Complex infection control strategies at the neonatal intensive care unit with a special focus on hand hygiene

Ph.D. thesis

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List of full papers that served as the basis of the Ph.D. thesis

I. Nagy K, Szél B.: Improving hand hygiene compliance at the University of Szeged [Kézhigiénés compliance fejlesztése a Szegedi Tudományegyetemen]. 2013(91) 4. 274–81. [Hungarian]

II. Szél B, Reiger Z, Urbán E, Lázár A, Mader K, Damjanova I, Nagy K, Tálosi G. Successful elimination of extended-spectrum beta-lactamase (ESBL)-producing nosocomial bacteria at a neonatal intensive care unit. World J Pediatr. 2017;13(3):210–216.

III. Szél B, Nagy K, Milassin M, Tálosi G. Beliefs - Misbeliefs, answering essential questions about hand hygiene from the view of the evidences [Hitek és tévhitek, azaz vitatott esszenciális kérdések a kézhigiénéről az evidencia tükrében]. Orv Hetil. 2017;158(6):212–220. [Hungarian]

Papers not related to the Ph.D. thesis

I. Fráter M, Szél B. MRSA and the dentistry [Az MRSA és a fogászat.] IME XII. évfolyam 3. szám 2013. [Hungarian]

II. Virok DP, Abrók M, Szél B, Tajti Z, Mader K, Urbán E, Tálosi G. Chryseobacterium gleum - a novel bacterium species detected in neonatal respiratory tract infections. J Matern Fetal Neonatal Med. 2014;27(18):1926–9.

Introduction

According to the Luxembourg declaration on patient safety, access to high-quality healthcare is a key human right that is recognized and valued by the European Union (EU), and also by its institutions and citizens. Healthcare-associated infections (HAIs) are complications of healthcare provision that contribute to increased patient morbidity and mortality. HAIs lead to increased healthcare costs for patients, their insurers and hospitals, due to unanticipated duration of hospital stay and associated treatment. There is also a psychological burden placed on patients, their carers, and their families, in addition to opportunity costs arising from patients and their carers' inability to work, attend school, etc., while hospital capacity impacts the efficiency of healthcare.

Although not all HAIs are preventable, hand hygiene (HH) is considered to be the most effective way of preventing microbial transmission and to reduce the spread of antimicrobial resistant bacteria. Studies are revealing negative correlations between the HH of healthcare workers (HCWs) and HAIs, estimating that HCWs' correct hand sanitation could prevent up to 50% of HAIs. Since Ignaz Semmelweis demonstrated dramatic reductions in puerperal sepsis after instituting a disinfectant hand-washing regimen in 1847, HH has been known to reduce HAIs and is recommended by the Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO) as the single most effective method of preventing the spread of nosocomial infections. Given the growing evidence it became obvious that preventing the spread of infection requires performing HH properly and at key moments during patient care as the critical preventive measure.
After the introductions of international HH campaigns and guidelines, the Hungarian guideline was launched in 2009.
Hand-washing and hand disinfection with alcohol-based hand rubs (AHRs) removes microrganisms effectively, and is the reference standard for effective HH. Although the mentioned procedures are quite simple and easily accomplishable, HH compliance remains low among HCWs, with reported adherence rates ranging from 20% to 50%.

Measuring AHR consumption for HH performance is a simple way to be able to describe and calculate the frequency of HH actions and to compare them between units or hospitals as well. Good correlations have been found in studies between AHR consumption and HH compliance rates, and also between AHR consumption and HAI reduction.

AHR consumption is calculated and reflected on 1000 patient days, which repsresents a standard population and time period for interpretation of the usage. From this value we can easily calculate how many times were HH performed at one patient during 24 hours. This data does not contain the amount of used surgical hand scrubs. In Hungary, the national average of AHR consumption has improved in all healthcare facilities due to national HH campaign (from an average 7L/1000 patient days in 2011–2012 to 9.9L/1000 patient days in 2015). Despite the above mentioned increase in AHR consumption, compliance still cannot be deemed acceptable. Barriers to correct HH practices include forgetfulness, lack of knowledge about expected standards, low priority, time constraints and inaccessible HH supplies.

