Healthcare-associated infection in the Grey's Hospital paediatric intensive care unit: does an Infection Control Programme work?

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Background: Healthcare-associated infections are an important cause of morbidity and mortality globally. Grey's Hospital introduced an Infection Control Programme in August 2016, which included Best Care Always bundles for reducing the occurrence of central line-associated bloodstream infections, catheter-associated urinary tract infections and ventilator-associated pneumonia.

Methods: An observational before–after quasi-experiment was conducted retrospectively reviewing healthcare-associated infection rates in the Grey's Hospital paediatric intensive care unit a year prior to (August 2015 to July 2016) and after (September 2016 to August 2017) implementation of an Infection Control Programme.

Results: There was an absolute decrease in healthcare-associated infection from 102 to 81 and a statistically significant decrease in bloodstream infections per 1 000 central venous catheter days from 36/1 000–15/1 000 after intervention (RR 0.42, 95% CI 0.23–0.79, $p = 0.004$). The rate of healthcare-associated infection decreased from 23/100 admissions prior to the intervention to 20/100 admissions after the intervention (RR 0.87, 95% CI 0.51–1.48, $p = 0.61$) and from 40/1 000 patient days to 32/1 000 patient days (RR 0.80, 95% CI 0.51–1.26, $p = 0.34$). Reductions in healthcare-associated infection were also seen in bloodstream infections and urinary tract infections.

Conclusion: The observed downward trend in overall healthcare-associated infections, bloodstream infections and urinary tract infections did not reach statistical significance except for bloodstream infections per 1 000 central venous catheter days. Further research or audit is needed to ascertain reasons for this less than expected decrease in healthcare-associated infections. In the meantime, meticulous adherence to bundles should be encouraged.

Keywords: Best Care Always bundle, Grey's Hospital, healthcare-associated infection, Hospital-acquired infection, infection control campaign, nosocomial infection, PICU

Background

Healthcare-associated infections (HAIs) are an important cause of morbidity and mortality globally, especially among critically ill patients admitted to intensive care units (ICUs).[1] HAIs, often due to multidrug resistant organisms, occur in approximately 1 in 10 admissions, leading to increased costs, increased length of stay and increased mortality.[2] It is estimated that healthcare-associated bloodstream infections (BSIs) may be responsible for 25 000 deaths in African children annually.[3]

The burden of HAIs is significantly higher in low- and middle-income countries compared with upper-income countries.[4] HAI rates in ICUs in low- and middle-income countries are at least double and even sometimes triple the rates of those in the USA.[5] Due to lack of adequate surveillance programmes in South Africa, there are limited data on local HAI rates.[6] In a meta-analysis of studies from 1995 to 2008 looking specifically at HAIs in low- and middle-income countries, only 13 African studies were included and none was from South Africa. These studies also showed HAI rates between double and triple those reported in the USA and the UK, highlighting the problem in low- and middle-income countries. This difference was most striking in the ICU setting.[7]

The International Nosocomial Infection Control Consortium, a multinational research network focused on measurement and reduction of HAIs, found that rates of device-associated infections were significantly higher in ICUs in low- and middle-income countries than in ICUs in the USA despite similar rates of device utilization.[8] This comparison was made with data from the report of the Centers for Disease Control and Prevention National Healthcare Safety Network, which reports data from facilities in and around the USA. More recent South African surveillance data have become available and are in keeping with the above-mentioned concern, with rates more than double those in upper-income countries.[9]

Over the last two decades, research in a variety of settings worldwide has focused on interventions targeting the reduction of HAIs. The Institute for Healthcare Improvement introduced the bundle concept in 2001. A bundle is a set of evidence-based interventions that when implemented together result in improved patient outcomes. There are bundles targeting central line associated bloodstream infections (CLABSIs), catheter associated urinary tract infections (CAUTIs), ventilator associated pneumonia (VAP), surgical site infections (SSIs) and antibiotic stewardship. This concept was introduced in South

Africa in 2009 with the Best Care Always (BCA) campaign.[10] Many studies have shown a significant reduction in infection rates where compliance is achieved.[11]

HAI rates in the Grey's Hospital paediatric intensive care unit (PICU) in 2013 and 2014 were 20.4 and 15.3 per 100 admissions and 27.5 and 33 per 1 000 patient days respectively.[12] This is much higher than the 6.1 per 100 admissions and 14.1 per 1 000 patient days reported for similar units in upper-income countries in a multicentre study in 61 PICUs in the USA.[13] A meta-analysis of studies looking at HAI rates in low- and middle-income countries reported a pooled prevalence of 15.5 per 100 admissions, which was closer to the Grey's Hospital rates.[7]

In response to the high HAI rates in the ICUs at Grey's Hospital, the Infection Prevention and Control Committee implemented an Infection Control Programme initiated by the Hospital-Acquired Infections in the ICU Team in August 2016. This programme included the BCA bundles for CLABSI, CAUTI and VAP in addition to other initiatives such as the 'Hands Off' campaign for promoting hand hygiene.

