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Mindful organizing as a healthcare strategy to decrease catheter-associated infections in neonatal and pediatric intensive care units. A systematic review and grading recommendations (GRADE) system

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Abstract

Purpose: To explore the clinical evidence available on mindful organizing (MO) that will improve teamwork for positioning and managing central venous catheters in patients admitted to neonatal intensive care and other pediatric intensive care units to decrease central-line-associated and catheter-related bloodstream infections (CLABSI and CRBSI). **Methods:** We searched several databases (PubMed, Embase, CINAHL, CENTRAL, SCOPUS, and Web of Science) up to June 2018. We included studies investigating the effectiveness of MO teamwork in reducing CLABSI and CRBSI. The systematic review followed the PRISMA guidelines. We used validated appraisal checklists to assess quality. **Results:** Seven studies were included: only one was a non-randomized case-controlled trial (CCT). All the others had a pre-post intervention design, one a time-series design and one an interrupted time-series design. The methodological heterogeneity precluded a meta-analysis. Despite the low certainty of evidence with the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system, three studies including thousands of participants provided numerical data for calculating risk ratios (RR) and 95% confidence intervals (CI) comparing MO with no intervention for decreasing the CLABSI rate in neonatal and pediatric ICUs. The one CCT disclosed no significant difference in the CLABSI rate decrease between groups (RR = 0.96; 95%CI 0.47–1.97). Nor did the pre- and post-intervention interrupted time-series design disclose a significant decrease (RR = 0.80; 95%CI 0.36 1.77). In the study using a before-after study design, the GRADE system found that the CLABSI rate decrease differed significantly in favor of post-intervention (RR = 0.13; 95%CI 0.03 0.57; $p = 0.007$). **Conclusions:** Despite the decreased CLABSI rate, the available evidence is low in quality. To reduce the unduly high CLABSI rates in neonatal and pediatric intensive care settings, custom-designed clinical trials should further define the clinical efficacy of MO to include it in care bundles as a new international standard.

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Introduction

Although central-vascular catheters (CVC) induce complications such as central line-associated bloodstream infections (CLABSI) and catheter-related bloodstream infections (CRBSI) in primary care and intensive care units (ICUs), they allow adults, neonates, and children to receive polytherapy, help them to recover immediately, and reduce days of admission, morbidity, and mortality rates.[1–3]

CLABSI is a term used for surveillance.[3] CLABSI are associated with a prolonged hospital stay, and a high estimated mortality rate (11%–20%).[2] The Centers for Disease Control and Prevention (CDC) define CLABSI as primary bacteremic infections in patients who had a CVC inserted 48 h before the infection and had a CVC in situ on the previous day or on the day when the infection was diagnosed.[3] One way to decrease CLABSI rates in adults and children is to undertake epidemiological surveillance.[3] Unlike CLABSI, CRBSI is a clinical term.[4] According to the infectious diseases society of America (IDSA) criteria, CRBSI are diagnosed as bacteremic infections due to CVC when grown from at least one percutaneous blood culture and from a catheter tip culture, or cultured on two blood samples (one drawn from a catheter hub and the other from a peripheral vein) meet CRBSI criteria for quantitative blood cultures or differential time to positivity (DTP) (the time necessary for peripheral vein and CVC cultures to become positive).[4–7] For the IDSA, how to interpret DTP remains an unsolved issue.[4]

CLABSI and CRBSI have several disadvantages. In neonatal ICUs (NICUs), CLABSI rates can reach over 18 infections per 1000 catheter/days depending on the lowest birth weight.[8] The CDC National Healthcare Safety Network (NHSN) ranged CLABSI in pediatric ICUs (PICUs) between 1.3 and 5.5 infections per 1000 catheter/days.[9] CLABSI can cost an average of $ 45,000 per episode, and in a sample of 22 critically ill children, a study found an attributable dollar cost of $ 33,039 per CLABSI.[3,10] One way to decrease CLABSI rates in hospitalized children is to pay meticulous attention to central line maintenance strategies.[3,11,12]

The published CDC guidelines for preventing CLABSI, and the National Association of Children's Hospitals and Related Institutions (NACHRI) identified best practices for a 29-hospital quality improvement (QI) collaborative study to decrease CLABSI rates in PICUs.[5,13] Another way to decrease CLABSI and CRBSI rates in ICUs is to apply diligently and monitor standard best practice pathways, namely "care bundles," although improving bundle compliance by teamwork in NICUs and PICUs may leave infection rates unchanged.[10–13] The systematic use of care bundles shows that safe and high-quality care depends critically on the clinical teams' engagement level.[14] Multidisciplinary efforts to decrease CLABSI and CRBSI rates should implement successful interventions (survey compliance, comply with barriers and opportunities), and mindful organizing (MO) strategies to engage teamwork leadership including nurses, clinicians, patients, and families.[3,10–14] These consistent practices might advance team staff empowerment and performance thus improving patients' clinical outcomes.[14]

We designed this systematic review to synthesize the available clinical evidence on whether MO strategies (including engagement, empowerment, positive reinforcement, or awards) applied to healthcare personnel experienced in positioning and managing CVC can decrease CLABSI and CRBSI rates in neonates, infants, and children admitted to NICUs and PICUs.

Methods

We systematically searched the available medical literature to identify all studies focused on a possible relationship between the effectiveness of MO, applied to healthcare personnel experienced in positioning and managing CVC in neonates, infants, and children admitted to NICUs and PICUs, and decreased CLABSI or CRBSI rates as the primary outcome.

Research question, population, inclusion, and exclusion criteria

This systematic review asked whether MO strategies applied to healthcare team staff and added to care bundle compliance surveyed on neonates, infants, and children admitted to NICUs and PICUs with positioned and monitored CVC help to decrease CLABSI or CRIBSI rates.

Our inclusion criteria took into consideration all study designs and clinical series, with documented approaches in MO interventions applied to healthcare teamwork in NICUs and PICUs.

We excluded unpublished studies, duplications, abstracts, conference presentations, letters, and editorials.

