

Hand Hygiene Outcomes in Pediatric and Neonatal Intensive Care Units: A Systematic Review

Fahd Somili¹, Areej Areeshi², Nihal Adawi³, Raffan Alhasani⁴, Omar Hadadi⁵, Walaa Areeshi⁶, Alyaj Hakami⁷, Ghaida Almuahysin⁸, Manal Madkhali⁹, Fatimah Moharg¹⁰, Shumokh Juraybi¹¹, Abdulrahman Hakami¹², Wedad Ahmed Suliman Alhuris¹³

¹Pediatric and Neonatal Intensive Care Consultant, King Fahd Central Hospital, Jazan, Saudi Arabia

ORCID: 0009-0008-6673-0993

Email: al-fahd-sa@hotmail.com; fahedalotaibi99@gmail.com

²College of Medicine, Jazan University, Jazan, Saudi Arabia

ORCID: 0009-0006-9157-4334

Email: Areshiareej@gmail.com; myadalwfy177@gmail.com

³College of Medicine, Jazan University, Jazan, Saudi Arabia

ORCID: 0009-0008-9156-8414

Email: nihalad9@gmail.com

⁴College of Medicine, Jazan University, Jazan, Saudi Arabia

ORCID: 0009-0008-9104-3298

Email: a0534782045@gmail.com

⁵College of Medicine, Jazan University, Jazan, Saudi Arabia

ORCID: 0009-0003-2281-4574

Email: alhadadi.omar333@gmail.com

⁶College of Medicine, Jazan University, Jazan, Saudi Arabia

ORCID: 0009-0002-0408-5390

Email: Wala3siddiq@gmail.com

⁷College of Medicine, Jazan University, Jazan, Saudi Arabia

ORCID: 0009-0007-5750-5949

Email: Hakamialiaj@gmail.com

⁸College of Medicine, Jazan University, Jazan, Saudi Arabia

ORCID: 0000-0003-0638-2065

Email: ghidaa2050@gmail.com

⁹College of Medicine, Jazan University, Jazan, Saudi Arabia

ORCID: 0009-0004-9953-9416

Email: dr.manal29.10@gmail.com

¹⁰College of Medicine, Jazan University, Jazan, Saudi Arabia

ORCID: 0009-0000-4729-2264

Email: fatimah.moharg@gmail.com

¹¹College of Medicine, Jazan University, Jazan, Saudi Arabia

ORCID: 0009-0009-3906-3475

Email: Shumookh.Fawaz@gmail.com

¹²College of Medicine, Jazan University, Jazan, Saudi Arabia

ORCID: 0000-0003-4154-2140

Email: Chestdr18@gmail.com

¹³Medical Intern, Najran University

Email: Wedadalhuris88@gmail.com

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ABSTRACT

Background and Aim:

The Pediatric and Neonatal Intensive Care Units (PICU and NICU) serve as critical settings where the risk of healthcare-associated infections (HAIs) is significantly high. Preventive measures are necessary, especially for healthcare professionals in direct contact with patients. Hand Hygiene (HH) is widely recognized as one of the most effective interventions for limiting pathogen transmission, thus we aimed to assess the association between proper hand hygiene measures versus regular or no HH in the PICU/NICU and possible clinical outcomes.

Methods:

Electronic databases were searched over the past 10 years using relevant terms. Any studies concerning adult patients or the practice of multifaceted infection control interventions were excluded. ROBINS-I tool was the main quality assessment used for pre-and post-intervention studies.

Results:

Twenty studies met our inclusion criteria and the most commonly used study design was the before-and-after non-randomised design. NICUs were studied in a total of 13 studies versus 4 mentioning PICU alone and 3 including both. Compliance rates were the most reported outcome with post-intervention rates ranging from 47.1% to 93%. Most of the studies implemented a multimodal strategy to improve HH compliance (N=14). Additional outcomes included HAI rates, mortality rates, cost, and length of hospital stay. The most common limitation described among studies was the Hawthorne effect.

Conclusion:

Multiple outcomes were reported across studies, most commonly compliance rates. Future studies should focus on testing HH enhancement in association with infection control outcomes.

