Decreasing infection in neonatal intensive care units through quality improvement

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ABSTRACT

Objective To decrease the incidence of bloodstream infection (BSI) for neonates <29 weeks gestation through quality improvement.

Design Commencing in September 2011, eight neonatal intensive care units (NICUs) in New South Wales and Australian Capital Territory, Australia participated in the Sepsis Prevention in NICUs Group project, a multicentre quality improvement initiative to reduce neonatal infection through implementation of potentially better practices and development of teaching resources. Data were collected for neonates <29 weeks gestation from D3 to 35, using point of care data entry, for BSI, central line-associated BSI (CLABSI) and antibiotic use. Exponentially weighted moving average data trend lines for rates of BSI, CLABSI and antibiotic use for each NICU were automatically generated and composite charts were provided each month to participating NICUs.

Results Between January 2012 and December 2014, data were collected from D3 to 35 for 1075 neonates <29 weeks gestation who survived >48 h, for a total of 33 933 bed days and 14 447 central line days. There was a significant decrease from 2012 to 2014 in BSI/1000 bed days (7.8±3.0 vs 3.8±1.1, p=0.000), CLABSI/1000 bed days (4.6±2.1 vs 2.1±0.8, p=0.003), CLABSI/1000 central line days (9.9±4.3 vs 5.4±1.7, p=0.012) and antibiotic days/100 bed days (31.1±4.3 vs 25.5±4.2, p=0.046).

Conclusions This study demonstrates a >50% reduction in BSI in extremely premature neonates from D3 to 35 following a collaborative quality improvement project to reduce neonatal infection across an NICU network, supported by timely provision of data.

What is already known on this topic?

- Late onset infection is a major cause of mortality and morbidity in preterm neonates.
- Quality improvement initiatives using care bundles have been shown to reduce infection rates in neonatal intensive care units.

What this study adds?

- Providing neonatal intensive care units (NICU) staff with an easily accessible teaching video showing a standard approach to neonatal peripherally inserted central catheter line insertion may assist in reducing neonatal infections.
- Automated monthly infection data reports, using close to 'real-time' point of care data collection increase the success of initiatives to reduce infection in the NICU.
- Using data censored from D3 to 35 for neonates admitted to NICU excludes outliers and allows NICUs to compare data from neonates with similar clinical characteristics.

BACKGROUND

Late-onset neonatal infection is a major cause of mortality, prolonged hospitalisation and increased hospital costs for neonatal intensive care unit (NICU) patients[1] and is associated with increased risk of neurodevelopmental impairment and cerebral palsy.[2 3] Extremely premature neonates have a high risk of infection due to biological immaturity,[4 5] frequent invasive procedures and prolonged requirement for respiratory support and parenteral nutrition. Infection rates also vary substantially across NICUs due to practice variation.[6 7] A number of studies have demonstrated reduction of infection following quality improvement (QI) activities.[8–11] The cornerstone of QI interventions has been the implementation of care bundles aimed at reducing exposure to pathogens and enhancing the microbiome.[12 13]

NICU network data collections can contribute to improved neonatal outcomes by providing surveillance data for benchmarking between institutions. To be effective, surveillance data should be provided in a timely manner, provide meaningful analysis of variations in neonatal outcomes across units and be combined with an active QI programme, incorporating regular data review to determine the effectiveness of interventions.[14–16]

In Australia, NICUs in New South Wales (NSW) and the Australian Capital Territory (ACT) have contributed annual data to the NSW/ACT Perinatal Services Network Neonatal Intensive Care Units (NICUS) data collection since 1992.[17] The NICUS data collection was upgraded in 2007 to include dates and times of interventions and outcomes, allowing temporal associations to be determined. Increasingly, point of care data have been used to populate the data set, providing the opportunity to rapidly assess the effectiveness of QI interventions, through provision of monthly data reports.

Aims and objectives

1. To decrease the incidence of bloodstream infection (BSI) in extremely premature neonates (<29 weeks gestation) in NICUs in NSW and ACT, Australia.

2. To describe the activities of a multicentre collaborative QI initiative developed under the auspices of the NICUS data collection group.
3. To describe the process of providing close to 'real-time' data audit of infections, using a centralised data collection and automatically generated data reports.