Literature search

We searched the following databases Cochrane Library (2018, Issue 6); PubMed (1966–); Embase (OVID, 1974–); CINAHL (EBSCO HOST 1982–); SCOPUS

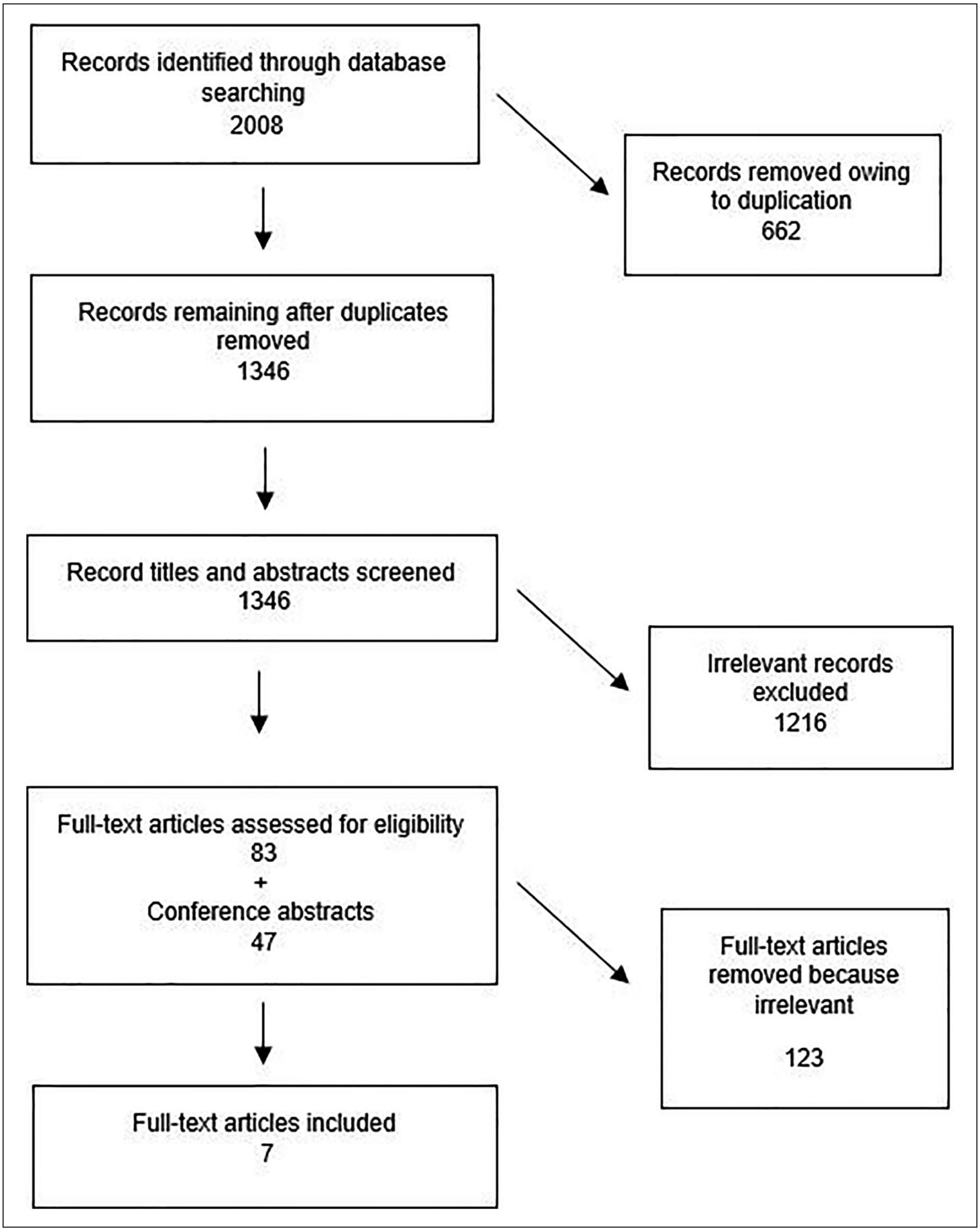

Figure 1. PRISMA flow diagram. PRISMA indicates preferred reporting items for systematic reviews and meta-analyses.

(1970–); and Web of Science (1990–) up to 26 June 2018. The search strategy for PubMed and similar search strategies for each database yielded several studies investigating MO to decrease CLABSI but no studies for MO in CRBSI (Appendix—Research strategies to identify studies). To find further relevant studies, we checked the reference lists for included studies. According to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) group guidelines,[15] we developed a flow diagram (Figure 1) to identify, screen, and include eligible studies (a complete PRISMA answer checklist in Supplemental Appendix 1).

Data extraction

Two authors (Rosella Saulle and Laura Amato) independently screened titles and abstracts for inclusion and extracted data for MO interventions aimed to decrease CLABSI from full-text articles that satisfied our inclusion criteria. We extracted data from studies including first author, year, patients, study design, care settings, healthcare professionals involved, intervention duration, tool or support for intervention, outcomes, qualitative and quantitative results, and authors' conclusions (Table 1). A third review author (Paola Rosati) resolved all discrepancies.

Quality appraisal

Two authors, working in rotation in couples, independently assessed the quality of the reported findings from the included studies by using the STrengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement, a validated critical appraisal checklist to assess possible reporting bias, limitations, generalizability, and external validity of the findings in observational studies (a complete STROBE answer checklist with 22 items and 33 subsections in Supplemental Appendix 1).[23] According to the criteria recommended in the Cochrane Handbook for Systematic Reviews of Interventions,[24] the quality for the non-randomized CCT study[16] was assessed using the Cochrane risk of bias tool (Figure 2). Two authors independently also used the NIH validated critical qualitative checklist data (range and median in Supplemental Appendix 1) to appraise the three studies that provided numerical data for statistical analysis[16,21,22,25] (Table 2; forest plots in Figure 3).

Data collection, measures, and analysis of intervention effect

We extracted data from the selected articles and stored data fields in an electronic database. Data fields included study design, number of patients, settings, methods used, interventions and control groups, outcome assessment measures, and primary and secondary outcomes. If methodological heterogeneity in some studies precluded a meta-analysis, we summarized and reported all results descriptively and, when possible, calculated with the Review Manager version 5.2.0 the anticipated absolute effect in CLABSI events per 1000 line-days based on the difference between the event risks in MO groups and controls, and the risk ratio (RR) (Table 2).

Grading of evidence

We assessed the body of evidence for the primary outcome (decreased CLABSI rates) using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system.[27]

Summary of findings and statistical analysis

For three included studies,[16,21,22] the findings were synthesized in an SoF table to provide key information concerning the quality of evidence, the effect magnitude of the interventions examined, and the sum of available data on the main outcomes (Table 2). The SoF summarized the main findings in a transparent and simple tabular format according to four rates: high certainty when the grading system suggested that the true effect lay close to the estimated effect; moderate certainty when the true effect almost certainly lay close to the estimated effect; low certainty when the true effect might differ substantially from the estimated effect; and very low certainty when the true effect probably differed substantially from the estimated effect (Table 2). The grading decreased for the following reasons: serious (−1 grade) or very serious (−2 grades) study limitations for risk of bias; serious (−1) or very serious (−2) inconsistency between study results; some (−1) or major (−2) uncertainty about the directness of the results; serious (−1) or very serious (−2) imprecision of the pooled estimate; and strongly suspected publication bias (−1). We used the GRADEpro GDT (GRADEpro GDT 2015) software[26] to prepare the SoF table, and to analyze dichotomous outcomes by calculating the RR for each study with the uncertainty in each result expressed as a 95% confidence interval (CI) (SoF in Table 2, forest plots in Figure 3).

