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Reducing Central Line Infections in Pediatric Critical Care Patients

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Early Identification of High-Risk Pediatric Patients in Reducing Central Line Infections

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Contents

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Executive Summary

The purpose of this project is to show how early identification of patients who are at high risk for developing central line infections has an impact on infection rates, and how prevention strategies directed towards that patient population could lead to positive patient outcomes and a decrease in central line-associated bloodstream infections (CLABSI). Central line infections are a major hospital-acquired condition within hospital settings. In pediatric critical care areas, central venous catheters are inevitable due to complex diagnoses, patient size, and small vessels. However, CLABSIs have a massive impact on pediatric patients increasing mortality from 4% to 37%, prolonged hospital stays, and hospital costs (La Torre et al., 2018). In pediatric critical care settings, many risk factors that patients present with are not modifiable; therefore, the care that is delivered to them needs to be highly reliable. Due to the negative impact CLABSIs have on patients, continuous attention to this topic is crucial. The literature review for this project supports that early identification of high-risk patients does have a positive impact on CLABSI rates, as well as with early identification providers can modify interventions to decrease central line infection rates. The following evidence will support that with early identification of high-risk patients, modifiable behaviors can be implemented including enhancing central line care bundles, utilizing daily rounding techniques, use of chlorhexidine bath wipes, and identifying the right access the first time for the patients will decrease central line infection rates. The research question developed is: In pediatric critical care patients, how does early identification of patients with high-risk factors for central line infections compared with no identification affect the rate of central line infections within three months? The proposed initiative will be a collaborative effort within the children's hospital to improve patient outcomes, decrease length of stay and costs for

the hospital as well as decreasing the rate of central line infection within pediatric critical care patients.

Early Identification of High-Risk Pediatric Patients in Reducing Central Line Infections

Central line-associated bloodstream infections (CLABSIs) are the leading cause of hospital-acquired infections in pediatric hospitals (Martinez et al., 2020). Patients in pediatric critical care present a higher risk for developing CLABSIs due to longer length of line days (typically greater than seven days), multiple surgeries, use of high-risk medication, and more difficult vascular access (Garcia et al., 2019). The purpose of this paper is to show how identifying patients at higher risk for central line infections affects CLABSI rates and how prevention strategies can be utilized to improve patient outcomes.

Rationale for the Project

As previously stated, CLABSIs are a major concern for hospital-acquired infections. Hsu et. al (2020) found that CLABSIs are among the most common healthcare-associated infections, resulting in increased mortality and morbidity, prolonged hospitalization, and higher healthcare costs. Specifically, the pediatric critical care patient population needs to be looked at since this patient population is at higher risk. Patients in pediatric critical care present a risk for developing infections due to surgery, parental nutrition, immunosuppression, and devices such as an endotracheal tube or urinary catheter (Fresán-Ruiz et. al, 2022). Due to this patient population being at higher risk, surveillance is necessary to provide infection prevention measures and implementation plans. According to the Agency of Healthcare Research and Quality (AHRQ) (2017), CLABSIs are the most expensive hospital-acquired condition, averaging $48,108. This project aims to show the importance of early identification of high-risk patients to prevent central line infections. Attention to this topic is necessary to prevent hospital-acquired infections in this already fragile patient population. The research question developed is: In pediatric critical care

patients, how does early identification of patients with high-risk factors for central line infections compared with no identification affect the rate of central line infections within three months?

Literature Synthesis

Central line infections continue to be a crucial hospital-acquired condition in hospital settings. Pediatric critical care patients pose a risk due to complex diagnoses, congenital conditions, and difficult vascular access due to their size compared to adult patients. A thorough literature review was completed utilizing CINAHL and PubMed to search for supporting evidence. To define inclusion criteria, keywords that were used include, “central line infection”, “pediatric”, and “risk factors”. Studies were found in the search that supports the idea that early identification of high-risk patients or risk factors can have an impact on central line infections. With early identification, delivery of care can be modified to reduce CLABSIs in pediatric critical care patients.