Keywords: Hand hygiene, Pediatric Intensive Care Unit, Neonatal Intensive Care Unit, Healthcare-associated infections, Compliance, Infection control, Systematic review

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Introduction

The Pediatric Intensive Care Unit (PICU) and Neonatal Intensive Care Unit (NICU) serve as critical settings for the care of seriously ill children, where the risk of healthcare-associated infections (HAIs) is substantially higher compared to other hospital units [1]. In the NICU, bloodstream infections (BSIs) occur at rates ranging from 12% to 53%. Invasive infectious diseases are responsible for around 1.4 million newborn deaths worldwide each year [2]. Healthcare workers' hands are the primary mode of transmission for bacterial infections that cause HAI. Poor hand hygiene (HH) accounts for 50-70% of HAI incidents [3,4]. As a consequence, hand hygiene (HH) is widely recognized as one of the most effective interventions for limiting pathogen transmission, lowering the frequency of HAIs, and optimizing patient outcomes [5,6].

Traditional hand hygiene practices, such as soap and water or alcohol-based hand sanitizers, have been widely implemented in healthcare settings. However, emerging evidence suggests that enhancing hand hygiene practices in the PICU may offer additional benefits in terms of infection control. To start with, the World Health Organisation (WHO) established the WHO multimodal hand hygiene improvement strategy. The five essential elements included are system change, including the provision of alcohol-based handrub at the point of patient care and/or access to a safe, constant water supply, soap, and towels; education and training of health-care professionals; tracking of hand hygiene practices and performance feedback; workplace reminders; and the creation of a hand hygiene safety culture [7]. Additionally, the

Centers for Disease Control and Prevention (CDC) published guidelines on proper HH practices [8]. All these measures have been used in a variety of research, including PICU and NICU settings in aims of improving compliance and thus reducing overall infection rates. Moreover, the WHO also established the "My Five Moments for HH" concept [9] to assess HH compliance and thus ensure proper HH adherence. Previous reviews have been published addressing overall HH compliance and outcomes in general hospitals wards or overall ICUs without a focus on pediatrics alone (<18 years-old). For instance, Lambe et al [10] described compliance with WHO HH guidelines in ICUs while describing different compliance levels across multiple ICU types. Moreover, Issa et al [11] assessed studies on HH compliance solely in the emergency department. To date, no systematic reviews have been published with a clear focus on pediatrics ICUs alone and the prospective outcomes of proper HH practice.

Our systematic review aimed to address the correlation between proper hand hygiene measures in the PICU/NICU and possible clinical outcomes to evaluate the effectiveness of enhanced hand hygiene practices in reducing HAIs and improving patient outcomes in the PICU. We covered multiple interventions for the enhancement of HH practices and their reported outcomes, including the use of innovative technologies, such as automated hand hygiene monitoring systems, improved hand hygiene compliance strategies, and education programs targeted specifically at healthcare providers in the PICU/NICU.

Methods

1. Search Strategy

Databases including PubMed, Web of Science, and Scopus were searched using relevant terms. Owing to multiple studies performed on the topic, we aimed to address the most recent outcomes so a filter of studies published within the last 10 years (2014-January 2024) was applied. No language restriction was applied. The search terms included “hand hygiene”, “pediatric intensive care unit” and all related synonyms. The detailed strategy can be found in **Supplementary File 1**.

2. Study Selection

Eligible studies for inclusion in our review had to fulfill the following criteria based on the PICO format:

- (1) Population of healthcare professionals (HCPs) in the setting of a pediatric (and/or neonatal) intensive care units (ICUs)
- (2) Any intervention leading to enhanced HH methods whether educational or visual.
- (3) Comparison with less strict or regular HH protocols.
- (4) Reporting of any possible related outcomes including compliance and infection rates.

Our exclusion criteria were removing any results concerning adult ICUs (>18 years-old) or those presenting the efficacy of multifaceted infection control interventions rather than HH alone. Additionally, any observational descriptive studies that only show baseline HH compliance rates without a comparison with enhanced HH practice or demonstrating outcomes were removed. Finally, studies conducted during outbreaks of Healthcare-associated infections (HCAIs), review articles, editorial, letters, conference abstracts, and articles before 2014 were excluded.