METHODS

Study design

The Sepsis Prevention in NICUs Group (SPRING) QI initiative began in September 2011, with an aim to monitor and reduce neonatal BSIs. This multicentre QI initiative was conducted in eight Level 3 NICUs associated with perinatal centres in NSW and ACT, Australia. The region has a population of 7.9 million and a birth rate of approximately 90 000 births per year. All neonates born <29 weeks gestation in this region are cared for in one of the participating NICUs. Neonates transferred to a stand-alone children's hospital for surgical care were not included during their children's hospital admission.

SPRING quality improvement process and interventions

SPRING membership comprised at least one neonatologist and clinical nurse consultant from each NICU. SPRING meetings occurred four to six times per year and provided a forum to review best practice related to infection prevention, develop standard practices and teaching resources, and share ideas on local QI initiatives.[15 18–21] Clinical practice improvement (CPI) skills of SPRING participants were also enhanced through participation in a CPI workshop.

SPRING activities included development of a potentially better practices framework (box 1) with agreement by all NICUs to implement major components of the framework; implementation of a standardised approach to insertion and maintenance of peripherally inserted central catheters (PICC);[22 23] production of an educational video for neonatal PICC insertion, with on-line access for all NICU staff;[24] implementation of Hand Hygiene Australia: '5 Moments for Hand Hygiene'[25–27] and exchange of practical ideas to reduce infection.[13 16]

Further details of the SPRING activities are included in online supplementary appendix 1.

Individual NICU QI activities

Each NICU was responsible for developing local QI activities, determined by local priorities. As part of the SPRING QI initiative, all NICUs developed a regular local forum to discuss and monitor infections.

Data definitions

Infection review meetings at each hospital were convened to review positive blood cultures and to determine whether the culture results, laboratory markers and the neonate's clinical condition were consistent with a diagnosis of infection.

Bloodstream infection

A neonate was considered to have a BSI[28 29] if there was

1. A definite pathogen in blood culture
   OR
2. Growth of a possible contaminant (eg, coagulase-negative staphylococcus, CONS) in blood
   PLUS
   treatment with antibiotics ≥96 h (or death <96 h)
   PLUS
   Growth of the same organism on repeat culture OR one or more abnormal laboratory markers (eg, C-reactive protein >10 mg/L, immature:total neutrophil ratio >0.2, etc) (definite infection) OR clinical features consistent with systemic infection (eg, lethargy, apnoea, significant change in respiratory condition, etc) (clinical infection).

A positive culture with the same organism within 14 days of the index infection was considered to be the same infection event.

Contaminant

A positive blood culture was coded as a contaminant if the organism was a potential skin contaminant AND the neonate was treated with antibiotics for <96 h. For neonates treated with antibiotics for ≥96 h, the culture was only classified as a contaminant if an infection review team determined that there was no evidence of BSI after review of laboratory markers and clinical condition.

Central line-associated BSI

A BSI was considered to be a central line-associated BSI (CLABSI) if it occurred while a central line (PICC or umbilical catheter) was in situ or within 48 h of removal of the central line, unless there was a clearly identified alternate source of infection.[30]

Data collection

Point of care data were entered into a central database by clinicians in each NICU for all neonates <29 weeks gestation admitted to an NICU. This included date of birth, gestational age (GA), birth weight, date of admission and discharge from each NICU, date of insertion and removal of PICC lines and umbilical catheters, date of commencement and completion of antibiotics.

Blood culture results were automatically downloaded from central pathology services into the database or entered by clinicians. For each positive blood culture an infection audit was completed, including process of infection review (eg, microbiologist, multidisciplinary review team), associated abnormal laboratory markers and classification of positive blood culture as infection or contaminant. Audit officers in each NICU checked the accuracy of the data, and completed the data entry and infection audit.

Data reporting

Data was reported for neonates <29 weeks gestation, censored to 3–35 days. Early onset infection in the first 48 h of life was excluded. Data for each neonate was censored to 35 days due to variation between NICUs in back transfer practice and the likelihood that infection beyond 35 days was more commonly due to individual patient factors than NICU factors.[31 32]

Exponentially weighted moving average (EWMA) trend line charts[31 33] were constructed with prior data weighted at 0.8 and current data at 0.2 to show changes over time in incidence of:

- BSI/1000 bed days (figure 1)
- CLABSI/1000 bed days
- CLABSI/1000 central line days
- Antibiotic days/100 bed days

Automated reports containing composite EWMA charts, mean GA and total bed days/month for neonates <29 weeks for all participating NICUs were generated from the central database and sent by email on the 15th day of each month, initially to SPRING members and subsequently to all neonatologists, nursing unit managers, clinical nurse consultants and audit officers in each

Box 1 Potentially better practices to reduce neonatal infection

Hand hygiene:
Alcohol-based hand rub/gel at each bed.
'5 moments for hand hygiene (HH)'.
Staff trained as HH champions.
Formal HH induction for staff.
Regular audit of hand hygiene compliance.

