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Original research article

Insights into healthcare workers' views on the electronic hand hygiene monitoring system

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Abstract
Aim: This study analyzed healthcare workers' attitudes towards an electronic digital hand hygiene (HH) monitoring system before and after its implementation at Trnava University Hospital (FNTT).
Methods: A comparative before-and-after study was conducted using the NosoEx® electronic HH monitoring system (GWA Hygiene GmbH) in two clinics at FNTT, Slovakia. The study periods were 24.04.2023 – 31.12.2023 and 22.04.2024 – 31.12.2024. A total of 277 healthcare workers participated in the surveys.
Results: After implementation, willingness to have behaviour monitored increased significantly at the clinic without transponders from 77.4% to 97.0% (p = 0.0181), along with acceptance of long-term monitoring (p = 0.0121). Stress related to monitoring decreased (p = 0.0069). At the clinic with transponders, discomfort with hand disinfection dropped from 72.7% to 42.1% (p = 0.0001) and stress levels also fell (p = 0.0001). Openness to permanent implementation increased at this clinic (p = 0.0072).
Conclusion: Introducing the electronic HH monitoring system positively influenced healthcare workers' attitudes, increased their willingness to be monitored, and reduced stress. This system is an effective tool to improve HH compliance in clinical settings.

Keywords: Automatization; Compliance; Digitalization; Hand hygiene; Healthcare-associated infections; Surveillance

Introduction

The Infection Prevention and Control (IPC) program should currently be an integral part of every healthcare facility. Its primary role is to bring evidence-based preventive solutions into daily practice, which reduce the occurrence of healthcare-associated infections (HAI) and their negative consequences (WHO, 2023). Surveillance of HAIs is one of the core pillars and essential functions of IPC, where relevant and timely detection contributes to improving the quality of healthcare and facilitates the assessment of compliance with procedural measures, the most important of which is hand hygiene (HH) (Shenoy et al., 2023).

Technological innovations have become an inseparable part of our daily lives. In recent years, information technologies, the internet, artificial intelligence, and virtual reality have contributed to the transformation of the healthcare system (Stoumpos et al., 2023). Digital technologies are evolving rapidly and have the potential to significantly enhance progress in key public health activities. However, it is important to identify their benefits and risks to appropriately apply this potential in the implementation of IPC programs. One example of the use of digital technologies in the context of IPC is the implementation of electronic HH monitoring systems. Numerous studies have provided significant evidence of HH's impact on reducing HAI. Nevertheless, many healthcare facilities continue to struggle with insufficient compliance (WHO, 2023). This creates an opportunity for the deployment of electronic monitoring systems dedicated to HH, which could serve as a supplementary monitoring approach, increase healthcare workers' motivation for HH, and thus contribute to reducing the incidence of HAI in hospitals. Electronic HH monitoring overcomes the limitations associated with manual audits, but it may vary in acceptability among healthcare workers, which is closely related to the level of organizational culture (Kelly et al., 2021). A more advanced electronic approach involves monitoring the activation of alcohol-based hand rub dispensers, ranging from simple counters to sophisticated electronic systems capable of recording the exact date and time of each activation during hand hygiene events (Kwok et al., 2016).

In addition, electronic monitoring of HH can include real-time tracking of healthcare personnel locations while performing HH. This method typically relies on badges worn by

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healthcare workers alongside their name tags during shifts, in combination with sensors placed at ward entrances or within patient zones. These sensors capture data when dispensers of alcohol-based hand rub are activated (Dufour et al., 2017). Moreover, certain electronic monitoring systems are designed to provide prompts or feedback, typically in the form of visual or auditory alerts, when a hand hygiene opportunity is missed (McKay et al., 2020).

The aim of this study was to analyze the attitudes and opinions of healthcare workers toward an electronic HH monitoring system before and after its implementation at Trnava University Hospital (FNTT) in Slovakia.

Materials and methods

Data collection was carried out through the implementation of a pilot project using the electronic NosoEx® system (GWA Hygiene GmbH) at FNTT. The NosoEx® system consisted of hardware and software components that enabled real-time recording, documentation, and analysis of HH among staff. Adequate HH included the required procedures for hand disinfection using liquid alcohol-based disinfectants from any brand of dispenser.