Several prevention strategies have been found to decrease the rate of central line infections in high-risk patients, including the implementation of a care bundle. Multiple studies identified pediatric critical care patients that posed a higher risk for developing CLABSIs including patients who undergo a surgical procedure, patients with gastrointestinal conditions, on parenteral therapy, and patients with medical devices such as gastrotomy tubes, foley, or chest tubes (Fresan-Ruiz et al., 2022, Haldar et al., 2022, Ormsby et al., 2018, Vachirapuranon et al., 2022). In the studies reviewed, CLABSI care bundles were implemented for patients that were identified as high risk and results showed a significant decrease in the rate of CLABSIs. Central line prevention care bundles were implemented in units that focused on hand hygiene, sterility practice, and utilizing checklists which then resulted in a decrease in central line infections post-implementation (Fresan-Ruiz et al., 2022, Haldar et al., 2022, Ormsby et al., 2018,

Vachirapuranon et al., 2022). One study found that with the initiation of a CLABSI bundle that emphasized proper hand hygiene, surgical checklists, and team-based practices bloodstream infections went from 8.4% to 3.4% after the implementation of the care bundle on patients that were identified as high-risk (Vachirapuranon et al., 2022). Another study found that adherence to enhanced bundle elements CLABSI rates averaged 1.41 per 1,000 central line days before implementation compared to 0.40 per 1,000 central line days after implementation, and an 85% reduction in CLABSI rates (Ormsby et al., 2018). The literature shows improvement after the implementation of a care bundle or enhanced compliance can have a significant impact on decreasing central line infections in high-risk pediatric patients. Identification of high-risk patients allowed providers to implement practice changes on these patients which led to a decrease in the incidence of central line infections.

Another factor that has been found to impact CLABSIs is daily rounds. Daily rounding on central lines to review the length of dwell time, line necessity, and early line removal is a modifiable behavior that impacts the rates of central line infections (Haldar et al., 2022, Hooshmand et al., 2021, Paioni et al., 2019, Torre et al., 2018). Studies identified immunocompromised pediatric critical care patients as high-risk patients for developing central lines, and daily rounds were then implemented on these patients to conduct a thorough review of line necessity which then led to longer lengths of time between positive central line infections (Dandoy et al., 2015, Haldar et al., 2022, Hooshmand et al., 2021, Torre et al., 2018). Early line removal and dwell time have also been a factor within daily rounds to reduce central line infections. Studies found that focusing on the prompt removal of devices from patients who present with risk factors can be beneficial in reducing infection risk (Fresan-Ruiz et al., 2022, Paioni et al., 2019). Longer dwell times are an independent risk factor for developing central line

infections (Haldar et al., 2022, Hooshmand et al., 2021, Woods-Hill et al., 2019). Haldar et al. (2022) found that the risk of central venous catheter infection increased significantly with increasing dwell time by providing a greater opportunity for exposure to bacteria. The literature supports that daily rounding to provide an in-depth review of line necessity, dwell time and early line removal can have an impact on central line infections. When high-risk patients are identified daily discussions, and advocation for early line removal can decrease the rate of central line infections.

Another nursing intervention that has shown a positive impact on the rates of central line infections is the use of chlorhexidine (CHG) bathing. Studies found that patients who were identified as at risk of developing central line infections and implementing the use of CHG had a significant decrease in the rates of CLABSIs (Dandoy et al., 2015, Martinez et al., 2020, Vachirapuranon et al., 2022). Martinez et al. (2020) found that patients with immunosuppression, the presence of an invasive medical device such as a gastrostomy tube, chest tube, etc., and children less than one year of age were at higher risk for developing central line infections. CHG 4% bathing protocol was implemented in the patients who were identified as high risk, and the incidence rate of central line infection went from 6.14/1000 catheter days to 2.80/1000 catheter days post-implementation (Martinez et al., 2020). The study showed that the addition of the daily CHG bathing targeted toward at-risk patients had significantly reduced central line infections. These studies support the implementation of targeted prevention practices that have an impact on patients who are at high risk compared to no changes in interventions on patients who are not identified as high risk.