Results

After eliminating duplicates, we identified 1,346 articles. By screening titles and abstracts, we excluded 1,216 articles. Of the remaining 83 publications, we excluded 76, because they fail to meet the inclusion criteria, and therefore included 7 studies[16,17–22] that evaluated whether MO interventions help to decrease CLABSI rates (PRISMA flow diagram in Figure 1).

Study characteristics

For each of the seven included studies,[16,17–22] we coded data for 10 items including the type of study, settings, patients, and healthcare professional involved, intervention tools or support studied, outcomes, qualitative and quantitative results, and authors' conclusions (Table 1). Only one study was a prospective non-randomized CCT with no intervention in the control group,[16] and all the other studies lacked a control group, four of these six studies had a pre-post intervention before-after study design,[17,19,20,22] one was a time series analysis,[18] and one was a prospective interrupted time series study.[21]

Study features

The study by Orwoll et al.[16] was a prospective non-randomized CCT QI study designed as a targeted implementation of a digital self-assessment application (CLABSI

Table 1. Mindful organizing (MO) coding data from the seven studies included in the review.

Study	Data coded	Data extracted from studies
Orwoll et al.[16]	Population	Nurses caring for children with indwelling central venous catheters from three high-risk units.
	Study design	Non-randomized case controlled (CCT) quality improvement (QI) study.
	Care setting	The University of California San Francisco (UCSF) Benioff Children's Hospital (study hospital) (USA), an academic quaternary care institution.
	Healthcare professional involved	Intervention group comprises nurses caring for inpatients from bone marrow transplant (BMT), hematology-oncology, and general critical care units selected on the basis of historically higher rates of central line associated bloodstream infection (CLABSI), attributed to their disproportionately larger immunocompromised patient populations. The control group comprised all other nurses caring for inpatient units including neonatal intensive care units (NICU), cardiac critical care, cardiac transitional care, general medical/surgical transitional care, and general medical/surgical ward).
	Study duration and period	The study lasted one year from September 2014 to August 2015. Competitions took place in September 2014, June 2015, and July 2015, and were formally publicized via staff meetings, posters, and email.
	Intervention tool or support	The study team developed a CLABSI self-assessment application (CLABSI App) for an existing cloud-based enterprise social network platform. The CLABSI App was designed as a self-assessment checklist, mirroring the institutional CLABSI prevention nursing care bundle audit tool, and tracking central venous catheter (CVC) type and location with associated nurses and units. Access to the CLABSI App was limited to those nurses whose primary unit was in the intervention group.
	Outcome	The primary outcome was the CLABSI rate. The CLABSI rate during the study period was compared with the rate during the preceding 12 months. An additional control analysis covered the 24 months before the study began (baseline period). Changes in CLABSI rates were compared between intervention and control groups. Secondary outcomes included numbers of self-assessments completed and self-reported compliance with each CLABSI bundle element. Competitions were associated with increased engagement as measured by individual participant self-assessments.
	Qualitative results	Competitions were associated with an increased engagement measured by individual self-assessments.
	Quantitative results	The study included more line-days for inpatients in intervention and control groups admitted to the hospital during the preceding year (18,864 total line days) than the line-days during the study (18,933) of which 52% in the intervention group versus and 46.6% in the preceding year. The overall CLABSI rate was lower during the study period than during the preceding year (1.64 vs 1.96 per 1000 line days, $p=0.5$). The CLABSI rate for the intervention group declined by 48% between the preceding year and the study period (3.31 vs 1.72, $p=0.03$). The combined CLABSI rate in the control units increased by 108% between the preceding year and the study period (0.79 vs 1.65, $p=0.09$). Expanding the analysis through the 24-month period before the study (September 2012 to August 2014), the baseline CLABSI rates differed significantly in the control group and the intervention groups (1.00 vs 3.36, 3.37-fold difference, $p=<0.001$). During the study, the CLABSI rate in the control group rose to 1.65 ($p=0.16$), whereas in the intervention group it decreased to 1.72 (69% reduction, $p=0.01$).
	Authors conclusions	Healthcare professionals should explore novel approaches such as GAME quality improvement to take alert frontline staff from passive to active social participant continuously, hence measuring healthcare quality by digital transformation tools.
Ceballos et al.[17]	Population	All neonates with central venous catheters and/or umbilical lines and/or patients who were mechanically ventilated. All patients were birth weight stratified on the basis of national healthcare safety network reporting requirements: category A, <750 g; category B, 751–1000 g; category C, 1001–1500 g; category D, 1501–2500 g; and category E, >2500 g.
	Study design	Quasi experimental quality improvement (QI) before-after study.
	Care setting	A level IIIB NICU hospital (Colorado, USA) within a 413-bed quaternary referral academic medical center. Most admissions are a result of an inpatient delivery service with an average yearly admission rate of 570 neonates.
	Healthcare professional involved	The interdisciplinary team included charge nurses, a clinical nurse manager, a clinical nurse specialist/educator, a clinical nurse specialist (CNS) outcomes coordinator, a medical director, a respiratory therapy clinical supervisor, and an infection-prevention nurse. The QI team believed that all individuals caring for neonates were accountable for following the practice guidelines to reduce CLABSI and ventilator associated pneumonia (VAP); however, the nurses were the most consistent providers and thus were empowered to lead practice change interventions. The identified QI nurse leaders for this project were the CNS/educator, the CNS outcomes coordinator, and the registered nurse (RN) infection-prevention.
	Study duration and period	The study period was performed from July 1, 2009 to July 30, 2010.
	Intervention tool or support	The intervention consisted in education and audit of CLABSI bundle updated and implemented on July 1, 2009, and the VAP bundle updated on February 1, 2010. After team consensus, the process for improvement followed the organizational QI model, Find, Organize, Clarify, Understand, Select, Plan, Do, Check, Act (FOCUS-PDCA). This method allowed nurses to find a problem, organize a team, clarify what they knew, understand the variation, select elements for practice improvement, plan a process change, do the practice change, check on the outcomes, and act to hold the practice improvement as a gain.
	Outcome	Reducing CLABSI and VAP
	Qualitative results	The bedside nurse, empowered to lead the bundle implementation, increased personal ownership and compliance, and ultimately improved practice and patient outcomes.