It is important to note that findings gathered from surveys and questionnaires on HH practice of HCWs often shed light to the existence of behaviours or attitudes, which are originated from inadequate knowledge in this topic. Such behaviours are clearly not a consequence of indiscipline but a misconception based on faulty information and lack of knowledge or previous erroneous beliefs. Improving HH compliance and sustaining a positive behavioural change remains a significant challenge, given the complexities of the healthcare environment and the difficulty of changing behaviour.

Besides the fact that the level of HH is not perfect among HCWs partly due to misbeliefs or deficient information and partly due to their inadequate compliance originating from multiple factors, the occurrence of multi-drug-resistant (MDR) bacteria is even aggravating the situation since the handborne route is of critical importance in nosocomial cross-infections. The appearance of MDR bacteria is a major concern among medical care providers all over the world. MDR Gram-negative bacterial infections have become prevalent already in some European countries. Moreover, increased use of broad-spectrum antimicrobial agents selects organisms with resistance and, by increasing their numbers, increases their chance of spread. Of these, extended-spectrum beta-lactamase (ESBL)-producing Gram-negative bacteria are especially problematic, as they are becoming increasingly resistant. The group of ESBL-producing bacteria typically includes *Escherichia coli*, *Enterobacter cloaceae* and *Klebsiella pneumoniae*. Once involved in HAI, the situation can become quite dangerous.

Nosocomial infections are one of the leading causes of mortality and morbidity in the neonatal intensive care unit (NICU).

The above mentioned ESBL-producing bacteria are highly dangerous to neonates, especially low-birthweight preterm infants, and their nosocomial persistence may lead to prolonged hospital stay, higher mortality and growing costs. Gram-negative organisms account for 18 to 31.2% of infections at the NICU. Therefore, their increasing presence is a significant risk factor in NICU, which must be dealt with.

The NICU of the Department of Paediatrics at the University of Szeged at the time of the study was a 17-bed tertiary care centre, with annual admissions of 210-250 newborns with the most severe perinatal conditions from the Southeast region of Hungary (with a population of almost 1.5 million). At this unit, the first ESBL-producing infection was detected in 2002. By 2008, ESBL-producing bacteria became standard nosocomial bacteria, and a total eradication was never achieved. The problem became critical in the second half of 2011, when more than half of the neonates on the ward were colonised, which called for immediate intervention. In the following I would like to describe a complex, multitask infection control (IC) project highlighting the period January 2011–September 2012, which finally led to successful IC management at our NICU.

Aims

I. Reaching a significant increase in the number of HH events in case of HCWs at the NICU by implementing a multimodal strategy.

II. Reducing the number of future infections and colonisations by identifying and subsequently eliminating all potential sources of infection.

III. Implementing non-invasive treatments at the ward which would possibly lead to the reduction of device-related infections.

IV. Assessing the current knowledge of nurse students on HH in order to identify potential factors related to future insufficient HH compliance.

Methods

As a consequence of the spread of ESBL-producing bacteria, a specific IC task force was formed, with representatives from the NICU, the Institute of Clinical Microbiology and the IC Unit. The group met weekly to discuss the situation. A three-step complex management plan was devised in September 2011, which involved retrospective data analysis aimed at identifying risk factors, education of staff and introduction of new hygienic measures based on the retrospective analysis, and a follow-up phase. We conducted the retrospective study from January 2011 to September 2011 and the prospective study from January 2012 to September 2012. Between the two periods we allowed the staff three months to become accustomed to the new protocols and strategies introduced. Patient-days/month were calculated by the electronic patient documentation system (eMedSolution® by T-Systems Hungary Ltd, Budapest), which provides up-to-date data and automatically generates statistical information upon the user's request.

Retrospective Analysis

Data were gathered retrospectively from the January-September 2011 period regarding HH compliance among HCWs and ESBL colonisation/infection data among patients treated at the NICU. HH compliance was assessed indirectly, based on the recorded use of AHR, from which the average number of HH procedures could be estimated according to the WHO Guidelines on Hand Hygiene in Health Care. Patient files were surveyed for microbiological documentation, in an attempt to determine the types of ESBL-producing bacteria on the ward, and the findings were recorded.