Certain patient diagnoses have been identified as high risk for developing a central line infection. These diagnoses and conditions cannot be modified in patients; however, with early

identification of certain diagnoses, changes can be made involving their care to reduce central line infections. The review of the literature supports that patients with underlying gastrointestinal tract disorders or abdominal pathology are at a higher risk of developing CLABSIs possibly due to the frequent need for long-term total parenteral nutrition, bacterial translocation, and bacterial overgrowth (Dathan et al., 2016, Garcia et al., 2018, Martinez et al., 2020, Ormsby et al., 2018, Paioni et al., 2020). When patients are identified as high-risk, modifications can be implemented toward the care of the patient that could impact the incidence of central line infections. Ormsby et al. (2018) and Paioni et al. (2020) found that patients with intestinal failure or gastrointestinal disorders requiring parenteral nutrition were at higher risk of developing CLABSIs and found that after implementation of modifiable factors, there was a reduction in line infections. An 85% reduction in CLABSI rate over twelve months was found after an enhanced CVC bundle was implemented in high-risk patients with intestinal failure (Ormsby et al., 2018). This evidence supports that with early identification of high-risk patients, a reduction in CLABSIs is obtainable. For certain situations, little can be done regarding a patient diagnosis, however, special measures can be taken when identified to improve care and patient outcomes.

In pediatric critical care patients, many unmodifiable risk factors have already been identified including age, diagnosis, or complexity of care. However, with certain risk factors, proper care can be considered in central venous catheter care including insertion, manipulation, and choosing the right access for the right patient. Studies have found that certain insertion sites, types of catheters, and number of manipulations can increase the risk of central line infections (Haldar et al., 2022, Paioni et al., Hooshmand et al., 2021, Paioni et al., 2020). Findings revealed that manipulations or repositioning catheters during insertion created a higher risk of developing central line infections, and the use of ultrasound guidance insertion practices could prevent

unnecessary manipulations (Hooshmand et al., 2021, Paioni et al., 2020). Choosing the right line and location has also been shown to have an impact on incidences of infection rates. Femoral catheterization and tunneled central venous catheters were found to have higher incidences of CLABSIs (Haldar et al., 2022, Paioni et al., 2020). Haldar et al. (2022) found the incidence of central bloodstream infections in the internal jugular was 7.4% compared to the femoral site at 29.6%. Although some risk factors cannot be controlled or modified, providers can choose sites and the type of catheter wisely, as well as evaluate for alternative access regularly to reduce the incidences of central line infections. Certain location sites, types of catheters, and manipulations of a catheter are risk factors for patients to develop central line infections. With this knowledge of identified risk factors, strategies can be taken to reduce CLABSIs including analyzing the choice of site, type of catheter, and proper insertion techniques.

Project Stakeholders

Stakeholders for this project include senior nursing leadership which consists of, the Chief Nursing Officer (CNO), nursing directors and managers, as well as medical directors and providers, and quality specialists. Key players also include bedside nurses, who will have the most direct bedside care with patients. All pediatric critical care patients with a central line will be included in this study. The collaboration between bedside staff and providers will be the foundation of this study, as they will have the highest impact on the care that is provided to patients with a central line.