(Continued)

Table 1. (Continued)

Study	Data coded	Data extracted from studies
	Quantitative results	During the year of the bundle implementation CLABSI rates significantly decreased in all categories of neonates with umbilical lines except category A (750 g at birth). Rates of infection in neonates with central venous catheters decreased in all weight categories except category B (751–1000 g at birth). This NICU achieved the goal of elimination of CLABSI in umbilical lines during the post-intervention year (July 1, 2010–June 30, 2011), reporting a rate of 0 in all weight categories of neonates with umbilical lines. Rates in infants with a central venous catheter were 0 in all categories except category C (1001–1500 g). NICU daily census remained stable. Comparing the pre-intervention with the post-intervention year, total line days decreased by 27%.
	Authors conclusions	Nurses are central in hospital efforts to improve quality care. The bundled interventions provided the nurses with a structure to successfully implement a systematic process for improvement. Nursing leaders ensure that bundles can be implemented strategically and provided consistent and specific feedback on intervention compliance with quarterly CLABSI and VAP rates. Real-time feedback is effective to assist the registered nurses, neonatal nurse practitioners, and physicians and appreciate their change in practice.
Dandoy et al.[18]	Population	Patients receiving therapy for cancer, or undergoing haematopoietic stem cell transplantation, compared with historical controls.
	Study design	A time series analysis.
	Care setting	The Cancer and Blood Diseases Institute at Cincinnati Children's Hospital Medical Center (Ohio, USA) includes both a Hematology Oncology (Hem/Onc) unit and a BMT unit. The Hem/Onc unit has a capacity of 32 patient beds, providing specialized hematology, oncology. and vascular malformation care to patients from infancy through adulthood.
	Healthcare professional involved	A multidisciplinary CLABSI oversight task force consisting of key stakeholders, including a senior hospital leadership, physicians, nursing leadership, RNs, Infection Control professionals, Vascular Access Team members, and patient care assistants.
	Study duration and period	From June 2013 to May 2015.
	Intervention tool or support	A multidisciplinary CLABSI oversight task force consisted of key stakeholders, including a senior hospital leader, physicians, nursing leadership, RNs, infection control professionals, vascular access team members, and patient care assistants. The team's focus was to identify and mitigate potential underlying causes of the increased CLABSI rate through analysis of current and historical CVC care practices; review of published recommendations and guidelines; quantitative and qualitative analysis of patient, environment, and healthcare delivery system variables; and rapid implementation of interventions based on plan-do-study-act (PDSA) testing.
	Outcome	CLABSI rate reduction.
	Qualitative results	Stress evaluation challenging CLABSI rate in this complex care system.
	Quantitative results	The CLABSI rate from June 2013 to May 2014 was 2.03 infections/1000 line days. After implementation of the experimental intervention, from June 2014 to May 2015, there was a significant decrease in the CLABSI rate to 0.39 infections/1000 line days ($p = 0.008$). Key processes became more reliable: with the new two-person standard process 100% of dressing changes were completed; daily hygiene adherence increased from 25% to 70%; 100% of nurses were approached daily by a senior nursing for assistance with high-risk procedures; and patients at risk for CLABSIs were identified daily.
	Authors conclusions	A complex system caring for high-risk patients can stress and challenge CLABSI rates. To stabilize reliably outcomes during times of system stress there is a need to identify key processes and execute them. An increased system stress includes changes in staffing, increased census, and/or adequate RN number for caring acute patients. To improve patient care safety and quality, hospitals should provide mechanisms including greater staffing assistance and systems responsiveness to increased care acuity and census fluctuations. The Authors believe their findings transferrable to other institutions with the same experience.
McKee et al.[19]	Population	All patients with percutaneous central venous catheters admitted to the pediatric intensive care unit (PICU) after February 1, 2004 compared with historical controls.
	Study design	Quasi experimental before-after study design.
	Care setting	The Johns Hopkins Hospital (Maryland, USA) is a 926-bed tertiary care medical center with multiple intensive care units (ICU), and full medical, surgical, pediatric, and psychiatric services. The PICU is a 22-bed multidisciplinary unit that provides full services for medical and surgical pediatric patients, up to age 22 years.
	Healthcare professional involved	All providers who insert CVC in the institution received identical training modules on best practices for insertion. CVC were routinely placed by pediatric anesthesiologists or surgeons in the operating room or by pediatric surgical and critical care medical staff in the PICU.
	Study duration and period	The pre-intervention period started from 2001 to February 2004, and the intervention period started from February 2004 to September 2006.
	Intervention tool or support	This quality improvement study monitored compliance with CVC insertion practices in the CVC inserted in the PICU subset.

(Continued)

Table 1. (Continued)

