et al., 2019).

Despite these innovations, challenges such as high implementation costs, staff resistance, and the need for seamless integration with existing workflows hinder their widespread adoption (McGuckin et al., 2009). Addressing these barriers is crucial to maximizing the potential of these technologies. This study aims to evaluate the effectiveness of technology-assisted hand hygiene monitoring systems in reducing the prevalence of MDROs in tertiary hospitals. By examining compliance rates and infection control outcomes, this research seeks to provide evidence for the broader adoption of such systems and their role in enhancing patient safety.

Literature Review

Hand Hygiene and Infection Prevention

Hand hygiene has long been recognized as a cornerstone of infection prevention in healthcare settings. The World Health Organization (WHO) emphasizes its importance in reducing the transmission of multidrug-resistant organisms (MDROs) in hospitals (Allegranzi & Pittet, 2009). Studies have consistently demonstrated that increased hand hygiene compliance correlates with a significant reduction in hospital-acquired infections (HAIs), highlighting its critical role in maintaining patient safety (Sax et al., 2007).

However, compliance with hand hygiene protocols among healthcare workers remains suboptimal. Factors contributing to low adherence include workload pressures, lack of training, and behavioral barriers (Erasmus et al., 2010). These challenges have spurred interest in innovative solutions to promote and monitor hand hygiene compliance more effectively.

Technology-Assisted Hand Hygiene Monitoring

Emerging technologies have revolutionized the monitoring and promotion of hand hygiene in hospitals. Electronic monitoring systems (EMS) have gained popularity due to their ability to provide real-time data on compliance rates. These systems typically use sensors or radio-frequency identification (RFID) to track hand hygiene moments and generate detailed compliance reports (Srigley et al., 2014). Such technologies have been shown to improve compliance by providing immediate feedback to healthcare workers (Boyce, 2017).

In addition to monitoring, automated feedback systems play a pivotal role in sustaining high compliance levels. Studies suggest that integrating EMS with visual and auditory feedback mechanisms leads to more consistent adherence to hand hygiene protocols (Cheng et al., 2011). Furthermore, the use of gamification and reward-based strategies has been shown to enhance healthcare workers' engagement with these systems (Farmani et al., 2019).

Impact of Technology on Infection Control Outcomes

The adoption of EMS and other technological interventions has demonstrated measurable reductions in HAI

rates. For example, a study by Venkateshet al. (2008) reported a 30% reduction in MDRO prevalence following the implementation of an electronic hand hygiene monitoring system. Similarly, Farmani et al. (2019) observed significant decreases in bloodstream infections in intensive care units using automated feedback systems.

While the benefits of these technologies are evident, their impact is influenced by several factors, including the hospital's baseline compliance rates, the type of technology used, and the frequency of feedback provided to staff (Rupp et al., 2019). The sustainability of these outcomes also depends on the integration of the technology with broader infection control programs.

Barriers to Implementation

Despite their proven efficacy, technology-assisted hand hygiene monitoring systems face several barriers to widespread adoption. High implementation costs are a major deterrent, particularly for resource-constrained healthcare facilities (McGuckin et al., 2009). Additionally, staff resistance to new technologies, driven by concerns over privacy and increased workload, can undermine the success of these systems (Erasmus et al., 2010).

Integrating EMS into existing workflows is another challenge. Hospitals must ensure that the data generated by these systems are actionable and that staff are adequately trained to interpret and respond to feedback (Venkateshet al., 2008). Addressing these barriers is crucial to maximizing the impact of technology on hand hygiene compliance and infection control.

Future Directions and Research Gaps

While current evidence supports the effectiveness of EMS in improving hand hygiene compliance, several research gaps remain. There is limited data on the long-term sustainability of these systems and their cost-effectiveness in different healthcare settings. Future research should explore the use of artificial intelligence and machine learning to enhance the accuracy and usability of hand hygiene monitoring technologies (Cheng et al., 2011).

Additionally, studies should investigate the impact of combining EMS with other infection control interventions, such as antimicrobial stewardship programs, to achieve synergistic effects in reducing HAIs. Addressing these gaps will provide valuable insights into optimizing the use of technology in infection prevention.

Methodology

Study Design

This study employed a quasi-experimental pre-and post-intervention design conducted in a tertiary hospital over 12 months. The study aimed to evaluate the effectiveness of a technology-assisted hand hygiene monitoring system in improving hand hygiene compliance and reducing multidrug-resistant organism (MDRO) prevalence.

Setting

The study was conducted in a tertiary hospital with a mix of general and specialized units, including intensive care units (ICUs), surgical wards, and general medicine wards. The hospital had an existing hand hygiene policy aligned with World Health Organization (WHO) guidelines but faced challenges with compliance and MDRO-related hospital-acquired infections (HAIs).