Implementation Plan

This change project will take place in a large children's hospital in Texas in critical care settings including Pediatric ICU, Neonatal ICU, and Heart Center ICU. The data that will be needed includes CLABSI rates and patient data from the current and previous fiscal year, as well

as a list of all patients with a current central line in pediatric critical care units. Permission from the organization through an IRB will be obtained to receive this information. The associated costs of a CLABSI will also be helpful information, to show the significance of CLABSI prevention to save money on hospital costs. Permission from the CNO, nursing, and medical director of each area will be needed to identify risk factors for patients developing central line infections. Barriers that could be foreseen are identifying patient risk factors in an already high-risk population and finding commonalities between cases, as well as current patients with a central line. To eliminate these barriers, the utilization of quality specialists from each area will be critical to finding common characteristics between cases. The resources needed for this project will be quality specialists from critical care units, data extraction from previous CLABSIs, and a list of patients that have a current central line. To carry out this change project, quality and safety specialists and the hospital's project manager will be assisting in this project to help extract data, and physician and nursing leadership will identify criteria identified as patients that have high-risk factors.

Timetable/Flowchart

To implement this project, there will be multiple phases including pre-data, identifying high-risk patients, any practice changes put into place, data collection, and review of data. An outline will be reviewed here, and the flowchart will be found in Appendix B. The first step of the implementation would be to gather data and conduct a thorough review of all patients that had a positive CLABSI in the last fiscal year, and current fiscal year. Costs associated with CLABSIs will also be collected, which will take about two weeks to collect and review information. In the next week, a meeting will need to be planned with the nursing administration, direct nursing leaders of each unit, medical directors, and quality and safety specialists that are

over each area to discuss the change project and provide evidence of the need for the change project. If approved, a meeting with nursing leadership, quality and safety, and medical directors will be conducted to discuss a plan for identifying what risk factors will be used within critical care settings. Each critical care area has different specialties, so agreeing on risk factors may take some time. A month to identify those patients will be expected. In the following week, the leaders will decide what practice changes will be put into place for patients who are identified as high-risk.

Once practice changes are decided on, nursing leadership will disseminate that information and provide education to their respective units which will take approximately two weeks. Patients who have met the criteria and have been identified as high-risk will have a smiley face sticker placed on their chart and kept at bedside, so they are easily identified. (See Appendix C). Quality specialists of each unit will receive a daily list of all patients with a central line in place. This process is already built within the organization, so no additional education will be needed. The quality specialists will work with unit leadership to identify which patients have met the criteria and will be labeled as high-risk. Data will be recorded and tracked for twelve weeks. After the trial period, data will be reviewed for all patients who were identified as high risk as well as all patients with positive CLABSIs during that timeframe, which will take about two weeks. This entire process should take about five months to complete.

Data Collection Methods

Data will be collected from quality and safety specialists within each critical care area. All patients with a central line will be included during the trial. During the twelve-week trial, a comparison will be made for patients who have been identified as high-risk compared to those who have not met the criteria. Patients who were identified as high-risk and all patients who had

a positive CLABSI during the trial will be reviewed with the nursing leadership and providers. A thorough review of the data will be reviewed to discuss any differences in CLABSI rates post-implementation, as well as feedback on the trial. The initial data collection process will take place for twelve weeks; however, for more accurate results, one year of data collection will provide more insightful information on whether this change had an impact on central line infection rates.

Evaluation

To evaluate the effectiveness of this change project, a meeting after the trial will be recommended to review the data that was collected with all team members, including the quality improvement team, nursing, and medical leaders. Information regarding all patients that had a central line will be reviewed as well as any CLABSIs that developed during the trial period. Indicators that will be seen if this project is successful include a reduction in the rate of central line infections, as well as nurses and providers finding identifying high-risk patients a useful tool to enhance practices. Another method to determine if this project is successful or not will be a post-implementation survey to determine if identification had any influence on the care that was provided by the bedside nurse (Appendix D). Ultimately, the measure would be considered successful as it would save the hospital thousands of dollars.