Study	Data coded	Data extracted from studies
	Outcome	The primary outcome variable measured was the reduction in catheter associated blood stream infections (CA-BSI) line days. Secondary outcome measures included physician adherence to evidence-based infection control practices during CVC insertions and degree of nurse-led enforcement needed to ensure reliable adherence.
	Qualitative results	Among pediatric patients, data showed that improving practices for insertion of CVC leaded to a reduction but not elimination of CA-BSI.
	Quantitative results	Reliable use of evidence-based best practices for insertion of CVC in the PICU was associated with a statistically and clinically significant decrease in CA-BSI rate in the 24 months post-intervention ($p < 0.05$). During a portion of this post-intervention period, authors experienced a dramatic increase in CA-BSI rate. It was attributed to the introduction of a new mechanical valve intravenous port displacement in April 2004. After removal of this mechanical valve, the CA-BSI rate dropped from 5.2–4.5 CA-BSI to a rate of 3.0–1.9 CA-BSI/1000 line days. Chart review of post-intervention yielded to the CA-BSI extinction in 10 weeks post-intervention period, but an increase in CA-BSI cases after insertion of most recent CVC displacement.
	Authors conclusions	More research is needed to identify best practices for maintenance of CVC for children. Authors' experience showed that even despite good interventions to control CA-BSI, institutions must remain vigilant to factors, such as a new apparent advantageous technology (insertion of new catheters) with short-use track records.
Owings et al.[20]	Population	Patients admitted to leukemia, solid tumor/neuro-oncology, stem-cell transplant units, and ICU.
	Study design	Quasi experimental before-after study design.
	Care setting	The St. Jude Children's Research Hospital (Tennessee, USA), a 68-bed inpatient pediatric oncology center with approximately 3,200 annual admissions for children receiving treatment for malignancy or hematopoietic stem cell transplant.
	Healthcare professional involved	The leadership line care rounds (LLCRs) team included an infection preventionist, a line care nurse, nursing quality staff, a CLABSI physician champion (identified as the medical director of infection prevention and control), and the unit nurse manager. The bedside nurse and patient's caregivers were also engaged in these rounds.
	Study duration and period	The CLABSI prevention improvement project started in January 2013. In January 2014, hour-long weekly LLCRs were implemented on the inpatient units using the audit tool.
	Intervention tool or support	LLCRs aimed 2-fold purposes: to educate caregivers about infection prevention (including hand hygiene, dressing maintenance, hub scrub and dry times, daily baths, and linen change), and to empower them to speak up if they observe noncompliant practices; and to evaluate compliance with the CVC maintenance bundle through direct observation of practice and documentation audit.
	Outcome	CLABSI prevention.
	Qualitative results	Multidisciplinary LLCRs have proven effective in CLABSI prevention.
	Quantitative results	Only a figure reported the data that were impossible to be extracted.
	Authors conclusions	Although authors failed to attribute their success in CLABSI reduction to the LLCRs strategy, they deemed the control rounds reported as a major contributor to identify barriers and opportunities to sustain the achieved improvement. The reported round implementation played an essential role in improving the overall safety culture. To make CLABSI prevention as an institutional priority at all levels, the multidisciplinary bedside LLCRs provided the leaders, managers, frontline staff, patients, and their caregivers a platform for direct interaction and for sharing patient safety as a common vision.
Rinke et al.[21]	Population	Patients with primary oncologic diagnoses admitted in the 186-bed children's center.
	Study design	Quasi experimental before-after study design. Prospective, interrupted time series study.
	Care setting	This study was conducted in the oncology children's center at the Johns Hopkins Hospital (Maryland, USA) visiting ~200 new oncologic diagnoses and performing 35 stem cell transplants each year. The unit is a 18-bed, self-contained floor with consistent nursing and support staff devoted to patients with primary oncologic diagnoses.
	Healthcare professional involved	A team of front-line nurses, the unit nurse manager, physicians, pharmacists, quality improvement specialists, and infection preventionists met monthly to complete mini-root cause analyses of all CLABSIs and discuss systems changes to improve compliance with the CVC care bundle, based on Centers for Disease Control and Prevention (CDC) recommendations. It emphasized CVC care best practices in all areas, including the three main bundle elements: a reduction in CVC entries; aseptic entries into the CVC; and aseptic procedures when changing line components. Education on the bundle began in November 2009. Through the audits in the medical team, the three main bundle element compliance of bedside nurses was tracked and reinforced by daily discussion. Local efforts and the authors' unit participation in a national collaborative were supported by oncology leadership and hospital-wide physician and nursing leadership.

(Continued)

Table 1. (Continued)

Study	Data coded	Data extracted from studies
	Study duration and period	Baseline data included 10 months from January 2009 through the start of the intervention education in November 2009, tracking data on CLABSI, and central line days until Spring 2011.
	Intervention tool or support	The strategy for translating evidence into practice was used as a conceptual model to summarize the evidence, identify local barriers, measure performance, and ensure that all patients receive the intervention through engage-educate-execute-evaluate improvement model.
	Outcome	CLABSI rates before-after the care bundle implementation.
	Qualitative results	This study suggested that best practice CVC bundles can be implemented in inpatient pediatric oncology patients and presented practical interventions that can be applied in other institutions aiming at reducing CLABSIs.
	Quantitative results	CLABSI rates decreased from 2.25 to 1.79/1000 line-days during the intervention period with an incidence rate ratio (IRR) 0.80 ($p = 0.58$). Secondary analyses indicated that CLABSI rates were reduced to 0.81/1000 line days in the second 12-month period after the intervention (IRR 0.36, $p = 0.091$). Fifty-nine percent of infections resulted from Gram-positive pathogens, 37% of patients with a CLABSI required CVC removal, and patients with Hickman catheters were more likely to have a CLABSI than patients with infusaports (IRR 4.62, $p = 0.02$).
	Authors conclusions	Although long ramp-up times may be necessary to reap maximal benefits, a best-practice CVC maintenance care bundle can be implemented in hospitalized pediatric oncology patients. Further research is needed to sustain and spread the intervention studied for a CLABSI rate reduction.
Rosenberg et al.[22]	Population	Bedside nursing pediatric staff and multi-specialist CLABSI prevention core team from all pediatric ICU and non-ICU.
	Study design	Quasi experimental before-after study design.
	Care setting	New York City Units at Langone Medical Center (NYULMC), a 1,069-bed tertiary care academic medical center.
	Healthcare professional involved	CVC team leaders, including infection prevention and control and nursing quality co-leader professionals and, at individual units, a nurse manager, a medical Director, and a champion or current RN.
	Study duration and period	January 2013 to September 2014 (pre-intervention 2012).
	Intervention tool or support	According to a standardized CLABSI prevention care bundle, during the booster 1 and 2, intervention measurement included nursing CVC self-audits by reviewing nurse checklists done at every shift, timely CLABSI cause analysis, and maintaining health professionals engagement.
	Outcome	CLABSI event reduction.
	Qualitative results	Expansion of nurse engagement. After the temporary NYULMC facility closure owing to the super-storm Sandy damage from January 2013 to September 2014, data in the subsequent 21 months showed an increase in maintenance bundle reliability with values consistently $>80\%$.
	Quantitative results	The inpatient CLABSI rate for patients <18 years decreased from an annual rate of 2.7/1000 line days (2012) to 0.6/1000 line days (2013) to 0.5/1000 line days in August 2014. No significant changes in line days during the study duration and period (16 CLABSI/5,835 line days in 2012; 3 CLABSI/4,779 line days in 2013; and 2 CLABSI/5,552 line days in 2014).
	Authors conclusions	Multifactorial key elements contributed to initial success with evolving QI capacity and resource use. The successful factors considered included the staff and leadership engagement, the culture change, the adherence to guidelines, and the accountability by individuals and by a multidisciplinary core team.

BMT: bone marrow transplant; CA-BSI: catheter associated blood stream infections; CLABSI: central line-associated bloodstream infection (CA-BSI and CLABSI are synonymous); CNS: clinical nurse specialist; CVC: central venous Catheter; ICU: intensive care units; LLCRs: leadership line care rounds; NICU: neonatal intensive care unit; PDSA: plan-do-study-act; PICU: pediatric intensive care unit; QI: quality improvement; RN: registered nurse; VAP: ventilator associated pneumonia.