PICC lines:
Staff/education:
PICC line champions.
Formal training for medical and nursing staff. Standard PICC procedure and teaching video.
2 person procedure.
1:1 nursing allocation for procedure.

Equipment:
Standard PICC pack or trolley.
Separate trolley for clean procedures.

Insertion:
Clinician asepsis bundle:
2 min procedural hand wash.
Sterile gloves and gown.
Hat, mask.

Patient asepsis bundle:
Skin asepsis.
Full drape of patient.
Barriers to restrict human traffic during insertion.

Dressing:
Sterile transparent semipermeable dressing

Documentation:
Surveillance of procedure.
Central venous line insertion record.

Catheter maintenance:
Frequent evaluation of insertion site, dressing integrity—change dressing if soiled or loose.
Bacterial filter (0.2 μ) on all intravenous lines.
Use of needless access ports, with extension sets if more than one lumen required.
Daily review of catheter necessity.
Catheter removed at 120–140ml/kg enteral fluids.

Catheter Access:
Hand hygiene pre/post access.
Aseptic access technique
(no-touch technique±sterile gloves).
- 'Scrub the hub':
  - using 2% chlorhexidine/70% alcohol swabs.
- *Decrease frequency of PICC access:*
  - 48 h TPN bags.
  - Intravenous medications bundled.

Peripheral cannula:
Standard cannula packs.
Separate trolley for clean procedure.
Sterile gloves for cannulation.
Sterile transparent semipermeable dressing.
Aseptic access technique and 'scrub the hub'.

Staff attire:
Plastic gowns for clinical contact.
Nails short, nail polish restricted, no jewellery.

Bedside equipment:
Individual bedside thermometers, stethoscope±calculators, pen sets.
Individual bedside trolley.
Automatically closing garbage bins.

Environmental issues:
- Restrict liquids in sinks:
  - No antibiotics, TPN or body fluids

Restrict visitor numbers (2–3/bed):
- Site-specific individual unit strategies including:
  - Relocation or upgrading hand-washing sinks.
  - Decontamination using hydrogen peroxide vaporiser to reduce MRSA.
  - Environmental swabs with outbreaks.

Antibiotics:
- First line antibiotics:
  - Early onset sepsis penicillin+gentamicin.
  - Late-onset sepsis flucloxicillin or vancomycin+gentamicin.

(Except when site-specific factors indicate requirement for other antibiotics.)
Cessation of antibiotics by 48 h unless positive culture or strong evidence of infection.
Antibiotics targeted to organism after 48 h.

Microbiome:
EBM as soon as available.
Kangaroo skin-to-skin encouraged daily.
Routine probiotics with milk feeds.

Sepsis audit:
Multidisciplinary sepsis review meetings.
Automated infection reports sent monthly to senior clinical staff.
Regular feedback to all clinical staff.

EBM, expressed breast milk; MRSA, methicillin-resistant Staphylococcus aureus; PICC, peripherally inserted central catheters; TPN, total parenteral nutrition.

NICU. Identifying data for neonates with positive blood cultures was also provided to the neonate's' admitting NICU.

Statistical analysis

Data were analysed for 3 years, from January 2012 to December 2014. The first 12 months of the project were assessed as a 'run-in' period. Data for 2013 and 2014 were then compared with data for 2012. Group differences over the three time periods were assessed using analysis of variance for continuous variables and Pearson's χ^2 test for categorical variables. The Mann-Kendall test was used to test for trend over time using monthly data for total BSI and 3-monthly data for bacterial organism subcategories. Statistical analysis was performed using Minitab 17 Statistical Software (Minitab 17 Statistical Software, Minitab, 2015).

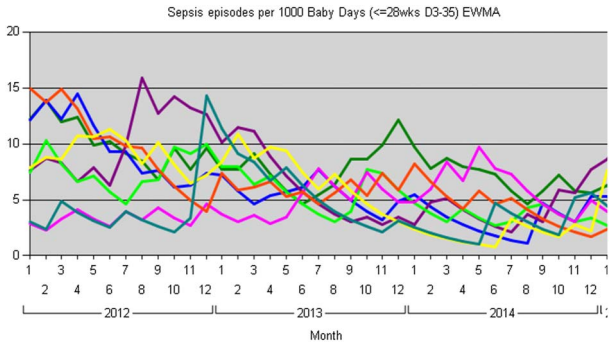

Figure 1 Example of automated composite EWMA chart showing bloodstream infections per 1000 days for each participating NICU. EWMA, exponentially weighted moving average infection rate (0.8 prior, 0.2 current); NICU, neonatal intensive care unit.