Preventive Measures and Prospective Analysis

Based on the findings of the retrospective phase, a number of preventive measures were introduced in the October–December 2011 period.

First of all, in September 2011, the intubation, surfactant therapy and extubation (INSURE) protocol was introduced. With INSURE, the mechanical ventilation time can be reduced, which helps reduce the number of ventilation-associated infections. The antibiotic protocol was also modified. On admission, blood culture and gastric aspirate were collected from each new patient. Progressive feeding was started within the first two hours after admission. The neonates received their own mother's breast milk through a gastric tube, if available. If not, premature and neonatal formulae were administered. As a new preventive measure the neonates were bathed every four days. Immersion baths were stopped. This was important because the risk of infection by biofilm-forming bacteria (i.e. on the surface of the basin or in the waterlines) could thus be reduced. Due to the potential risk of cross-infection with ESBL-producing *Klebsiella pneumoniae* transferred via the hands of HCWs at the NICU our team has put great emphasize on proper HH. HH training was a central step in the complex intervention. Multiple education sessions were provided for all staff, including video-assisted instruction and hands-on practice. Disinfected hands were also examined under UV light to ascertain efficacy.

In order to identify potential reservoirs and risk factors, environmental screening was performed and samples were taken from various surfaces.

New filters were used on taps and the sinks were regularly dismounted and disinfected, while the staff was instructed that hand-washing with soap and water should be done as far as possible at the wash basins outside the hospital rooms. This was important since germs may be emitted as aerosols from the siphon traps into the ambient air during water drainage. Additionally, new AHR dispensers were placed in the ward wherever healthcare procedures are performed. The quality of cleaning was also evaluated and monitored.

In order to stop the spread of ESBL-producing bacteria, patients were screened for these on admission. Once colonisation or infection was detected, contact precautions were implemented and maintained throughout the hospital stay.

Microbiological analysis

Identification of isolates was carried out with the conventional biochemical identifications and VITEK GN (bioMérieux, France). Genetic relationships between *Klebsiella pneumoniae* and *Enterobacter cloacae* isolates were investigated with the pulsed field electrophoresis method using *Xba*I restriction endonuclease according to the standardized PulseNet protocol.

Statistical analyses

The Mann-Whitney U-test, Wilcoxon- test, and Student's t-test were used, as appropriate. Level of significance was set at $p<0.05$. Statistical analyses were performed with SPSS 19 (IBM Corp., Armonk, NY).

Knowledge survey for students

Also within the mentioned retrospective period, simultaneously with the multitask IC intervention at the NICU, knowledge assessment was performed via a questionnaire on HH among nurse students. The students who participated in the assessment were already involved in patient care during their practice, therefore they hold the possibility of spreading pathogens in the healthcare environment. The questionnaire aimed to assess the basic knowledge regarding HH among the participating students attending at higher and lower educational courses. These students had active gradual student status in the 2011–2012 autumn semester either at the Faculty of Health Science and Social Studies in the BSc Nursing and Patient Care nursing specialization program (college students) or at the Secondary Vocational School (certification course students).

Results

Compared to the retrospective period, in the prospective period the average number of patient-days decreased from 343.72 days per month to 292.44 days per months, though this difference is not significant (p=0.058). In the prospective period a significant reduction was observed both in the number of colonised (from 72/188 to 26/167; p=0.029) and infected patients (from 9/188 to 3/167; p=0.033) when compared to the retrospective examination interval.
It is worth mentioning that in the retrospective period five infected patients died, while no deaths occurred after the introduction of the new measures.

The number of invasive mechanical ventilation days per patient care days was also decreased significantly, almost by 50% (Table I).

Table I. Descriptive statistics of the study parameters from the two examined periods.