Cost/Benefit Analysis

Central line infections are a major hospital-acquired condition within a hospital setting. Hsu et. al (2020) found that CLABSIs are among the most common healthcare-associated infections, resulting in increased mortality and morbidity, prolonged hospitalization, and higher healthcare costs. According to the Agency of Healthcare Research and Quality (AHRQ) (2017), CLABSIs are the most expensive hospital-acquired condition, averaging $48,108. For this

benchmark project, the added costs for implementation will be minimal. Added costs include education for nurses and providers about the new process. Education to the providers will be no added costs as providers are employed by another organization. Nursing leaders can educate nurses in a staff meeting, which typically lasts an hour. Therefore, the only predicted cost will be one hour of education pay for nurses. It will also not be necessary to train the quality improvement team on data extraction, as this process is already in place within the organization and central lines are reviewed daily by this team. Since there are minimal added costs to this benchmark project, the organization could be saving thousands of dollars even if there is a reduction in one hospital CLABSI in the fiscal year. Therefore, the organization will benefit greatly due to the reduction of costs associated with central line infections.

Discussion of Results

This is a benchmark project that will be proposed at my organization, and an approval process from leadership will be expected. This project was not able to be implemented due to leadership structure changes. However, now that executive leadership changes have been in place, it is likely this change project can be trialed in the future. Once implemented it will be expected to learn if this change project has an impact on infection rates. Challenges that will be foreseen include if CLABSI rates had an impact from early identification, as well as if the ICUs can agree on identifying which types of patients meet the criteria. To help prevent barriers, effective leadership strategies include open communication between all parties, outlying expectations, and goals so that all team members understand the initiative and what is the overall goal of this project. If positive benefits were found after this project, sustainability would be an important factor to consider. Check-ins between units will be encouraged, and continued feedback from staff and providers will help sustain this change.

Conclusions/Recommendations

Central line infections present a serious healthcare concern for pediatric critical patients who need attention. The recommendation for this project is that pediatric critical care settings with high-risk factors for central line infections are identified, and a subset population will meet this criterion. Early identification of patients who are at higher risk can lead to earlier intervention and development of prevention strategies by care teams to decrease rates of central line infection. A decrease in the rate of central line infections can lead to an improvement in patient outcomes and a decrease in hospital costs.

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Appendix A

Evidence Table

Citation: (i.e., author(s), date of publication, & title)	Conceptual Framework	Design/ Method	Sample/ Setting	Major Variables Studied and Their Definitions	Measurement of Major Variables	Data Analysis	Study Findings	Strength of the Evidence (i.e., level of evidence + quality [study strengths and weaknesses])
1.Dahan et al., 2016. CLABSI risk factors in the NICU: potential for prevention: a picnic study	N/A	R CCS To determine risk factor for CLABSI	4 yr study 24 bed NICU & 69 bed NICU. 120 cases and 293 controls.	IV: IAP DV: CLABSI rate	LR	UA	IV-DV: 95% CI, 2.50-14.06	Strengths: identified multiple RF of CLABSI Limitations: retrospective unable to identify causation Risk of harm: low risk Feasibility: feasible Level of evidence: III Strength level: good

2.Dandoy et al., 2016. Rapid cycle development of a multifactorial intervention achieved sustained reductions in central line-associated bloodstream infections in haematol	N/A	TSA Advanced bundle formed to see effect of CLABSI on HR* pts	36 BMT unit & 32 hem/onc unit. 1 yr study Pts w/ CVC	IV= CLABSI bundle DV= CLABSI rate	CLABSI per 1000 inpatient CVC days	WRST T chart U chart	Pre implementation CLABSI rate: 2.03/1000 line days Post implantation CLABSI rate: 0.395/1000 line days	Strengths: study was collaborative, and resources available to implement new processes. Limitations: difficulty associating 1 intervention w/ improvement; multiple interventions implemented at once. Risk: low risk Feasibility: multiple resources utilized in this study can make difficult for implementation Level of evidence: V Strength level: fair

ogy oncology units at children's hospital: a time series analysis								
3. Fresan-Ruiz et al., 2022, Device exposure and patient risk factors' impact on the healthcare-associated infection	N/A	MPS To test if HAI ZB influence HAI rates	26 bd PICU 3 mo period from 2014-2019 11,260 pediatric pts	IV: ZB IV1: IF DV: HAI rate	LR	FT MW-UT	Implementation of HAI ZB < HAI rates IF exposure > HAI	Strengths: large sample volume, study focuses on IF on pediatric patients Risks: no harm identified Feasibility: implementing bundle would be cost effective for hospital Level of evidence: II Strength level: good