RESULTS

Between 1 January 2012 and 31 December 2014, 1131 neonates with GA <29 weeks were admitted to one of the participating NICUs. The study cohort comprised 1075 neonates who survived >48 h. Of these, 26 died between day 3 (D3) and day 35 (D35). The mean GA was 26.6 weeks, with 22.4% of neonates <26 weeks gestation. There were no statistically significant differences in GA or birth weight between neonates admitted in 2012, 2013 or 2014 (table 1).

Infection data were collected for these babies over a total of 33 933 bed days (D3–35), with an average of 4241 bed days in each NICU (range: 2807–5477 days). A central line was in situ on 14 447 (42.5%) bed days. A total of 1627 blood cultures were collected at a rate of 48.1 blood cultures per 1000 bed days. Of these, 314 (19%) had a positive bacterial growth, including 119 (7.3%) classified as contaminants. There were 195 episodes of BSI, including 116 associated with the presence of a central line (table 2). There was considerable variation in rates of BSI reported each month, both between and within NICUs, with monthly BSI rates for individual NICUs ranging from 1 BSI/1000 baby days to 16 BSI/1000 baby days (figure 1). BSI rates for the total cohort decreased significantly over the period from January 2012 to December 2014, as shown in figure 2 (Z_{MK}=−3.52, p for trend <0.001).

There was a statistically significant decrease from 2012 to 2014 in incidence of blood cultures positive for growth of any organism/1000 bed days (including contaminants) (11.3±3.6 vs 6.7±2.0, p=0.000), BSI/1000 bed days (7.8±3.0 vs 3.8±1.1, p=0.000), CLABSI/1000 bed days (4.6±2.1 vs 2.1±0.8, p=0.000) and CLABSI/1000 central line days (9.9±4.3 vs 5.4 ±1.7, p=0.000) (table 2). There was also a statistically significant decrease in antibiotic days/100 bed days from 2012 to 2014 (31.1±4.3 vs 25.5±4.2, p=0.046) (table 2).

Of the 195 positive blood cultures classified as BSIs, 129 (66%) grew CONS, 40 (21%) grew Gram-negative organisms, and 26 (13%) grew other Gram-positive bacteria. The total number of BSIs decreased from 90 in 2012 to 44 in 2014, primarily due to a significant decrease in CONS infection (2012: 67 vs 2014: 19, (Z_{MK}=−2.27, p for trend <0.05)). This was not associated with an increase in positive blood cultures classified as contaminants (table 3).

DISCUSSION

This study demonstrates the effectiveness of a state-wide QI initiative, with a 51% reduction in the incidence of BSI in neonates <29 weeks gestation between day 3 and day 35 from 7.8 to 3.8 per 1000 bed days between 2012 and 2014. The majority of this reduction was due to a decrease in CONS BSI, suggesting improved hand hygiene and decreased bloodstream exposure to skin commensals associated with invasive procedures, including PICC line insertion and management.

Important components of this intervention included the identification of potentially better practices, exchange of ideas and resources between NICUs, engagement of local clinical staff and timely reporting of data. Interventions that were considered to have made the biggest impact were the introduction of a teaching video demonstrating standard PICC insertion in February 2013,[24] distribution of monthly comparative infection reports to senior NICU clinicians from October 2013 and a focus on PICC line asepsis and '5 moments for hand hygiene'[25 26] throughout the study period. Units with relatively higher rates of BSI at the start of the project had more immediate success in reducing infection rates (figure 1); however, all NICUs benefited from review of variance in outcomes and practices between NICUs.