App) with inter-unit social competition (gamification) between nursing groups (Table 1). It permitted also in-context micro-learning, engaging nurses in CLABSI prevention. The CLABSI App used in the intervention group mirrored a game with a competition award. A nurse self-assessment checklist was used to mimic the institutional CLABSI prevention nursing care bundle audit tool, including CVC type and site, the associated nurse, and the setting. The study lasted 10-months and comprised three competitions that took place when the study began, and 9 and 10 months later. Compared with the preceding year, the intervention group (17/9,886 line-days) showed a 48% decreased CLABSI rate ($p=0.03$). In the control group, the CLABSI rate between the preceding year and the study period (8/10,096 vs 13/7,879 line-days) increased by 108% ($p=0.09$). As the authors' reported, this study lacked a randomization at the unit or at the patient level, and the inability to control for specific patient risk factors within the study groups. Although the bundled intervention reduced CLABSI, the study team could not distinguish the extent to which the impact was driven by the nurse self-assessments, the just-in-time micro-learning, or the social gamification. Causality therefore failed to be attributed directly to the intervention studied.

The study by Ceballos et al.[17] had a quasi-experimental before-after study design and lasted 1 year (Table 1). The intervention consisted of a NICU interdisciplinary QI team plan including audits and, if necessary, one-on-one education provided by nurse educators and leaders on the use of an updated CLABSI and ventilator-associated pneumonia (VAP) care bundle updated checklist. To ensure standardized infection control practices, the intervention started when nurses inserted the line or assisted mechanically ventilated patients. CLABSI and VAP bundle compliance was

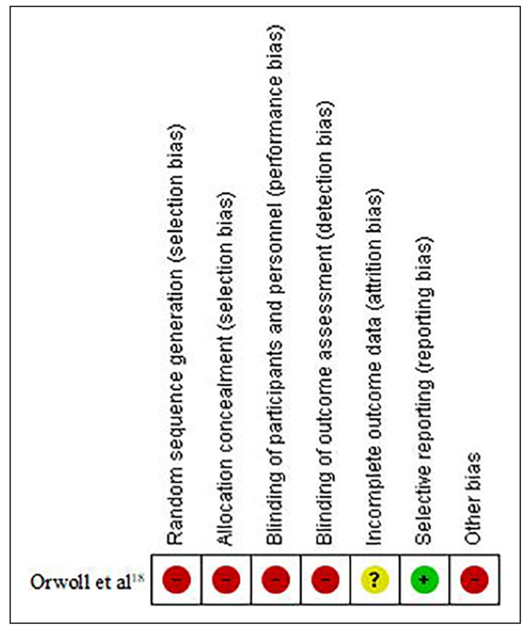

Figure 2. Risk of bias summary: review author's judgments about each risk of bias item for Orwoll et al.[16]

Table 2. Mindful organizing (MO) versus no intervention related to the central line-associated bloodstream infection (CLABSI) rate decrease per 1000 line-days in children from high-risk units, pediatric intensive care units (PICUs), and non-PICUs. Summary of Findings (SoF).

Study, population and setting (study design)	Certainty of the evidence in the studies (GRADE)[24,26]	Anticipated absolute effect in CLABSI events per 1000 line-days		Risk Ratio (RR)** (95%CI)
		Event risk in controls	Event risk difference* with MO (95%CI)	
Orwoll et al.[16] 17,765 children from three high-risk units (one CCT)	⊕⊕◯◯LOW[a,b]	2	2 (1 fewer to 2 more)	0.96 (0.47–1.97)
Rinke et al.[21] 14,059 children from an oncology unit (one interrupted time series study, observational study)	⊕⊕◯◯LOW[b,c]	2	2 (1 fewer to 2 more)	0.80 (0.36–1.77)
Rosenberg et al.[22] 11,387 children from PICUs and non PICUs (one before-after study, observational study)	⊕◯◯◯VERY LOW[b,c,d]	3	3 (3 fewer to 1 fewer)	0.13 (0.03–0.57)

CCT: non-randomized case-controlled trial; SoF: summary of findings.
[a]By applying the GRADE criteria[26,27] we downgraded the study Orwoll et al.[16] by two levels owing to the high risk of bias including "random sequence generation (selection bias)," "allocation concealment (selection bias)," "blinding of participants and personnel (performance bias)," "blinding of outcome assessment (detection bias)," unclear risk for "incomplete outcome data (attrition bias)," and high risk for "other bias" (because the authors disclosed receiving financial support for the research, and declared potential conflicts of interest) (Risk of Bias tool, Figure 2).
[b]The GRADE criterion for evaluating inconsistency was not applicable because the outcome results came from a single study.
[c]We assessed quality in Rinke et al.[21] and Rosenberg et al.[22] studies according to the assessment tool for before-after studies of the National Institutes of Health (NIH), National Heart Lung and Blood Institute (NHLBI).[25]
[d]We downgraded by one level the study by Rosenberg et al.[22] because the NIH quality assessment checklist rated the study of poor quality (the study yielded a 6/12 score) (a complete NIH checklist reported in Supplemental Appendix 1).
*Risk difference (excess risk) is the difference between the risk of CLABSI events in the control group and the intervention group.
**The risk ratio (RR) and its 95% confidence interval (CI) indicate the assumed risk in the control group versus the intervention group.