The *before-and-after comparative study* was conducted at FNTT during two observation periods: before the implementation of the system (April 24, 2023 – December 31, 2023) and after its implementation (April 22, 2024 – December 31, 2024). FNTT is a tertiary healthcare facility with 645 beds, where two clinics were selected for the implementation of the project, covering a total of 101 patient beds, including 17 intensive care unit beds. At the first clinic, HH was monitored solely through sensors on the alcohol-based disinfectant dispensers, without the use of transponders or classification into professional groups (clinic without transponders). At the second clinic, HH was monitored using both dispenser sensors and transponders attached to the name tags of healthcare workers (clinic with transponders). These transponders were assigned based on professional categories: physicians, nurses, orderlies, and auxiliary healthcare workers (AHWs).

A qualitative survey using a questionnaire was conducted among the observed healthcare workers to evaluate their attitudes, opinions, and the possibility of providing feedback on the implemented electronic HH system. The questionnaire was initially developed by GWA Hygiene GmbH and subsequently translated into Slovak by HARTMANN, which also collaborated in the realization of the project. The instrument was administered in an anonymous format and comprised a total of 46 items, including 41 Likert-scale questions and 5 closed-ended items. For the purposes of this paper, 18 Likert-scale questions and 5 closed-ended questions specifically aligned with our research objectives were selected (Suppl. materials).

A total of 277 healthcare workers participated in the questionnaire survey. The entry questionnaire was distributed to staff before the installation of the electronic HH monitoring system. The exit questionnaire was conducted at the final stage of the project. The return rate was 55.1% for the entry questionnaire and 62.3% for the exit questionnaire.

At the clinic without transponders, 64 healthcare workers participated in the questionnaire survey, with 31 respondents in the initial survey and 33 for the exit questionnaire. Of those completing the entry questionnaire, 15 were nurses (48.3%), 13 physicians (41.9%), and 3 were orderlies/AHWs (9.8%). For the exit questionnaire, 33 healthcare workers participated, of whom 63.5% were nurses, 24.4% were orderlies/AHWs, and 12.1% were physicians. At the clinic with transponders, a total of 213 healthcare workers participated in the questionnaire survey, with 99 employees in the initial survey and 114 in the follow-up survey. Among those completing the entry questionnaire at this clinic, 46 were nurses (46.5%), 30 were physicians (30.3%), and 23 were orderlies/AHWs (23.2%). In the exit questionnaire, 64 nurses participated (56.1%), 29 physicians (25.5%), and 21 orderlies/AHWs (18.4%).

Statistical analysis

The chi-square test was used to determine whether there was a statistically significant difference in healthcare workers' attitudes toward the implemented electronic HH monitoring system. Statistical significance was assessed at a threshold of $p = 0.05$. Statistical analysis was performed using R-Project software with corresponding 95% confidence intervals (CI).

Results

Clinic without transponders

All healthcare workers who participated in both survey rounds agreed that proper hand disinfection is absolutely essential for preventing the occurrence of HAI (Question 1) (Fig. 1). Respondents from this clinic also demonstrated the necessary theoretical knowledge of correct HH procedures and understood which situations require HH (Questions 2 and 3). Additionally, all healthcare workers at this clinic stated that the working environment facilitates proper HH – for example, due to the good availability of disinfectants or the suitable placement of dispensers (Question 6). This opinion remained unchanged before and after project implementation.

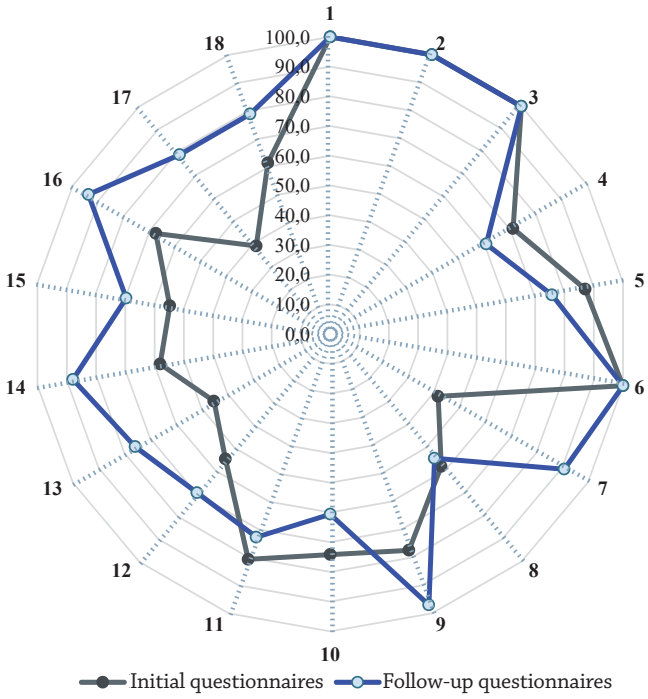

Fig. 1. Comparison of responses to individual questions from the initial and follow-up questionnaires among healthcare workers at the clinic without transponders