3. Methodological Quality Assessment

The “Risk Of Bias In Non-randomised Studies - of Interventions” (ROBINS-I) tool was used for the assessment of quasi-experiments or other non-randomized trials including the before-and-after studies. Observational cohort studies were assessed for bias using the Newcastle-Ottawa Scale (NOS), which consists of three aspects: the selection of exposure, comparability, and assessment of outcome. The maximum score was nine, and scores of seven or more were

graded as good quality, from two to six points were considered “fair”, and ≤ 1 point was judged “poor” quality. For the pilot study of a randomized clinical trial (RCT), version 2 of the Cochrane risk-of-bias tool for randomized trials (ROB-2) tool was used.

4. Data Extraction

Data was extracted from the selected articles into an Excel sheet including author name, year, country of publication, study design, detailed study duration, baseline and follow-up periods, HCPs sample size (if mentioned), ICU type, type of HH interventions performed, the compliance observation method (if any), outcomes reported, and study limitations. Any disagreements regarding extracted data were resolved through group discussions or consensus.

5. Data Synthesis

Because of the extensive heterogeneity among the presented studies with regards to the study design, measures taken for HH enhancement, outcomes description, and presentation, a meta-analysis was deemed ineligible thus only a descriptive analysis (narrative synthesis) was conducted.

Results

1. Study Selection

A total of 886 studies were produced from our databases search, where the number came down to 565 after removing of duplicates. Afterwards, 105 articles were assessed for eligibility using full-text screening where a total of 20 studies [12–31] met our inclusion criteria and entered our review as shown by the PRISMA flow diagram (**Figure 1**).

2. Baseline characteristics of included studies

The most commonly utilized study design is the before-and-after experiment for ethical considerations limiting the possible randomisation (N=17). Of the studies included, 1 was a pilot RCT and another two were observational cohort studies from which one was observing medical records (**Table 1**). According to the study country, the United States of America (USA) came in first with 4 studies, followed by India (N=3), Ghana (N=2) and multiple other countries with one study each including Canada, Iran, Colombia, and others (**Table 1**).

Since our review included only recently published articles, most of the results were within the past 10 years, however, four studies were discussing data going back to dates earlier than 2014 [21, 24,25,29].

The ICU type varied among the included studies where 4 of them mentioned data in the PICU, 13

in the NICU and 3 studies worked with both. The main observed HCPs included physicians, residents, nurses, and nurse practitioners. Detailed sample sizes can be found in **Table 1**.

3. Assessment of the potential for bias

Most of the included studies were before-and-after non-randomised trials so they were assessed using the ROBINS-I tool where they mostly showed an overall serious/critical risk of bias especially in the confounding domain and the bias in measurement of outcomes domain (**Figure 2**).

Only one study was a pilot RCT so the ROB-2 was suitable for bias assessment which showed some concerns regarding risk of bias (**Figure 3**). Another two studies were observational prospective studies which were assessed using the NOS tool where one showed an overall score of 7 point demonstrating good quality and the other reached five points only thus was regarded as fair quality. Detailed data on the quality assessments can be found in **Supplementary File 2, Table S1&S2**.

4. Outcomes

4.1. Compliance

4.1.1. Intervention strategies to improve HH compliance/outcomes:

Most of the studies commonly implemented a multimodal strategy based on WHO recommendations with its five key components (N=14). However, other studies were based on the CDC guidelines [19,26], and one study used a combination of both [25]. Only two studies implemented a single intervention strategy whether video didactic or low-cost visual reminder tools [19,30]. The Plan-Do-Study-Act (PDSA) method was used by two studies for enhancing HH methodologies [17,26]. Another two studies used gloving in addition to regular HH for improving HH outcomes [17,19].

The International Nosocomial Infection Control Consortium (INICC) multidimensional HH approach (IMHHA) was used by three studies in Colombia, Turkey and Mexico [21,24,25]. It focused on main six components; administrative support, supplies availability, education and training, reminders in the workplace, process surveillance, and performance feedback.

Five studies used visual methods for increasing compliance including video reminders, posters or lighting systems [12, 19, 23, 28,30]. On the other hand, using educational material was the most common intervention (N=16). Monitoring and providing feedback on HH compliance were used in seven studies. The interventions implemented within each study are summarized in **Table 2**.