Engagement of local clinical staff in QI projects within each NICU was the key to the success. Each NICU was encouraged to focus on aspects of care most relevant for their own NICU. Over the course of the project, individual NICUs developed a number of innovative local initiatives[34] and two NICUs received NSW health awards for 'Innovations for MRSA control in an NICU population' and 'A Team Approach Every Day Keeps the Germs at Bay'.[35]

Provision of hospital comparison data by email to senior clinicians every month provided a strong incentive to assess unit practices. Although all participating NICUs began to contribute data from January 2012, several units only became actively engaged in QI activities in late 2013 when infection rates on hospital comparison charts were found to be higher than expected compared with other equivalent NICUs. These NICUs

Table 1 Gestational age and birthweight data for cohort

	2012 n=362	2013 n=356	2014 n=357	p Value
Gestational age, mean±SD weeks	26.6±1.4	26.5±1.3	26.6±1.4	0.636*
Gestational age group n (%)				
23–25 weeks	79 (21.8%)	81 (22.8%)	81 (22.7%)	
26–28 weeks	283 (78.2%)	275 (77.2%)	276 (77.3%)	0.112†
Birth weight, mean±SD grams	951±240	941±237	945±225	0.857*
Died 3–35 days n (%)	25 (6.9%)	21 (5.9%)	21 (5.9%)	0.427†

*p Value for analysis of variance across three time periods.
†p Value for χ^2 test for difference between groups.

Table 2 Bed days, central line days, blood cultures and antibiotic use

	2012	2013	2014	p Value*
Total bed days (day 3–35)	11 377	10 822	11 734	
Bed days/month†	948±179	902±218	978±158	0.608
Total central line days (D3–35)	5215	4689	4543	
Central line days/month†	435±86	391±102	379±58	0.244
Central line days/100 bed days†	45.9±4.9	43.4±4.1	39.2±5.9	0.008
Total blood cultures (D3–35)	574	558	495	
Blood cultures/1000 bed days†	50±12.5	52±6.7	43±7.5	0.058
Positive blood cultures	130	106	78	
Positive blood cultures/1000 bed days† (including contaminants)	11.3±3.6	9.7±1.7	6.7±2.0	0.000
BSIs	90	61	44	
BSI/1000 bed days†	7.8±3.0	5.5±1.4	3.8±1.1	0.000
CLABSI	53	38	25	
CLABSI/1000 bed days†	4.6±2.1	3.5±1.7	2.1±0.8	0.003
CLABSI/1000 central line days†	9.9±4.3	8.1±3.9	5.4±1.7	0.012
Total antibiotic days (D3–35)	3576	3216	2976	
Antibiotic days/month†	298±94	268±95	248±48	0.332
Antibiotic days/100 bed days†	31.1±4.3	29.4±5.2	25.5±4.2	0.046

*p Value for analysis of variance across three time periods.
†Data=mean±SD per month.
BSI, bloodstream infection; CLABSI, central line-associated bloodstream infection.

then commenced intensive education programmes on PICC management and increased surveillance of hand hygiene compliance for both nursing and medical personnel, resulting in significant reduction in infection rates.

The use of EWMA charts was also valuable. As neonatal BSI is a relatively rare event in individual units, providing raw data each month can result in wide fluctuations in event rates. EWMA charts provide visual evidence of trends in infection rates in a manner that is easy for clinical staff to comprehend, with rapid evidence of improvement when interventions result in a decrease in infection frequency.[31] Although EWMA charts were not corrected for GA or bed occupancy, provision of GA and total bed days each month allowed units to explore the contribution of these factors to variation in infection rates.

Providing identifying data for neonates with a positive blood culture also allowed each NICU to review episodes of sepsis in detail. All positive blood cultures (including contaminants) were classified as infection until a formal review had occurred,

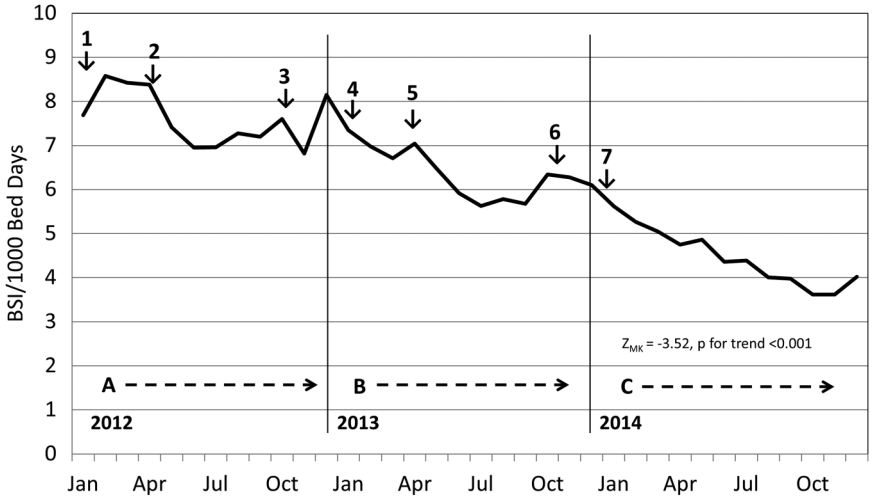

Figure 2 Bloodstream infections/1000 bed days and interventions. EWMA BSI rate (0.8 prior: 0.2 current).