In the entry questionnaire, 71.0% of healthcare workers (95% CI: 53.4–83.9) stated that they did not find frequent hand disinfection unpleasant (Question 4). However, in the exit questionnaire, this opinion was held by only 60.6% (95% CI: 43.7–75.3), indicating a slight decline in perceived comfort. A similar decline was observed for Question 5, regarding whether staff would remind a colleague if they forgot to perform HH. In the pre-intervention survey, 87.1% (95% CI: 71.1–94.9) of respondents said they would remind a colleague, while only 75.8% (95% CI: 59.0–87.2) reported this in the post-intervention survey. Before the introduction of the electronic HH monitoring system, 58.1% of healthcare workers (95% CI: 40.8–73.6) expected to receive regular feedback on their HH behaviour. After implementation, this expectation was expressed by 54.5% (95% CI: 38.0–70.2) (Question 8). However, the changes in responses to these questions were not statistically significant.

Question 9 addressed healthcare workers' attitudes toward having their HH behaviour monitored. In the entry questionnaire, 77.4% (95% CI: 60.2–88.6) supported this idea, rising significantly to 97.0% (95% CI: 84.7–99.5) in the exit questionnaire (p = 0.0181). This shows a positive shift in attitude after implementing the electronic HH monitoring system. A statistically significant difference was also observed in Question 13, which asked whether staff could imagine being monitored long-term by such a system (p = 0.0121). Question 14 revealed a significant change regarding stress associated with system implementation: 58.1% (95% CI: 40.8–73.6) initially said the system did not cause stress for them, rising to 87.9% (95% CI: 72.7–95.2) afterward (p = 0.0069). Question 16 revealed a 26.2% increase in healthcare workers open to permanent implementation of the electronic system (p = 0.0072) – from 67.7% (95% CI: 50.1–81.4) before the project to 93.9% (95% CI: 80.4–98.3) after. There was also a notable shift in perceptions of being "observed". Initially, 61.3% (95% CI: 43.8–76.3) of healthcare workers said they felt monitored during direct observation. After implementing electronic monitoring, only 21.2% (95% CI: 10.7–37.8) felt this way (p = 0.0011).

Clinic with transponders

As with the clinic without transponders, all healthcare workers at this clinic unanimously stated that proper hand disinfection is key to preventing the spread of HAI (Question 1). They also reported having the necessary knowledge about hand hygiene care (Question 2) and being aware of situations requiring appropriate HH (Question 3). These responses were consistently confirmed in both survey questionnaires (Fig. 2).

At this clinic, statistically significant differences were recorded in 11 questions (61.1%). Before the electronic system was implemented, 72.7% (95% CI: 63.2–80.5) of healthcare workers found HH unpleasant, but this dropped to 42.1% (95% CI: 33.2–51.3) after implementation (p = 0.00001). Question 7 revealed an increase in perceived obstacles to HH – from 5.1% (95% CI: 2.2–11.3) to 14.0% (95% CI: 8.8–21.6; p = 0.0282). System implementation also led to improved feedback (Question 8), rising from 52.5% (95% CI: 42.8–62.1) to 65.8% (95% CI: 56.7–73.9; p = 0.0490), and greater willingness to be monitored (Question 9), from 65.7% (95% CI: 55.9–74.3) to 86.8% (95% CI: 79.4–91.9; p = 0.0024). In Question 10, self-monitoring of HH increased from 64.6% (95% CI: 54.8–73.4) to 79.8% (95% CI: 71.5–86.2; p = 0.0130). Willingness to wear a transponder rose from 37.4% (95% CI: 28.5–47.2) to 59.6% (p = 0.0011). Feelings of stress decreased significantly – from 28.3% (95% CI: 20.4–37.8) to 69.3% (95% CI: 60.3–77.0; p = 0.0001). More workers also reported not feeling monitored by the electronic system (Question 15), increasing from 22.2% (95% CI: 15.2–31.4) to 42.1% (95% CI: 33.4–51.3; p = 0.0020). However, perception of direct human observation as a form of control increased from 19.2% (95% CI: 12.6–28.0) to 41.2% (95% CI: 32.6–50.4). In Question 18, fewer staff reported disinfecting hands more frequently in the presence of observers, dropping from 70.7% (95% CI: 61.1–78.8) to 54.4% (95% CI: 45.2–63.2; p = 0.1439). No statistically significant differences were noted in Question 5 (reminding colleagues), Question 6 (suitability of working area), Question 11 (feedback usefulness), or Question 16 (willingness to use the system long-term), though a positive trend was observed in Question 16 (46.5% to 56.1%).