4.1.2. Observation methods

HH compliance observation included direct trained observers in the majority of studies (N=16), where it was not applicable four studies, one was assessing cost-effectiveness [22], another used surveillance camera to record HH moments [20], the third was an observational study from medical records [19], and the final one used wireless transmission of data through their implemented testing systems [12] (**Table 2**).

4.1.3. Compliance Rates:

The majority of included studies mainly focused in the compliance rate as an outcome (N=15). The pre- intervention compliance ranged from 17.8% to 87% while the intervention phase and post-intervention rates ranged from 47.1% to 93% (**Table 3**). Almost all studies included reported an increase in compliance after intervention except for Dramowski et al [23] where the overall neonatal unit HH compliance rate was unchanged from baseline to intensive phases.

4.2. Other outcomes

Multiple other outcomes other than compliance have been reported by the included studies but with varying measures. First, infections were discussed in different forms among studies starting with sepsis rates which were measured by two included studies. One presented an overall nosocomial sepsis surveillance per 100 or 1000 patient days where it showed a significant decrease in sepsis rate per 100 patients from 46% to 21% ($p<0.0001$) [26]. The other tested difference in the incidence of late onset sepsis before and

after wearing gloves in addition to proper HH where the incidence per 1000 patient days decreased from 2.99 to 0 ($p=0.028$) [19] (**Table 4**).

Another infection-related outcome was the incidence of a BSI in general, also discussed by two studies. Dramowski et al [23] reported no change in the neonatal unit HA-BSI rate during their intervention (from 2.9 to 3.1 episodes/1000 patient days between baseline and intensive phases) while Fenny et al [22] reported a decrease in neonatal BSI risk from 28% to 17.9% after intervention (optimal hand hygiene care).

Moreover, HAIs rates were presented by one study [13] which showed a decrease from 5.44% to 1.68% after HH enhancement interventions. Additionally, Hoang et al [20] calculated bacterial growth in relation to hand-washing time in seconds where 27 second were associated with zero growth, while 18 seconds wash resulted in heavy bacterial growth. Kallam et al [18] also discussed a related term which is the increase in the percentage of hands with 'low' or 'medium' contamination before-and-after intervention as a motivational tool for HH compliance. The results showed an increase in percentage of low/medium contaminated hands after intervention from 60% to 83%. Finally, Khan et al [17] described infections in terms of any sterile site infection and non-sterile site infection with their overall rates. Their results showed that most late-onset infections (LOIs) were non-sterile-site infections. Additionally, no decrease in sterile site 1st episode infection rates was observed (**Table 4**).

Other outcomes included the change in mortality rates. Fenny and colleagues reported a decrease from 26% to 8.3% in total mortalities among BSI neonates while Sadeghi et al demonstrated a decrease from 14.52% to 8.92% in overall mortality rates.

As for cost effectiveness, only one study [22] specifically targeted analysis of costs where it showed that the hospital cost attributable to neonatal BSI decreased after alcohol-based hand rub application compared to regular hand

wash with soap and water alone without alcohol (from 1,010 USD to 520 USD). They additionally tested the difference in mean length of hospital stay for the overall sample showing a decrease from a mean of 13 days to 11.4 days. Janota et al [19] also stated the change in hospital stay which showed a non-statistically significant decrease from 18.06 to 16.64 days ($p=0.509$) (**Table 4**).

One final outcome is the measurement of pre and post intervention handwashing or alcohol drying time. Hoang et al demonstrated an increase from 18 to 29 seconds for handwashing time while Van Gils et al reported the increase in alcohol drying time from 24.5 seconds to 32 seconds (**Table 4**).

5. Common limitations

Nine studies reported the potential for Hawthorne effect (improved compliance while being observed) as their main limitation. Another recurrent limitation was not measuring the "My five moments for hand hygiene" as advised by WHO, which was indicated by four studies [21, 23,25,26]. Other common drawbacks included the technical limitations, lack of consistent access to supplies, short-term follow-up, not measuring microbiology or clinical/infection outcomes, and the inability to include a control group in the study design because such a study would be unethical to perform. Detailed limitations and conclusions for all studies can be found in **Supplementary File 2, Table S3**.