rates in picus								
4. Garcia et al. (2019). Risk factors for central line-associate	N/A	CCS Identify risk factors in critically ill neonats to	SS- 148 (74 cases= CLABSI; and 74 controls= no CLSABI)	IV: surgical intervention DV: CLABSI rate	CLABSI Dx	FT MWUT CI	IV-DV: (RR=1.99, 95% CI 1..0-3.7).	Strengths: multiple factors studied Limitations: population of study- multiple underlying diseases, birth defects Risk of harm: none noted

d bloodstream infection in critically ill neonates		develop CLASIs	24 unit bed					Feasibility of use of the evidence in your practice: : can be time consuming identifying risk factors Level of evidence: IV Strength of the evidence: fair
5. Haldar et al. (2021). Central Venous Catheter-Related	N/A	RS Determine risk factors for occurrence of central venous	260 children 182 pts no CVC infection	IV 1: age IV 2: CL location DV: CRBSI rate	Age DT Rate of CRBSI	K-W H test	IV 1-DV: p=0.009 IV2-DV; p<-.001	Strengths: independent risk factors identified with higher rate of CRBSI Limitations: RS- limited ability to demonstrate causation; possible observation bias; data sometimes inconsistent in MAR

Infectious Complications in Pediatric Surgical Patients: A Single-Center Experience		catheter colonization and CRBSI	51 pts with CVC colonization 2 pts with CRBSI					Risk of harm: no risk observed Feasibility of use of the evidence in your practice: feasible, identifying younger age, location of CVC can reveal higher risk of developing CRBSI Level of evidence: IV Strength of the evidence: fair
6. Hoosmand et al. (2022).	N/A	CCS Use of data analytic	5779 samples from 3947 pts.	IV: number of surgeries	Risk score Datasets	CPHM BS	IV-DV= (P=.003)	Strengths: identify patients with an escalated risk used CLABSI HR; large sample size.

Data Analytics for Diagnosis and Prediction of Central Line-Associated Bloodstream Infection in Critical Care units		s in the identifcation of CLABSI risk factors and patient risk scores for CLABSI	96 pts + CLABSI Setting: 18 mo period	DV: risk factors for CLABSI	Logistic regression			Limitations: one hospital facility, retrospective data with limited CLABSI cases; missing data sets Risk of harm: no risk observed Feasibility of use of the evidence in your practice: developing data analytics can be time consuming, using resources and money, feasibility will be difficult. Level of evidence: IV Strength of the evidence: fair

7. Martinez et al (2020) Central-line-associated bloodstream infections in surgical paediatric intensive care unit: Risk	N/A	MS Identify EFs & impact of CHG4% on CLABSI rates	34 bed PICU in PS 775 pts < 18 yo w/ CVC > 1 day	IV: EF DV: CLABSI rate	CLABSI rate Logistic regression	UA FT	IV-DV: P= <0.0007	Strengths: study correlated risk factors with intervention to reduce CLABSI Limitations: other EFs could have been identified Risk of harm: none noted feasibility: identification of EFs is feasible and use of CHG4% is feasible on high risk pts Level of evidence: IV strength of evidence: fair

factors and prevention with chlorhexidine bathing								
8. Ormsby et al., 2018. Enhanced central venous catheter bundle for pediatric parental-dependent intestinal failure	N/A	QI Enhanced CVC maintenance bundle on pts with IF* to monitor effect on CLABSI rate	2 surgical inpt units of pediatric pts w/ IF* 4 yr study 2,292 encounters	IV= MB DV= clabsi rate	Linear model	WRM test PT	IV-DV: p=0.03, reduce CLABSI rate by 85%	Strengths: study identified modifiable measures to reduce CLABSI rate on high-risk pts Limitations: self-report audit tool, did not have standard CVC bundle compliance data before implementation Risk of harm: low risk of harm for implementation of bundle Feasibility: parts of bundle are feasible, other require more coordination and collaboration