Participants

The study included:

- **Healthcare workers (HCWs):** All doctors, nurses, allied health professionals, and ancillary staff working in the selected units.
- **Patients:** All inpatients admitted to the selected units during the study period were included for MDRO screening.

Inclusion Criteria:

- HCWs providing direct patient care.
- Patients admitted for more than 48 hours.

Exclusion Criteria:

- Pediatric wards and outpatient departments were excluded due to differing hand hygiene protocols.
- Patients discharged within 48 hours of admission.

Intervention

The intervention involved the implementation of a technology-assisted hand hygiene monitoring system (THHMS) across selected units. The system included:

- **Electronic Monitoring Devices (EMD):** Sensors installed near hand sanitizer dispensers and soap dispensers to record hand hygiene events.
- **Real-Time Feedback:** HCWs received visual or auditory alerts to reinforce hand hygiene compliance.
- **Dashboard Analytics:** A centralized dashboard provided unit-level and individual-level compliance data accessible to infection control teams.

The intervention was rolled out in three phases:

1. **Baseline Observation (Months 1–3):** Data on hand hygiene compliance and MDRO prevalence were collected without the use of the THHMS to establish baseline metrics.
2. **System Implementation (Month 4):** The THHMS was introduced, and all HCWs received training on its use.
3. **Post-Implementation Monitoring (Months 5–12):** Data were collected to evaluate changes in hand hygiene compliance and MDRO prevalence.

Data Collection

1. **Hand Hygiene Compliance:**

- **Pre-Intervention:** Compliance was measured using direct observations conducted by trained infection control personnel during baseline months.
 - **Post-Intervention:** Compliance data were automatically recorded by the THHMS.
2. **MDRO Prevalence:**
 - Routine microbiological screening of patients was conducted for common MDROs, including methicillin-resistant *Staphylococcus aureus* (MRSA) and carbapenem-resistant *Enterobacteriaceae* (CRE).
 - Samples were collected from high-risk sites (e.g., blood, urine, and wounds).
 3. **Feedback and Perception:**
 - Semi-structured interviews and surveys were conducted with HCWs to assess their experiences with the THHMS and its impact on their behavior.

Outcome Measures

1. **Primary Outcome:**
 - Change in hand hygiene compliance rates before and after the intervention.
2. **Secondary Outcomes:**
 - Reduction in MDRO prevalence among patients.
 - Staff satisfaction and acceptance of the THHMS.

Data Analysis

- **Compliance Rates:** Hand hygiene compliance was expressed as the percentage of opportunities in which hand hygiene was performed. Data were analyzed using chi-square tests to compare pre- and post-intervention compliance.
- **MDRO Prevalence:** The prevalence of MDROs was calculated as the percentage of patients with positive cultures out of the total number of screened patients. Pre- and post-intervention prevalence was compared using Fisher's exact test.
- **Perception Surveys:** Survey responses were analyzed using thematic analysis for qualitative data and descriptive statistics for quantitative data.

Ethical Considerations

Ethical approval was obtained from the hospital's ethics committee. Written informed consent was obtained from HCWs participating in the survey and interviews. Patient data were anonymized to ensure confidentiality.

Limitations

- The quasi-experimental design lacked a control group, limiting the ability to attribute observed changes solely to the intervention.
- Potential Hawthorne effect due to HCWs' awareness of being monitored.

Findings

The findings are presented in three sections: hand hygiene compliance rates, MDRO prevalence, and staff perception and satisfaction with the technology-assisted hand hygiene monitoring system (THHMS).

1. Hand Hygiene Compliance Rates

Hand hygiene compliance improved significantly after implementing the THHMS. Pre-intervention, compliance rates were recorded manually, while post-intervention rates were obtained from the electronic system.

Table 1: Hand Hygiene Compliance Rates

Time Period	Compliance Rate (%)	Number of Observations
Pre-Intervention (Baseline)	52%	1,200
Post-Intervention (3 Months)	75%	1,500
Post-Intervention (12 Months)	83%	1,800

Key Insight:

The compliance rate increased by 60% from baseline (52%) to the 12-month mark (83%) after implementing the THHMS. The most significant improvement was observed during the first three months of implementation, followed by sustained gains.

2. MDRO Prevalence

The prevalence of MDROs was assessed pre- and post-intervention by analyzing patient samples for methicillin-resistant *Staphylococcus aureus* (MRSA) and carbapenem-resistant *Enterobacteriaceae* (CRE).

Table 2: MDRO Prevalence Before and After Intervention

MDRO Type	Prevalence Pre-Intervention (%)	Prevalence Post-Intervention (%)
MRSA	18%	11%
CRE	12%	7%
Overall MDRO Rate	15%	9%

Key Insight:

The implementation of the THHMS was associated with a significant reduction in MDRO prevalence. The overall MDRO rate decreased from 15% pre-intervention to 9% post-intervention, with notable reductions in MRSA and CRE.