Discussion

Hand hygiene is a critical component of infection control practices, particularly in pediatric and neonatal intensive care units, where vulnerable patients are at a higher risk of developing HAIs. While the importance of hand hygiene is well-established, the literature lacks comprehensive data on important outcomes such as infection rates specifically related to hand hygiene practices in pediatric ICUs. This review aimed to discuss potential HH improvement findings and address the current gaps in knowledge while proposing future directions for research in this area. We included studies improving HH without affecting any other risk factors for nosocomial infections i.e., no other newer infection preventive measures were implemented and no change in the hospital's antibiotic policy also did not change during the studies' periods.

The results of this systematic review on HH compliance rate in PICUs and/or NICUs rate after applying interventions ranged from 47.1% to 93%.

However, one study stood out [23] where the overall neonatal unit HH compliance rate was unchanged post-intervention. This could be attributed to variances in compliance definitions, a range of variables such as a lack of time, an urgent clinical emergencies overcrowding, severe workloads, and personnel shortages, as well as a complex and challenging healthcare environment in the intensive care units [32]. Additional common barriers to HH could be the increased work burden, skin dryness and irritation, emptiness or unavailability of materials in the work area, lack of training and experience, lack of feedback, and lack of role models in the team, all of which are worth exploring for enhanced HH performance and efficacy [21,25]. Behavioural factors may have also contributed to suboptimal HH compliance factors such as suspicion about the significance of HH and forgetfulness, but full compliance may be an unachievable aim, especially in neonatal settings that need regular patient handling [33].

Multimodal approaches that incorporate education, written materials, reminders, and ongoing performance evaluation can have a significant impact on handwashing compliance and hospital-acquired infection rates. This is evident in the studies that applies the IMHHA where compliance greatly increase after this multidimensional approach [21,24,25]. This is in agreement with a previous systematic review which suggested that multimodal operations detained more potential effectiveness than single HH intervention [34].

A limitation of hand hygiene auditing processes used in most studies is the potential for Hawthorne effect, which should falsely elevate compliance rates above true compliance due to visible observers. Subsequently, most studies' results published are subject to uncertainty of evidence in real-life long applications. A possible solution incorporated by Amaan et al [30] is the use of close circuit (CC) camera system also allows indirect remote observation without the Hawthorne effect but nevertheless is not widely used for observation as the direct observation method has been accepted as the gold standard for monitoring the HH compliance [35]. This possible false increase in compliance is similar to a review by Seo et al [32] where half of their included studies were subjective to Hawthorne effect due to direct observations. Though in agreement, it is important to note that their study focused on results in the emergency department versus the ICU setting in our review. Subsequently, it seems that HCPs demonstrate similar compliance rates in critical care settings.

One main conclusion drawn by this systematic review is a lack of data on infection rates as consequences of hand hygiene procedures in PICUs. Existing research focuses mostly on hand hygiene

compliance rates or equivalent outcomes like technique, knowledge, or perception. The absence of data on actual infection rates makes it difficult to establish a causal link between hand hygiene compliance and its influence on lowering HAIs in PICUs. Infection rates were discussed with varying definitions and measures among a few included studies. For instance, Chhapola et al [26] focused on nosocomial sepsis rate per 100 and 1000 patient-days where they noticed a significant reduction in rates. Moreover, they clearly stated that they assume the reduction in infection rate was most likely attributed to the improvement in HH since there were no other included interventions. On the other hand, another study by Khan et al [17] showed no decrease in infection rates, but actually a slight increase in rate per 1000 days.

This could be owing to the misconception that HH is unnecessary when using gloves, despite staff education on HH recommended practices. If physicians consider those around them to be less compliant with hand cleanliness during gloving, they may be more inclined to examine nonspecific symptoms in newborns as potential sepsis, resulting in a higher rate of culture negative sepsis events. However, most LOIs were non-sterile-site infections which is considered a less clinically relevant outcome compared to sterile-site LOI [17].