Variables	2011 January–September Retrospective period	2012 January–September Prospective period
Patient day /month	324.50 (306.00-403.5)	296.00 (175.50-376.50)
Admitted patients/month	22 (14-28)	19 (15-22)
ESBL colonised patients	7 (1-15)	2 (0-8)*
ESBL nosocomial infected patients	2 (0-4)	0 (0-1)*
ABHR consumption/L	26.5 (19.5-34.5)	32.5 (23.0-46.4)*
Monthly mechanical ventilation days / ventilated patients	9.77 (5.88-18.11)	5.00 (3.24-8.88)**
Performed hand hygiene/patient/day [*average*]	27.39 (17.22-31.08) [*26,02*]	39.17 (33.28-44.07)*** [*33,6*]

Values are given as median (minimum-maximum). The significance of the given parameter between the two periods is indicated at: *p<0.05; **p<0.01; ***p<0.001

Regarding the samples taken from the ESBL-positive patients, during the whole interval, 26 out of 29 *Klebsiella pneumoniae* isolates exhibited pulsotype Z. As for the 25 *Enterobacter cloacae* isolates studied, 23 belonged to EbC052, one to EbC054 and another to EbC038.

170 environmental swab samples were taken during the intervention period (October to December 2011). These samples were collected from 107 critical and 63 non-critical surfaces. 25 out of 107 critical and 14 out of 63 non-critical surface samples were culture positive, respectively, thus highlighting inadequately cleaned areas. Of these samples, a few were taken from a wash basin, three taps, a common warming bath for feeding bottles and the dish tray in the nurses' room; all of these contained ESBL-producing *Enterobacter cloacae*, belonging to pulsotype EbC052. In February 2012, we also took samples from HCWs' stool in search of ESBL-producing bacteria and further potential sources of infection because these caregivers are in close, direct contact with the infants. Two samples from 32 HCWs showed ESBL-producing *Escherichia coli* positivity; however, no infants showed ESBL-producing *Escherichia coli* positivity at the ward.

In a comparison of the two periods under examination, a significant increase can be seen in the prospective period regarding the consumption of AHR solutions ($p=0.03$). In the first phase this represented an average of 77.90 L AHR per 1000 patient-days, while in the second interval this figure increased to 114.96 L per 1000 patient-days. Compared to the baseline data at the beginning of the retrospective period under examination (81 infected and colonised patients out of 188 inpatients leading to 26.18 ESBL-positive patients per 1000 patient-days), a significant reduction can be seen in the incidence of ESBL-positive patients by the end of the prospective phase (only 29 infected and colonised patients out of 167 inpatients leading to 11.01 positive patients per 1000 patient-days, $p=0.02$), as it is clearly visible from Figure 1.

Indirect HH compliance showed a significant increase in the prospective examination period compared to the retrospective examination period ($p< 0.001$) (Figure 1).