3. Staff Perception and Satisfaction

A total of 120 healthcare workers participated in the post-implementation survey to assess their perceptions of the THHMS.

Table 3: Staff Perceptions of the THHMS

Aspect	Positive Feedback (%)	Neutral Feedback (%)	Negative Feedback (%)
Ease of Use	85%	10%	5%
Real-Time Feedback Utility	78%	15%	7%
Impact on Compliance Behavior	88%	8%	4%
Privacy Concerns	25%	30%	45%

Key Insight:

Most healthcare workers reported positive experiences with the system, particularly regarding ease of use and its impact on compliance behavior. However, a significant proportion (45%) expressed concerns about privacy related to monitoring.

Discussion

Summary of Key Findings

This study demonstrates the significant impact of implementing a technology-assisted hand hygiene monitoring system (THHMS) in a tertiary hospital. The findings indicate that hand hygiene compliance rates improved from 52% to 83% over a 12-month period, accompanied by a substantial reduction in the prevalence of multidrug-resistant organisms (MDROs), including MRSA and CRE. Furthermore, most healthcare workers (HCWs) positively perceived the system, though privacy concerns were noted.

Comparison with Existing Literature

The observed improvements in hand hygiene compliance align with previous studies highlighting the effectiveness of electronic monitoring systems. For instance, Srigley et al. (2014) reported similar increases in compliance rates when real-time feedback systems were introduced. The sustained compliance observed in this study underscores the value of continuous feedback and automated monitoring in promoting adherence to infection control protocols.

The reduction in MDRO prevalence is consistent with findings from Boyce (2017), who documented a 30% reduction in healthcare-associated infections (HAIs) following the implementation of a hand hygiene monitoring system. The decline in MRSA and CRE rates reinforces the importance of high compliance rates in mitigating MDRO transmission, especially in high-risk areas such as intensive care units.

Interpretation of Results

The substantial improvement in hand hygiene compliance can be attributed to the THHMS's real-time feedback and centralized analytics. These features not only enhanced accountability but also allowed infection control teams to identify and address gaps in compliance promptly. The reduction in MDRO

prevalence further validates the system's effectiveness in breaking the chain of transmission, particularly in a tertiary care setting where patients are more vulnerable to infections.

However, the increase in compliance was more pronounced during the initial months, suggesting that ongoing efforts are needed to maintain high compliance rates. Integrating periodic training and gamification strategies may help sustain motivation and engagement among HCWs.

Strengths of the Study

1. **Real-World Setting:** The study was conducted in a functioning tertiary hospital, ensuring the findings are directly applicable to similar healthcare settings.
2. **Comprehensive Approach:** By combining compliance monitoring with MDRO prevalence data, the study provides a holistic evaluation of the THHMS's impact.
3. **Diverse Metrics:** Both quantitative (compliance rates, MDRO prevalence) and qualitative (staff perceptions) data were analyzed, offering a well-rounded perspective.

Limitations

Despite its strengths, the study has several limitations:

1. **Quasi-Experimental Design:** The lack of a control group limits the ability to attribute observed improvements solely to the THHMS. Other infection control measures, such as antimicrobial stewardship programs, may have contributed to the results.
2. **Privacy Concerns:** A significant proportion of HCWs expressed discomfort with being monitored, which could affect long-term acceptance of the system.
3. **Resource Constraints:** The cost of implementing and maintaining the THHMS may limit its feasibility in resource-constrained settings.

Implications for Practice

The findings suggest that THHMS can be an effective tool for improving hand hygiene compliance and reducing MDRO prevalence in tertiary hospitals. However, successful implementation requires addressing privacy concerns and integrating the system with existing infection prevention programs. Hospitals should also consider providing ongoing training and feedback to sustain compliance rates.

Recommendations for Future Research

1. **Controlled Studies:** Future research should include randomized controlled trials to isolate the effect of THHMS on compliance and infection rates.
2. **Cost-Benefit Analysis:** Evaluating the economic feasibility of implementing THHMS in different healthcare settings is crucial.
3. **Long-Term Sustainability:** Studies should explore the long-term effectiveness of THHMS, including strategies to address privacy concerns and sustain compliance over extended periods.
4. **Technological Innovations:** Investigating the role of artificial intelligence and machine learning in enhancing monitoring accuracy and personalization could offer valuable insights.

Conclusion

The implementation of a technology-assisted hand hygiene monitoring system significantly improved compliance rates and reduced MDRO prevalence in a tertiary hospital. These findings highlight the potential of THHMS as a scalable solution for enhancing infection prevention practices. However, addressing barriers such as privacy concerns and ensuring cost-effectiveness will be critical for broader adoption.

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