Some studies addressed the fact the studies based on the observational, before-and-after methodology point toward less strength of evidence than other study designs. However, an RCT in the pediatrics ICU setting using no HH intentionally would be unethical to perform and endangering to patients. The pre-post design allowed use of pre-intervention phase as the reference for all comparisons without needing an external control group [26] thus preserving patient safety and ethical considerations. It is possible, however, to pilot RCTs similar to Khan et al [17] observing higher HH measures using gloves versus less strict ones applying standard HH care without causing any patient harm.

Limitations and Strengths

An obvious limitation in our review is the significant heterogeneity among included studies which in turn prohibited the possibility of a meta-analysis. An additional drawback is the high risk of bias presented in most studies due the quasi-experiment design with no control group, however we addressed it by stating that it is unethical to include a control group in such cases. Another limitation is the high risk of bias shown by our quality assessment which could mean that the conduct of the studies gave misleading results so real-life applications might result in different outcomes. As stated by Hoang et al [20], one might criticize the studies' outcomes supported by the inability to credit

any single intervention due to the implementation of multiple simultaneous changes, lack of microbiological data, and inconsistent outcomes among study groups (i.e., physician, nurses, technical staff). Even though we excluded studies with multiple infection control measures, the multifaceted world of infection control makes it tough to assure the produced judgments are purely because of increased HH compliance without any other confounding variables. Finally, most hand hygiene interventions do not use microbiological testing to assess improvements in hand hygiene outcomes. This is probably due to the complexity of microbiological testing as the primary mechanism for measuring change in adherence [18]. On the other hand, we believe our study is the first to review enhancement of HH and its outcomes in pediatric and neonatal ICU settings. Our findings show a significant gap in presenting infection control rates in relation to HH and thus guide future research in addressing these needs.

Conclusion and Future Directions

Overall, our review demonstrated the possible outcomes of enhanced HH in the PIUC/NICU. Multiple outcomes were reported across studies with compliance rates being the most assessed. Future studies should focus on testing HH enhancement in correlation to infection control outcomes. The paucity of research in such connection is alarming and needs vast measures for improvement. This can be achieved by integrating surveillance systems within PICUs/NICUs to enable continuous and real-time monitoring of infection rates, hand hygiene compliance, and other relevant variables. Integrating these data sources would offer researchers and healthcare practitioners with a more thorough understanding of the relationship between hand hygiene conduct and infection rates, resulting in targeted treatments and enhanced outcomes for patients.

Moreover, large-scale, multi-center collaborative longitudinal research are required to overcome the scarcity of data on infection rates and outcomes in PICUs/NICUs. These studies would allow for a larger sample size, stronger statistical power, longer follow-up durations, and a wider applicability of the findings, ultimately leading to an improved comprehension of the influence of hand cleanliness on infection rates in such critical patient settings.

References

1. Northway T, Langley JM, Skippen P. Health Care-Associated Infection in the Pediatric Intensive Care Unit. In: *Pediatric Critical Care* [Internet]. Elsevier; 2011. p. 1349–63. Available from: <https://linkinghub.elsevier.com/retrieve/pii/B9780323073073100977>
2. Shane AL, Stoll BJ. Neonatal sepsis: progress towards improved outcomes. *J Infect* [Internet]. 2014 Jan;68 Suppl 1:S24–32. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/24140138>
3. Gould DJ, Moralejo D, Drey N, Chudleigh JH, Taljaard M. Interventions to improve hand hygiene compliance in patient care. *Cochrane database Syst Rev* [Internet]. 2017 Sep 1;9(9):CD005186. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/28862335>
4. Peters A, Masson-Roy S, Pittet D. Healthcare-associated sepsis and the role of clean hands: When we do not see the trees for the forest. *Int J Infect Dis* [Internet]. 2018 May;70:101–3. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/29501872>
5. Santosaningsih D, Erikawati D, Santoso S, et al. Intervening with healthcare workers' hand hygiene compliance, knowledge, and perception in a limited-resource hospital in Indonesia: a randomized controlled trial study. *Antimicrob Resist Infect Control* [Internet]. 2017;6:23. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/28239452>
6. Pittet D. The Lowbury lecture: behaviour in infection control. *J Hosp Infect* [Internet]. 2004 Sep;58(1):1–13. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/15350707>
7. World Health Organization. A Guide to the Implementation WHO Multimodal Hand Hygiene Improvement Strategy. [Internet]. Who. 2009. p. 1–47. Available from: http://whqlibdoc.who.int/hq/2009/WHO_IER_PSP_2009.02_eng.pdf
8. CDC. Hand Hygiene Guidance | Hand Hygiene | CDC [Internet]. Centers for Disease Control and Prevention. 2020. Available from: <https://www.cdc.gov/handhygiene/providers/guideline.html>
9. Allegranzi B, Kilpatrick C, Sax H, Pittet D. “My Five Moments”: understanding a user-centred approach to hand hygiene improvement within a broader implementation strategy. *BMJ Qual Saf* [Internet]. 2022 Apr;31(4):259–62. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/35131895>
10. Lambe KA, Lydon S, Madden C, et al. Hand Hygiene Compliance in the ICU: A Systematic Review. *Crit Care Med* [Internet].