Fig. 2. Comparison of responses to individual questions from the initial and follow-up questionnaires among healthcare workers at the clinic with transponders

Discussion

This study represents the first scientifically documented use of an electronic HH monitoring system in both Slovakia and the Czech Republic, providing valuable real-world data on its implementation in healthcare settings. A major strength of this work was the high level of participation among healthcare workers, many of whom were actively monitored and willing to share feedback.

Evidence suggests that HH compliance increases when healthcare workers feel they are being monitored, regardless of the monitoring type (Boyce, 2017; Xu et al., 2021). Although findings on electronic HH systems vary, few studies have explored subjective perceptions and acceptance among staff, which are crucial for system adoption. Healthcare workers in the UK reported that wearing transponders and being monitored increased their sense of responsibility, though some admitted to consciously ignoring HH protocols. While they were

aware of being tracked, they didn't feel it actually improved their HH performance and preferred personal feedback and personal interaction (Kelly et al., 2021). A qualitative descriptive study involving nurses and physicians highlighted a lack of feedback from hospitals, leading participants to view reminder-based electronic systems positively for improving HH compliance. The system was accepted and seen as a behavioural tool (Blomgren et al., 2021).

In our study, the clinic with transponders showed a significant increase in healthcare workers self-monitoring their HH behaviour (p = 0.0130) and in the desire to be monitored (p = 0.0024). Significant differences were also seen in stress perception, with both clinics reporting decreased stress related to system implementation (clinic without transponder: p = 0.0069; clinic with transponder: p = 0.0001).

Previous studies emphasize the importance of building trust in electronic HH systems for long-term adoption (Blomgren et al., 2021; Granqvist et al., 2022). Therefore, qualitative evaluations are essential in clinical settings. Assessment should distinguish between HH opportunities and HH actions, both key elements in proper monitoring (Granqvist et al., 2022). Electronic systems offer 24/7 monitoring and reduce bias from observer-subject interaction, minimizing the Hawthorne effect (Boyce, 2017). They also generate real-time data without requiring observer overtime (Iversen et al., 2020).

Our study results may be subject to selection bias, as the chosen clinics may not provide a representative sample of the entire healthcare facility or other types of healthcare institutions.

Conclusion

The results showed that healthcare workers at both clinics fully understood the importance of proper HH in preventing HAI. After implementing the electronic HH monitoring system, we observed several statistically significant changes in staff attitudes and behaviours. This suggests that electronic HH monitoring can be an effective tool for supporting HH compliance, especially when accompanied by effective communication, education, and a sensitive approach to perceived surveillance. We recommend considering the integration of such systems when designing new hospitals, particularly in single-patient room settings, which offer ideal conditions for monitoring the first and fifth moments of HH – when entering and exiting patient rooms. Implementation of such systems can improve not only objective behaviours but also subjective attitudes, which is critical for sustaining preventive practices in clinical care.

Author contribution statement

V. Chebenová: Writing – Data curation, Original draft preparation. *V. Bučková:* Formal analysis. *Z. Škvarková:* Writing – Review and editing. *A. Botíková:* Writing – Review and editing. *J. Sokolová:* Conceptualization, Methodology, Supervision.

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Ethical aspects

The Ethics Committee of FNTT approved the collection and publication of data obtained from the implementation of the NosoEx® project at FNTT.

Conflict of interest

The authors have no conflict of interest to declare.

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