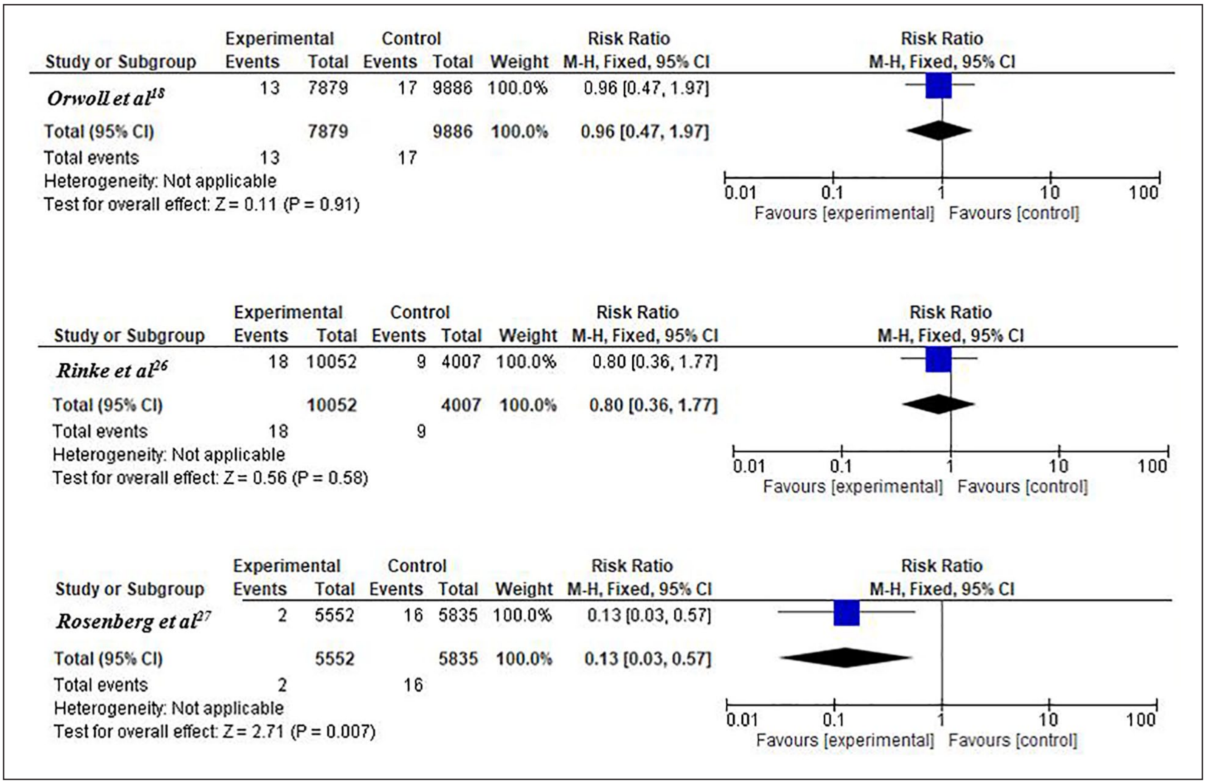

Figure 3. Forest plots for the three studies investigated according to the GRADE system.[26]

audited, and infection rates were measured before-after both bundle implementations following specific national healthcare safety network inclusion criteria for CLABSI and VAP determination. During the intervention, the overall CLABSI rate in the NICU was 0.4 infections/1000 line-days, with 84 fewer hospital days, an estimated additional cost saving of $ 348,000, and a 27% reduction in central-line days.

In a similar study, Dandoy et al.[18] used another before-after-study design and a time-series analysis (Table 1). They established for the intervention a multidisciplinary CLABSI audit task force consisting of key stakeholder team members, and a standard CLABSI bundle process. The team's focused on identifying and mitigating potential underlying causes for the increased CLABSI rate by analyzing current (June 2014–May 2015) and historical CVC care practices (June 2013–May 2014). Despite several continued stressors in a complex healthcare delivery system caring for patients with cancer, Dandoy et al.[18] showed that implementing the intervention decreased the CLABSI rate by nearly 70% (from 2.03 to 0.39 CLABSI/1000 line-days). To implement the intervention rapidly, they used a plan-do-study-act (PDSA) testing, comprising unit leadership, unit-specific CVC champions and senior nurses, and continuous education. This procedure included a formal nursing staff re-education, a stressed microsystem variable-associated real-time analysis, incentivized program for senior nurses extra-working during system stress times, bi-weekly room assessments, and daily linen changes in patients' cribs.

Another before-after study was conducted by McKee et al.[19] (Table 1). The study aimed to eradicate CLABSI with a multifaceted pediatric-relevant intervention proven effective in adult patients. The multifaceted six-step intervention involved a pre-intervention survey on CVC practices, a provider educational program for implementing evidence-based infection control practices, a new procedure guideline-supported CVC insertion checklist, an independent double-checking for checklist adherence, a nursing staff empowerment to stop procedures that breached guidelines, and real-time data feedback to the PICU leadership. The rate of CLABSI/1000 line-days decreased statistically and clinically for 24 months post-intervention ($p < 0.05$). The CLABSI rate dropped from 5.2 ± 4.5 to 3.0 ± 1.9 CLABSI/1000 line-days. McKee et al.[19] showed that improving practices for inserting CVC reduced CLABSI but failed to eliminate them among pediatric patients. Although the ten subsequent consecutive weeks after implementing the six-step-intervention CLABSI initiative yielded zero CLABSI, the CLABSI rate thereafter significantly increased thus surpassing the historical control period. McKee et al.[19] attributed this CLABSI increment to a new positive mechanical valve displaced in the intravenous port. After this new device was removed, CLABSI decreased again.

The project reported in the study by Owings et al.[20] revised and implemented evidence-based care maintenance bundles, education, and compliance monitoring by using an anonymous nursing self-report tool (audit tool) (Table 1). The authors' program included an audit compliance to identify barriers and opportunities, empower patients and their caregivers, and engage leadership. A multi-specialist leadership line care rounds team included infection preventionists such as nursing quality staff members, physicians, and patient's caregivers. Although the intervention by Owings et al.[20] included mixed technical and empowerment actions, the empowerment effectiveness, owing to the results reported only in a figure, remained unmeasurable.

The aim of the project reported by Rinke et al.,[21] a prospective interrupted time series study, was to investigate whether multidisciplinary, best-practice CVC maintenance care bundles reduced CLABSI rates in hospitalized pediatric oncology patients (Table 1). The intervention was a continuous QI model including targeted interventions instituted to improve compliance with each of three main bundle elements. CLABSI rates decreased in the period studied, yielding an incidence rate ratio of 0.80 ($p=0.58$). Daily rounds with health professionals from all disciplines developed a "workgroup" of pediatric oncology nurses to keep the momentum in the study going, assist with disseminating information to the nursing staff and developing projects for analyzing root-cause-results in the CLABSI bulletin board in the nursing break room.

In their study, Rosenberg et al.[22] applied a before-after study design in ICU and non-ICU from one pediatric setting (Table 1). The authors studied a CLABSI-prevention multi-specialist core team and a standardized QI plan-do-study-act cycle intervention in two phases, a planning initial phase and a maintenance and supporting phase. The in-patient ICU and non-ICU CLABSI rate for patients <18 years decreased from an annual rate of 2.7–0.6/1000 line-days from 2012 to 2013. The authors failed to provide data on significance. Key elements contributing to the success with evolving QI capacity and resources were probably multifactorial, including staff and leadership engagement, culture change, adherence to guidelines, and accountability by individuals in the multidisciplinary core team.

Critical appraisal of study quality

The STROBE statement checklist[23] identified generally low study quality in the reporting for all the seven studies (overall scoring from 2 to 14 over 22 reporting items in the seven studies included (STROBE statement answers checklist and scoring in Supplemental Appendix 1).