(A) Commencement of SPRING (September 2011). Development of a potentially better practices framework (2011/2012). Quality improvement activities to reduce sepsis in some, but not all NICUs. Commencement of Hand Hygiene Australia: '5 Moments for Hand Hygiene' initiative. (B) Infection review process established in all NICUs. Focus on PICC line insertion/management and hand hygiene. (C) Quality improvement activities to reduce sepsis in all NICUs. Continued focus on PICC lines and hand hygiene.

(1) January 2012: Commencement of standard infection data collection. (2) January–June 2012: Training of hand hygiene champions. (3) November 2012: Clinical practice improvement workshop training for all SPRING members. (4) February 2013: Launch of teaching video for standard PICC line insertion technique.[24] (5) April 2013: Automated monthly infection data reports to SPRING members. (6) October 2013: Monthly infection data reports to senior medical and nursing staff in all NICUs. (7) January 2014: All participating NICUs actively engaged in quality improvement activities.

For more detail see online supplementary table, SPRING timeline. ACT, Australian Capital Territory; BSI, bloodstream infection; EWMA, exponentially weighted moving average; NICU, neonatal intensive care unit; NSW, New South Wales; PICC, peripherally inserted central catheter; SPRING, Sepsis Prevention in NICUs Group.

Table 3 Positive blood cultures and organism by year of birth

	2012 n=130	2013 n=106	2014 n=78	p Value*
Bloodstream infection (BSI)				
Coagulase-negative staphylococci	67	43	19	<0.05
Gram-negative bacteria†	16	10	14	NS
Gram-positive bacteria‡	7	8	11	NS
Contaminant	40	45	34	NS

*p Value for Mann–Kendall test for trend.
†Gram-negative bacteria: Escherichia coli (19), Klebsiella (7), Pseudomonas (2), Proteus (1), Acinetobacter (2), Enterobacter (5), Haemophillus (1) unspecified (3).
‡Gram-positive bacteria: Staph aureus (12 including 2 MRSA), Enterococcus (5), Group B Streptococcus (2), other Gram-positive (8).

providing an incentive for each unit to review every baby with a positive blood culture, leading to greater awareness among clinicians of infection and antibiotic use in their NICU.

Data for this study was censored to 35 days to overcome variation in practice between NICUs in transfer or discharge practice, ensuring that similar neonates were represented in each NICU. It should be noted, however, that infection rates for data censored to 35 days are not comparable to other data sets which report infection rates until discharge. Infection rates for D3–35 are expected to be two to three times higher than infection rates measured to discharge, due to higher rates of infection in neonates seen in the first 35 days of admission, compared with the later convalescent period.[7 32] The definition of BSI in this study was also intentionally broad to ensure inclusion of all neonates with culture-positive infection, resulting in higher BSI rates than those reported in studies with more stringent definitions of BSI.

Strengths of this study include the use of a consistent definition for BSI across all NICUs, the accurate collection of data obtained from all units through the use of automated download of pathology results and confirmation of point of care data by audit officers in each NICU. Limitations include the inability to link specific interventions with change in infection rates, as multiple interventions were applied over the period of the study, and a lack of data to demonstrate compliance with hand hygiene and PICC line protocols.

CONCLUSION

This study demonstrated the effectiveness of a QI initiative in reducing infection rates in a state-wide neonatal network in Australia. The challenge for participating NICUs will be to maintain current achievements and to develop new interventions to further reduce infection, especially for non-commensal organisms including Gram-negative bacteria. Strategies may include enhancing the neonate's protective microbiome and limiting antibiotic use.[12 13 36]

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Contributors JRB was Chair of the SPRING group, analysed the data and wrote the first draft of the manuscript. IC was the Database Developer, extracted data from the database and facilitated the automated data feedback to NICUs. KBL was Co-chair of the SPRING group and coordinated production of the PICC insertion teaching video. RR and KBL developed the potentially better practices framework and supported NICU quality improvement activities. All authors contributed to interpretation of the data and have approved the final manuscript.

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