								Level of evidence: V Strength of evidence: fair
9. Paioni et al (2020). Risk factors for central line-associated bloodstream infections in children with tunneled central	N/A	O Examine the epidemiology of CLABSI in tunneled catheters and analyze risk factors	Pts with TC < 18 yo 316 TC	IV1: age-2-5 yo IV2: GI disease DV: CLABSI rate	LT HR MW FT	M SD	IV1-DV: p=.001 IV2-DV: P<.001	Strengths: study focused on tunneled CVC infection in pediatric population Limitations: size of study affecting significance of significant statistical analyses; single center study Risk of harm: none noted. Feasibility of use of the evidence in your practice: identifying risk factors is feasible, choosing the right CL can be difficult due to age. Level of evidence: IV

venous catheters								Strength of the evidence: fair
10. Torre et al., 2018. Risk factors for vascular catheter-related bloodstream infections in pediatric inensive care units	N/A	MPS Identify CLABSI risk factors in PICU and etiology of CLABSIs	3 hospitals Pts 1mo-18 yo with CVC 170 pts w/ CVC	IV1: line duration IV2: more than 1 CVC DV: CLABSI rate	MA	LR	IV1-DV= p=0.019 IV2-DV= p= 0.048	Strengths: results taken over a year- high reliability Limitations: possible bias in study Risk of harm: low risk Feasibility: resources for CLABSI surveillance will cost hospitals money Level of evidence: IV Strength of evidence: fair