With substantial evidence that bundles decrease HAIs, a decrease in HAI rates would be expected when implemented in new sites. The aim of the study was to ascertain if there was a decrease in HAI rates in the Grey's Hospital PICU following the implementation of the Infection Control Programme.

Methods

The study was conducted in the PICU at Grey's Hospital from August 2015 to August 2017. The PICU at Grey's Hospital is an eight-bed intensive care and high care unit that serves the western part of KwaZulu-Natal, which has a population of approximately 1.2 million children.[14] There is a high turnover of both medical and surgical cases referred from both regional and district hospitals. The children range in age from 2 weeks to 12 years and come from rural, peri-urban and urban areas. The PICU medical staff consists of nurses, medical officers, registrars and paediatricians. The nursing staff and paediatricians are permanent, but the medical officers, registrars and after-hours paediatricians all work on a rotational basis.

The study was an observational before–after quasi-experiment through retrospective review of HAI rates in the PICU a year prior to (August 2015 to July 2016) and a year after (September 2016 to August 2017) implementation of an Infection Control Programme including the BCA bundles for CLABSI, CAUTI and VAP.

Data sources

Patient throughput data were sourced from the admissions and separations register as well as from the daily catheter records kept in the PICU. The HAI data were obtained from the Infection Prevention and Control Committee register. This register is compiled by the Infection Prevention and Control Committee using both clinical data from the PICU and microbial culture results obtained from the onsite National Health Laboratory Service (NHLS). Positive cultures are collated and tallied weekly and then sent to the committee for further review. The team reviews microbiological results along with each patient's clinical status to determine whether the infection is currently active and, based on timing of the positive culture in relation to admission, whether it is community acquired or healthcare associated. HAIs are defined as those not present or incubating at the time of admission but found in samples taken more than 48 hours after hospital admission. Specimens sent for culture include blood, urine, respiratory aspirates, fluid (pleural, pericardial, peritoneal and cerebrospinal), tissue and superficial swabs. These specimens are usually obtained and sent to the laboratory based on definite clinical grounds or suspicion of infection. All patients have blood sampled for culture on admission to the PICU and endotracheal aspirates (ETAs) are routinely sent for culture for ventilated patients twice weekly. Patients who were transferred from another hospital or had an admission to a healthcare facility within two weeks of presentation with admission cultures positive were labelled as HAI but excluded from the study because these would not have been in the PICU.

The intervention

At implementation of the BCA bundles, the Hospital Acquired Infections in the ICU team met with the heads of the PICU and chose a BCA champion to enforce the protocols. Each PICU chart was to be stamped with the BCA bundles compliance stamp, which allowed for review of compliance with the bundle elements and line/catheter necessities twice daily. An audit procedure was then followed on a two-monthly basis to review bundle compliance. There was specific training for the nurses in the PICU by the Infection Prevention and Control Committee on bundle elements. This training did not include all doctors and auxiliary staff.

HAI occurrence was recorded per month then tallied for the time periods before and after the implementation of the Infection Control Programme, which occurred in the month of August 2016. HAI rates were calculated per 100 admissions, per 1 000 patient days and per 1 000 device days and categorised into BSIs, urinary tract infections (UTIs), VAP and other.

Data analysis

Relative risk (RR) with confidence intervals (CI) was used to measure the effect of the Infection Control Programme on HAI occurrence with p-values to assess the significance of observed differences before and after. Proportions and categorical variables were compared using Pearson's chi-square test or Fisher's exact test as appropriate. All analyses were performed using SPSS (version 24; IBM Corp, Armonk, NY, USA) with the level of significance set at $p < 0.05$.

Results

There was a total of 449 admissions to the PICU in the year prior to the Infection Control Programme and 410 in the year after (Table 1). Patient days before were 2 537 and after 2 532. Device days were 4 118 before and 3 321 after. There were three months in the post-intervention period that had incomplete device data for urinary catheters and central venous catheters (CVCs). These three months could therefore not be included in the after analysis for device day infection rates.

Some 44% of admissions both before and after were in the less than one-year age group. There were similar proportions of medical and surgical admissions before and after the intervention. There were 102 HAIs before and 81 after the intervention. The most common category of HAI before and after was VAP, followed by BSI and then UTI.