- 2019 Sep;47(9):1251–7. Available from: <https://journals.lww.com/10.1097/CCM.0000000000003868>
11. Issa M, Dunne S, Dunne C. Hand hygiene practices for prevention of health care-associated infections associated with admitted infectious patients in the emergency department: a systematic review. *Irish J Med Sci* (1971 -) [Internet]. 2023 Apr 18;192(2):871–99. Available from: <https://link.springer.com/10.1007/s11845-022-03004-y>
12. Gils R Van, Kornelisse R, Dankelman J, Helder O. Validation of a hand hygiene visual feedback system to improve compliance with drying time of alcohol-based handrub in a Neonatal Intensive Care Unit: The Incubator Traffic Light system. *J Hosp Infect* [Internet]. 2024; Available from: <https://doi.org/10.1016/j.jhin.2024.01.007>
13. Sadeghi-Moghaddam P, Arjmandnia M, Shokrollahi M, Aghaali M. Does training improve compliance with hand hygiene and decrease infections in the neonatal intensive care unit? A prospective study. *J Neonatal Perinatal Med*. 2015;8(3):221–5.
14. Fenny AP, Otioku E, Appiah-Korang Labi K, Asante FA, Enemark U. Cost-effectiveness analysis of alcohol handrub for the prevention of neonatal bloodstream infections: Evidence from HAI-Ghana study. *PLoS One* [Internet]. 2022;17(3 March):1–14. Available from: <http://dx.doi.org/10.1371/journal.pone.0264905>
15. Dramowski A, Erasmus LM, Aucamp M, et al. SafeHANDS: A Multimodal Hand Hygiene Intervention in a Resource-Limited Neonatal Unit. *Trop Med Infect Dis*. 2023;8(1).
16. Deshommes T, Nagel C, Tucker R, et al. A Quality Improvement Initiative to Increase Hand Hygiene Awareness and Compliance in a Neonatal Intensive Care Unit in Haiti. *J Trop Pediatr*. 2021;67(3):1–8.
17. Chitamanni P, Allana A, Hand I. Quality Improvement Project to Improve Hand Hygiene Compliance in a Level III Neonatal Intensive Care Unit. *Children*. 2023;10(9):1–11.
18. Chhapola V, Brar R. Impact of an educational intervention on hand hygiene compliance and infection rate in a developing country neonatal intensive care unit. *Int J Nurs Pract*. 2015;21(5):486–92.
19. Campbell JI, Pham TT, Le T, et al. A family empowerment strategy is associated with increased healthcare worker hand hygiene in a resource-limited setting. *Infect Control Hosp Epidemiol*. 2019;41(2):202–8.
20. Belela-Anacleto ASC, Kusahara DM, Peterlini MAS, Pedreira MLG. Hand hygiene compliance and behavioural determinants in a paediatric intensive care unit: An observational study. *Aust Crit Care*. 2019;32(1):21–7.
21. Barahona-Guzmán N, Rodríguez-Calderón ME, Rosenthal VD, et al. Impact of the International Nosocomial Infection Control Consortium (INICC) multidimensional hand hygiene approach in three cities of Colombia. *Int J Infect Dis*. 2014;19(1):67–73.
22. Amaan A, Dey SK, Zahan K. Improvement of Hand Hygiene Practices among the Healthcare Workers in a Neonatal Intensive Care Unit. *Can J Infect Dis Med Microbiol*. 2022;2022.
23. Albert BD, Petti C, Caraglia A, et al. Multidisciplinary Quality Improvement Intervention to Achieve Sustained Improvement in Hand Hygiene Reliability in a Pediatric Intensive Care Unit. *Pediatr Qual Saf*. 2019;4(6).
24. Miranda-Novales MG, Sobreyra-Oropeza M, Rosenthal VD, et al. Impact of the International Nosocomial Infection Control Consortium (INICC) Multidimensional Hand Hygiene Approach during 3 Years in 6 Hospitals in 3 Mexican Cities. *J Patient Saf*. 2019;15(1):49–54.
25. Leblebicioglu H, Koksai I, Rosenthal VD, et al. Impact of the International Nosocomial Infection Control Consortium (INICC) Multidimensional Hand Hygiene Approach, over 8 years, in 11 cities of Turkey. *J Infect Prev*. 2015;16(4):146–54.
26. Kumar A, Kumar R, Gupta AK, et al. Improvement of Hand Hygiene Compliance Using the Plan-Do-Study-Act Method: Quality Improvement Project From a Tertiary Care Institute in Bihar, India. *Cureus*. 2022;14(6).
27. Khan S, Tsang KK, Hu ZJ, et al. GloveCare: a pilot study in preparation for a cluster crossover randomized controlled trial of non-sterile glove-based care in preventing late-onset infection in the NICU. *Pilot Feasibility Stud* [Internet]. 2023;9(1):1–15. Available from: <https://doi.org/10.1186/s40814-023-01271-9>
28. Kallam B, Pettitt-Schieber C, Owen M, Asante RA, Darko E, Ramaswamy R. Implementation science in low-resource settings: Using the interactive systems framework to improve hand hygiene in a tertiary hospital in Ghana.