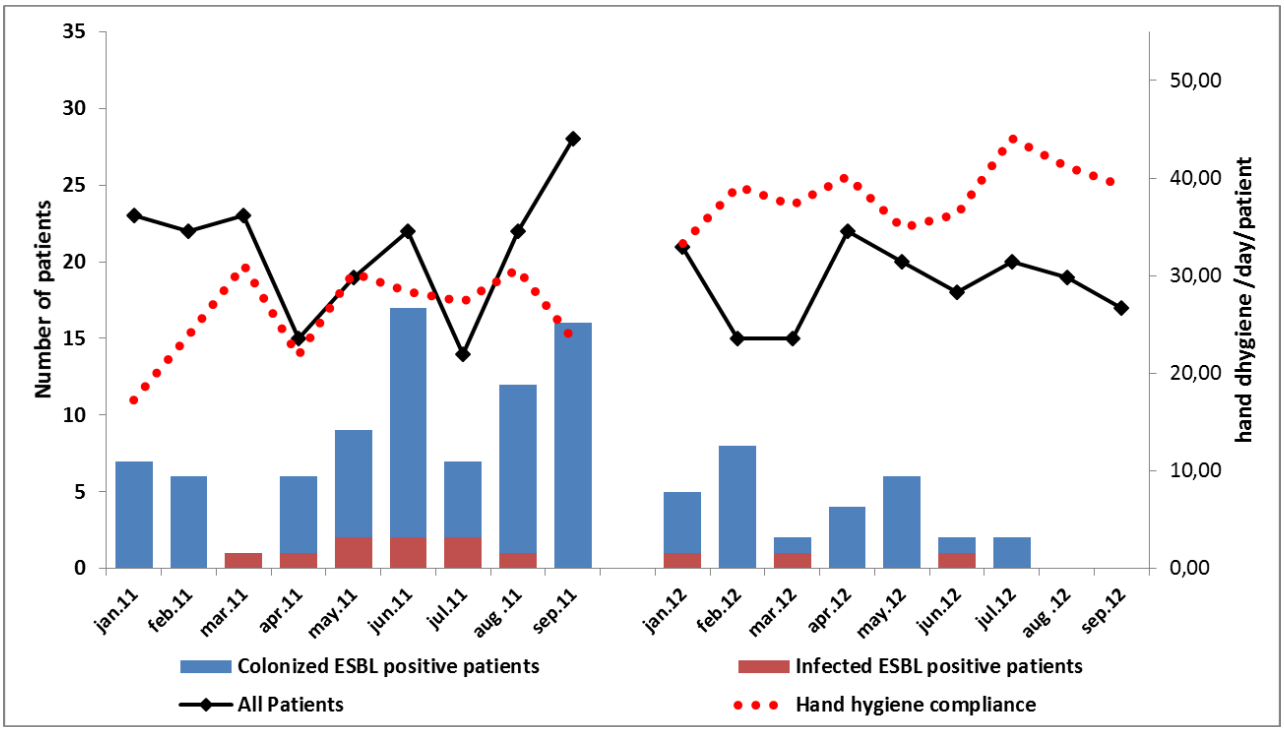

Figure 1. Comparison of the retrospective and prospective periods in terms of colonisation, infection and hand hygiene compliance "hand hygiene/day/patient" refers to the number of hand hygiene procedures performed in the case of one patient during one day at hospital.

In the retrospective phase, 26.02 HH procedures were performed on average per patient per hospital day, and this increased to 33.6 in the prospective phase**.** As a result of the HH education performed for the staff and with the useful aid of a UV lamp for supervision, the efficacy of hand cleaning among HCWs also improved significantly. In the retrospective period, when HH practice was examined, the nail beds and dorsal surfaces of the thumbs were usually missed (perfect results were only achieved in 14% of the cases). During a three-week period, staff was supplied with a UV lamp for detecting fluorescent AHR to provide them with an opportunity to practice and evaluate their own HH technique. During the UV lamp-supported training, perfect HH practice increased to 77%.

Regarding the knowledge test among students there was no significant difference between the levels of correct answers between the two student groups, thus their knowledge regarding basic HH seemed to be similar. (OR: 0.984 95%; CI: 0.954–1.016). Only 41.3 % of the students recognised the contaminated hands as the main source of cross-infection in patient care. Only 19% of the responders identified the patient as one of the potential sources of HAIs, which is deemed the most important source by the WHO. Fortunately, 83% of the responding students are aware of the fact HH with AHRs is more effective against pathogens than hand-washing with soap and water. In respect to this a lot of students could give correct answer to the question dealing with which HH technique (hand-washing with soap and water or HH with AHR) to use in different situations (OR: 0.721 95%; CI: 0.535–0.972). On average the reached value was 60.36% (SD: 11.57%).

Discussion

IC has a remarkable historical connection with the paediatric population. Ignác Semmelweis already found a link between HH and perinatal infection rates in the nineteenth century.

In our study, there was a sharp decrease in the number of patients colonised and infected with ESBL-producing bacteria after the above mentioned steps were implemented. ESBL-producing Gram-negative bacteria can survive on environmental surfaces, preferably in moist sites, for weeks; environmental decontamination is therefore a highly important issue in ICUs. After an evaluation of the results and an identification of possible sources, the usage of wash basins was minimised and the dish tray was removed permanently from the nurses' room. Also, the local specific warming method (i.e. that all feeding bottles were warmed in a common warming bath) was immediately banned from the ward. The quality of cleaning critical surfaces near the patients improved, as none of these surfaces have produced positive samples after the introduction of the new cleaning regimen.