Organisms

There were more Gram-negative organisms ($n = 164$, 81%) identified than Gram-positive ($n = 38$, 19%). Among the Gram-negative organisms, the most prevalent organism was *Klebsiella*

Table 1: PICU patient and line characteristics

Admissions		Before (n = 449) no. (%)	After (n = 410) no. (%)
Clinical category	Medical	242 (54)	216 (53)
	Surgical	207 (46)	194 (47)
Age groups	< 28 days	18 (4)	12 (3)
	28 days to < 1 year	193 (43)	152 (37)
	1 year to 5 years	127 (28)	129 (32)
	> 5 years	111 (25)	117 (28)
Patient days		2 537	2 532
Device days		Before (n = 4 118)	After (n = 3 321)*
Type of device	Central venous catheter	721 (18)	519 (16)*
	Urinary catheter	1 903 (46)	1 309 (39)*
	Endotracheal tube (ETT)	1 494 (36)	1 493 (45)

*In the post-intervention period three months had incomplete device data and were therefore not included in the analysis.

pneumoniae (n = 50, 25%), almost half of which were multidrug resistant. Other Gram-negative organisms identified included *Acinetobacter baumannii* (n = 32, 16%) and *Pseudomonas aeruginosa* (n = 28, 14%) (Table 2: HAI organism profile).

HAI occurrence
There was an absolute decrease in HAIs from 102 to 81. The rate of HAI decreased from 23 per 100 admissions prior to the intervention to 20 per 100 admissions after the intervention (RR 0.9, 95% CI 0.51–1.48, p = 0.61) and from 40 per 1 000 patient days to 32 per 1 000 patient days (RR 0.8, 95% CI 0.51–1.56, p = 0.34). There was a statistically significant decrease in BSI per 1 000 CVC days from 36 per 1 000 before intervention to 15 per 1 000 after (RR 0.4, 95% CI 0.23–0.79, p = 0.004). Reductions in HAI were also seen in BSIs and UTIs but these were not statistically significant. VAP showed a slight increase per 100 admissions (RR 1.4, 95% CI 0.48–3.70; p = 0.58), per 1 000 patient days and per 1 000 ETT days (see Table 3).

Discussion
Our study looked at HAI occurrence in 449 admissions before and 410 admissions after the implementation of a

Table 2: HAI organism profile

Type	Organism	Before (n = 109§) no. (%)	After (n = 93§) no. (%)
Gram-negative	All *Klebsiella pneumoniae*	27 (24)	23 (25)
	Multidrug-resistant *Klebsiella*	13 (48)	11 (48)
	Acinetobacter baumannii	20 (18)	12 (13)
	Pseudomonas aeruginosa	9 (8)	19 (20)
	Escherichia coli	11 (10)	10 (11)
	Serratia marcescens	5 (5)	0 (0)
	Other*	16 (15)	12 (13)
	Total	88 (80)	76 (82)
Gram-positive	*Enterococcus* species	14 (13)	14 (15)
	Staphylococcus aureus	6 (6)	3 (3)
	Streptococcus mitis	1 (1)	0 (0)
	Total	21 (20)	17 (18)

§Organisims identified are more than the total HAI because some cultures yielded more than one organism.
*Other included *Stenotrophomonas maltophilia* and *Citrobacter, Enterobacter, Morganella* and *Proteus* species.

comprehensive Infection Control Programme. Our results showed a trend towards patients being less likely to acquire an HAI after the intervention. The most noteworthy finding was the significant decrease in BSI per 1 000 CVC days with

Table 3: HAI occurrence before and after implementation of the Infection Control Programme, and relative risk for HAI after the intervention

Factor	Before (n = 102)	After (n = 81)	Relative risk (95% confidence interval)	p-value
HAI per 100 admissions	23	20	0.9 (0.5–1.5)	0.61
HAI per 1 000 patient days	40	32	0.8 (0.5–1.3)	0.34
BSI number	26	15	0.7 (0.4–1.3)	0.27
Per 100 admissions	6	4	0.7 (0.2–2.3)	0.52
Per 1 000 patient days	10	6	0.6 (0.2–1.6)	0.32
Per 1 000 CVC days	36	15*	0.4 (0.2–0.8)	0.004
UTI number	16	10	0.8 (0.4–1.6)	0.52
Per 100 admissions	4	2	0.5 (0.1–2.7)	0.42
Per 1 000 patient days	6	4	0.7 (0.2–2.4)	0.53
Per 1 000 urinary catheter days	8	5*	0.6 (0.2–1.9)	0.41
VAP number	28	31	1.4 (0.9–2.1)	0.12
Per 100 admissions	6	8	1.3 (0.5–3.7)	0.58
Per 1 000 patient days	11	12	1.1 (0.5–2.5)	0.83
Per 1 000 ETT days	19	21	1.1 (0.6–2.0)	0.75
'Other' number	32	25	1.0 (0.6–1.5)	0.94
Per 100 admissions	7	6	0.9 (0.3–2.5)	0.77
Per 1 000 patient days	13	10	0.8 (0.3–1.8)	0.53

*In the post-intervention period three months had incomplete line data and were therefore not included in the after analysis.

patients being 0.42 times as likely to acquire a BSI after the intervention (RR 0.42, 95% CI 0.23–0.79, $p = 0.004$).