- Int J Qual Heal Care. 2018;30(9):724–30.
29. Janota J, Šebková S, Višňovská M, Kudláčková J, Hamplová D, Zach J. Hand hygiene with alcohol hand rub and gloves reduces the incidence of late onset sepsis in preterm neonates. *Acta Paediatr Int J Paediatr*. 2014;103(10):1053–6.
30. Hoang D, Khawar N, George M, Gad A, Sy F, Narula P. Video didactic at the point of care impacts hand hygiene compliance in the neonatal intensive care unit (NICU). *J Healthc Risk Manag*. 2018;37(4):9–15.
31. Gopalakrishnan S, Chaurasia S, Sankar MJ, et al. Stepwise interventions for improving hand hygiene compliance in a level 3 academic neonatal intensive care unit in north India. *J Perinatol*. 2021;41(12):2834–9.
32. Rashid H, Shafi S, Haworth E, et al. Viral respiratory infections at the Hajj: comparison between UK and Saudi pilgrims. *Clin Microbiol Infect*. 2008;14(6):569.
33. Seo HJ, Sohng KY, Chang SO, Chaung SK, Won JS, Choi MJ. Interventions to improve hand hygiene compliance in emergency departments: a systematic review. *J Hosp Infect* [Internet]. 2019 Aug;102(4):394–406. Available from: <https://linkinghub.elsevier.com/retrieve/pii/S0195670119301471>
34. COHEN B, SAIMAN L, CIMIOTTI J, LARSON E. Factors associated with hand hygiene practices in two neonatal intensive care units. *Pediatr Infect Dis J* [Internet]. 2003 June;22(6):494–8. Available from: <https://journals.lww.com/00006454-200306000-00003>
35. Naikoba S, Hayward A. The effectiveness of interventions aimed at increasing handwashing in healthcare workers - a systematic review. *J Hosp Infect* [Internet]. 2001 Mar;47(3):173–80. Available from: <https://linkinghub.elsevier.com/retrieve/pii/S019567010090882X>
36. Boyce JM. Electronic monitoring in combination with direct observation as a means to significantly improve hand hygiene compliance. *Am J Infect Control* [Internet]. 2017 May;45(5):528–35. Available from: <https://linkinghub.elsevier.com/retrieve/pii/S0196655316310963>