We also carried out faecal sampling from HCWs' stool in search of ESBL-producing bacteria. Although two samples from 32 HCWs exhibited ESBL-producing *Escherichia coli* positivity, no infants showed positivity with this specific species at the ward. Therefore, the two positive cases cannot be regarded as potential sources of the infection, which occurred among the infants. Patients in the NICU are more likely to be infected by MDR microorganisms and most of these infections are spread by carriage of microorganisms on the HCWs' hands, thus outbreaks of infections resulting from cross-transmission are frequent here. It has been emphasized that HCWs' compliance with HH protocols in the NICU is highly important to limit the spread of pathogens by the hands of HCWs and thus to prevent nosocomial infections. In the process of improving HH compliance it is a key element to clarify those essential questions in the field of HH which could either cause confusion among HCWs or they were under the influence of anecdotal misbeliefs regarding these questions or topics, inhibiting them from reaching adequate HH compliance. By analysing the collected questionnaires from nurse students, knowing the possible weak points in HH from previous surveys, reviewing current evidence in the literature in this topic, and also with the experience gathered on the field during the direct observations and regular supervisions in practice, ten key questions were highlighted and discussed thoroughly.

As a result of the hygienic interventions, namely the examination of hands under UV light and small-group training sessions for clinicians and staff, including instruction on correct HH procedure, indirect HH compliance showed a significant increase.

Currently it is clear that HH is recognized as the single most important measure for preventing the spread of HAIs and has been embraced as a standard for healthcare settings by the CDC and the WHO as a critical component of IC programs. Such standards mandate that to promote HH compliance, HH resources must be made readily accessible at critical locations, and behavior change must be supported through the use of a multimodal strategy that includes education, training, monitoring, feedback, and organizational support.

In our proposed multistep intervention, posters were placed at the ward to draw the attention to current, specific IC problems. The posters as reminders address the issue of ‘forgetting’, which has been identified as a common cause of missed HH opportunities. Furthermore, aiming to produce peer and even leader pressure or motivation, the head of the NICU on purpose continuously paid attention to show a good example for the HCWs at the Unit.

With the aid of using the specific UV lamp-based Semmelweis Scanner (Hand in Scan ®) at the ward, we managed to see and show the individual improvements to each HCW.

In order to sustain the reached superior results compared to the baseline ones, continuous feedback was and is still provided by the IC task force to the wards.

Performance feedback is a core behaviour improvement strategy in healthcare and HH promotion.

Conclusion

During our work, we could reach the aims of the study:

I. There was a significant increase in the number of HH events in case of HCWs at the NICU by implementing a multimodal strategy.

II. We could reduce the number of HAI and colonisations by identifying and subsequently eliminating all potential sources of the infections.

III. We implemented non-invasive treatments at the ward which lead to the reduction of device-related infections.

IV. We assessed the actual knowledge of nurse students on HH and identified potential factors related to future insufficient HH compliance.

It is universally agreed that the prevention of HAIs is an important patient safety activity, and good HH has both a financial and ethical imperative. Therefore, hospitals are under enormous pressure to improve HH and reduce HAIs. In our proposed case, rolling back ESBL-producing bacteria at our NICU was successful. We attribute this success mainly to the multidisciplinary approach, the continuous feedback and monitoring, and the high compliance of the staff. Although the staff of a NICU is in closer contact with neonates, compared to a ward with older patients, colonisation of HCWs did not play any role in the nosocomial persistence of ESBL-producing bacteria. Applying a multimodal approach involves the use of multiple strategies simultaneously. Our proposed multimodal IC strategy process constituted of three critical steps: measuring baseline compliance rate, identifying barriers, and instituting measures to remove barriers prohibiting effective HH. This multimodal intervention is verified by multiple studies proving that behaviour change must be supported through the use of a multimodal strategy that includes education, training, monitoring, feedback, and organizational support. Despite the diversity of participants in our case, the data collected from HCWs was useful to identify focused areas for improvement and eventually led to improvements in compliance. Parameters for noncompliance with HH are not just related to individual health professionals, but also to the team and the institution they belong to. HAI prevention is the responsibility of everyone, and cannot be delegated to experts in the field of IC and prevention. However, IC activities need to be organized and managed by competent experts in the field.

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