In the after period there were 21 fewer HAIs. For every 100 admissions there were 3 fewer HAIs and for every 1 000 patient days there were 8 fewer HAIs. When calculated per admissions, per patient days and per device days there was no difference in relative risk (CIs include 1, $p > 0.05$). Analysis of other subgroups showed absolute decreases in occurrence of BSIs and UTIs but the findings were not statistically significant.

VAP occurrence increased slightly. This could be explained by the frequency of routine ETAs being taken biweekly giving increased positive cultures, some of which may have reflected colonisation rather than infection.

Gram-negative organisms predominated (81%), which was similar to studies from Tygerberg Hospital in Cape Town in both paediatric and neonatal settings. The incidence was higher, however, than the 66% of BSI reported by Tygerberg Children's Hospital over a six-year period from 2008 to 2013.[15] Of the Gram-negative organisms, *Klebsiella* was the most prevalent species and this too was similar to data from Tygerberg Children's Hospital and to those from a newly opened PICU in Turkey over a four-year period (2011–2014).[16, 17]

In our unit, the implementation of the Infection Control Programme showed the expected reduction in BSIs but not in UTIs and VAP. In other settings where BCA bundles have been implemented a greater than 50% reduction in infections has been reported,[18–20] suggesting that there is room for improvement in our unit.

One of the main challenges of infection prevention strategies is health-worker compliance with bundle protocols. All aspects of the bundle must be adhered to in order to see optimal reduction in CLABSI and VAP.[19] In a study conducted at Tygerberg Hospital looking at paediatric healthcare providers' knowledge, attitudes and practice with regard to infection control, knowledge scores were low but self-reported compliance with infection control measures was high. It was concluded that in-service and undergraduate training in hand hygiene and routes of infection transmission should be emphasised.[21] In our unit, there is a high turnover of staff resulting in inconsistent teaching of the principles and practices of the Infection Control Programme. In addition, monitoring of bundle compliance may have been suboptimal for reasons of workload pressure and staffing constraints.

Limitations

The before–after quasi-experimental design, while making the study feasible, contains a risk of bias and confounding. Although there were 39 fewer admissions in the year following the intervention, the number of patient days differed by 5, indicating that the length of stay was longer in the after period, which is a recognised risk for acquiring an HAI and could have masked the effect of the Infection Control Programme. The proportion of surgical admissions (less at risk for infection, and shorter stay) both before and after intervention was similar; however, in the before period there were more admissions of infants (< 1 year) who are more vulnerable to acquiring infections.

The incomplete line data for CVCs and urinary catheters for three of the months in the after period meant that data for these three months could not be analysed and were therefore omitted. This decreased the sample size for BSIs and UTIs and device days, but is unlikely to have affected proportions and rates. Organism profiles were similar in both periods.

Although the baseline characteristics of the before and after groups were similar, the changes in staff and the availability of equipment and resources at different times were not measurable and may have had an impact on risk of acquiring HAI.

Recommendations

The significant decrease in BSIs per 1 000 CVC days and an overall decreasing trend in HAI were encouraging. The less than expected reduction in HAIs provides opportunity in the Grey's PICU for further research into the most effective processes for implementation of an Infection Control Programme as well as opportunity for ongoing action to further reduce HAI rates.

Achieving high-quality programme implementation is critical to achieving expected outcomes.[22] Durlak *et al.* describe four main phases in a quality implementation framework: (1) Initial considerations regarding the host setting, (2) Creating a structure for implementation, (3) Ongoing structure once implementation begins and (4) Improving future applications.[23] Broken down into steps, the implementation process involves awareness, adopting the concept, mobilisation of resources, evidence of practice, evidence of routine, and integration and sustainable practice.[24] These steps could provide a framework for reviewing the Infection Control Programme implementation and may provide concrete proposals for better impact.

In the meantime, intensification of orientation of new staff, enforcement of bundle protocols and monitoring of adherence to all bundle elements is advised. Involving clinicians in the HAI review process may improve both HAI identification and awareness as well as bundles enforcement and stewardship.

Conclusion

HAIs remain very important globally and also in Grey's Hospital. Our downward trend in HAIs after the intervention was less than expected. Further research or audit is needed in our PICU to ascertain reasons for this with a view to optimising the impact of the Infection Control Programme and BCA.

Ethics review

The research protocol was reviewed and approved by the Biomedical Research Ethics Committee (University of KwaZulu-Natal, South Africa) (BE003/17).

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