Based on the study type, the three studies evaluated through the GRADE system were assessed for quality (Table 2). Rinke et al.[21] and Rosenberg et al.[22] were evaluated by using the NIH checklist[25] (quality assessment for the before-after study design). These two studies yielded 10/12 and 6/12 points (median 8/12) (a complete NIH checklist in Supplemental Appendix 1). The prospective CCT by Orwoll et al.[16] assessed with the risk of bias tool (Review Manager version 5.2.0) showed a low level of quality (Figure 2). By assessing quality with the risk of bias tool this CCT disclosed a high risk for "random sequence generation (selection bias)," "allocation concealment (selection bias)," "blinding of participants and personnel (performance bias)" and "blinding of outcome assessment (detection bias)," an unclear risk for "incomplete outcome data (attrition bias)," low risk for "selective reporting (reporting bias)," and high risk for "other bias" (because the investigators disclosed receiving financial support for the research and declared potential conflict of interests) (Table 2).

Effects of interventions and certainty of evidence

We could extract numerical data to calculate the RR with 95%CI only from the prospective CCT[16] and from the two observational studies from Rinke et al.[21] and Rosenberg et al.[22] (forest plots of the three studies in Figure 3).

In the study by Orwoll et al.,[16] we found no difference between the CLABSI decrease in the intervention and the control group (RR 0.96, 95%CI 0.47–1.97; 17,765 participants). Similarly, in the study by Rinke et al.,[21] we found no difference between the CLABSI decrease in the intervention and the control group (RR 0.80, 95%CI 0.36–1.77; 14,059 participants). Conversely, in the study by Rosenberg et al.,[22] the CLABSI decrease differed in the intervention and the control group (RR 0.13, 95%CI 0.03–0.57; 11,387 participants) (SoF in Table 2).

According to the GRADE system certainty of evidence, the results from Orwoll et al.[16] and Rinke et al.[21] were of low certainty, and from Rosenberg et al.[22] of very low certainty (SoF in Table 2).

Discussion

Although MO strategies in all the included and analyzed studies decreased the CLABSI rates in various settings, none provides evidence on their effectiveness in specific NICU and PICU settings, or analyzed human or other factors such as age, case mix in the ICUs, or seasonality. Equally important, even though some studies yielded promising results because they favor MO strategies, none analyzed the possible influence on CLABSI rates from turnover of the caregivers involved in patients' care. Owing to the low quality of the evidence regarding study designs, conduction, and possible bias, current evidence remains uncertain. We found no studies on the effectiveness of MO in decreasing CRBSI, a more specific term to address clinical outcomes particularly in neonates, infants, and children admitted to NICUs and PICUs.

Because none of the studies investigated randomization at the unit or patient level or controlled for specific patient risk factors within the study groups, clinical conditions in NICUs and PICUs presumably differ in other ways, including dissimilar groups. Causality cannot therefore be attributed directly to MO interventions. Only one study had a prospective CCT design[16] and all the other studies were prospective with a before-after study design.[17–22] Hence the results may reflect temporal changes in CLABSI rates or patient populations, or the various interventions applied with MO strategies. Another reason why we found the results difficult to interpret was the high heterogeneity across intervention types. Studies were also conducted in different ways, with different interventions and tools and at different follow-up periods. When we used the STROBE answer checklist, adapted and applied the score according to previous studies,[28,29] the seven included studies showed poorly reported items and yielded a total score cutoff of less than 75% for the overall score (a complete STROBE checklist in Supplemental Appendix 1).

When evaluating the relative effectiveness of MO strategies, no study mentioned the importance of institutional infection control in constantly monitoring and containing CLABSI and CRIBSI to a zero target.[3,11] We therefore need to undertake more research comparing institutional intervention strategies versus no intervention or other intervention types. For example, to target all health care team workers in MO for reducing CLABSI and CRBSI, we need to address staff empowerment knowing that evidence on the psychological stimulus of being singled out and made to feel important (Hawthorne effect) can also increase hand hygiene in care bundles.[30] To reach an institutional target of zero CLABSI and CRIBSI rates to improve patient safety strategies, we also need to support millennial nurses with senior leadership champions whose clinical experience can potentially improve safety culture plans by directly influencing clinical care processes and outcomes.[31] The current five-generation employees in the health workforce is an unprecedented challenge.[32] Generational gaps and employment status can be barriers to a successful MO implementation plan as a recent comparative survey on nurse leadership suggests.[33] Evidence-based MO action plans for addressing generational gaps need to include interventions for successful nurse engagements. For example, younger nurses are frequently reassured and receive feedback from senior nurses; experienced and novice nurses develop adequate staff mentoring by intergenerational support; manager visibility and accessibility are expanded; nurses know their voices are considered by purposeful communication; teamwork is promoted to reduce conflicts; and opportunities implemented to promote staff to act as a volunteer "superuser" such as unit champion, early adopter, or innovation champion.[34]

To give conclusive answers on the efficacy of MO to decrease CLABSI in NICUs and PICUs settings, we need further RCTs testing all the aforementioned possible MO interventions. These trials should be custom designed, of high quality, and conducted over a long follow-up in NICUs and PICUs to support comparison of strategies implemented in different modalities, at various levels, empowering and targeting all health care team staff workers who take care of pediatric populations.

Limitations

This systematic review is limited owing to the few studies available. Only one of the seven studies included was a CCT,[16] thus precluding strongly reliable review results. Although all the studies included gave information on the effectiveness of MO in decreasing CLABSI, they were of low quality, possible bias from seasonality, caregiver turnover or applied MO in case mix in intensive pediatric contexts such as in units admitting children at high-risk or with various severe diseases including cancer and transplantations, unreliable for addressing external validity. For example, McKee et al.[19] mentioned that mechanical valves were no longer used because they increased the risk of infections.[13] Nor did the studies included in this review mention the importance of undertaking pre and post study MO for institutional infection control by constantly monitoring and containing CLABSI and CRIBSI to a zero target goal. Although we failed to apply an interrater variability to define the STROBE scores, we created a score sheet adapting the scores validated and applied by others.[28,29] Because we used the GRADEpro GTD software to synthesize results, we did not create for our review paper a weighted mean.

Conclusion

Even though some studies provide promising results, current evidence remains uncertain regarding which MO strategy could be customized so as best to decrease the unduly high CLABSI rates in neonates, infants, and children admitted to NICUs and PICUs.

Custom-designed RCTs should be conducted with high quality standards and prolonged follow-up to define which MO type should be added to pediatric care bundles to reduce or eliminate CLABSI and CRBSI rates in NICUs and PICUs.

Author's note

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Supplemental material

Supplemental material for this article is available online.

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