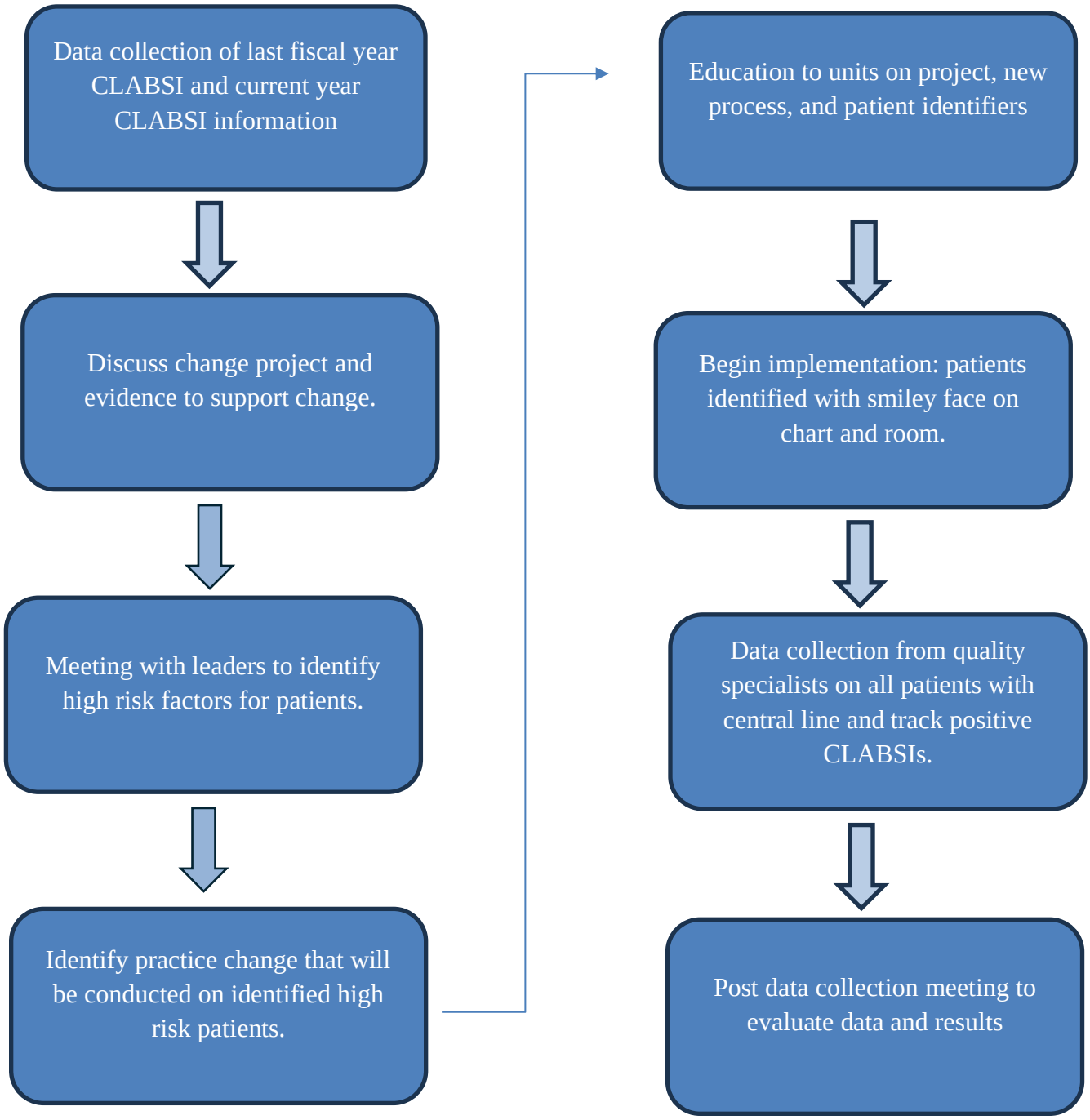
11. Vachirapuranon et al. (2022). Major infections following pediatric cardiac surgery pre- and post-CLABSI bundle implementation	N/A	RS To identify risk factors for major infections, and incidence of infection after implementation of CLABSI bundle	Children < 18 yo undergoing CCS* 548 pts 286 n- Pre-CLABSI bundle 262n – post-CLABSI bundle	IV1: < 6 mo IV2: CL usage > 4 days IV3: CLABI bundle DV: rate of infection	CLABSI rate	MV LR RV	IV1- DV: p=.04 IV2-DV: p=.04 IV3-DV: p=.01	Strengths: Identified independent risk factors for developing infections. Limitations: subjects not randomized, retrospective study, possibility of bias. Risk of harm: none found. Feasibility of use of the evidence in your practice: feasible, implementing CLABI bundle, and identifying risk factors is feasible. Level of evidence: III Strength of the evidence: good

12. Woods-Hill et al., 2020. Novel risk factors for central-line associated bloodstream infections in critically ill children	N/A	RMCS Examine RF for CLABSI to identify new infxn prevention strategies.	60 bed PICU over 5 year review 72 CLABSI matched to 281 controls	IV1: line access IV2: CVL duration> 7 days IV3: acute behavioral health pt IV4: H/I disease DV: CLABSI occurrence	T test X^2 Test	LR	IV1-DV: p= 0.01 IV2-DV: p=0.01 IV3-DV: p=0.02 IV4-DV: p=0.05	Strengths: study targets modifiable risk factors Limitations: single study may limit generalizability, unable to accurate data on blood transfusion frequency Risk of harm: low risk identified Feasibility: can be challenging to capture all risk factors Level of evidence: III Strength of evidence: good

Legend: BS= boot strapping; BSI= Bloodstream infection; CCS= case control study; CCS*= congenital cardiac surgery; CHG 4%= chlorhexidine 4%; CI= confidence interval; CL= central line; CLABSIs=central line associated bloodstream infections; CPHM= cox proportional hazards model; CRBSI= Catheter related bloodstream infection; CV=central venous; CVC= central venous catheter; CVL=Central venous line; DO=direct observation; EF= exposition factorDrg= dressing; DV= dependent variable; Dx= diagnosis; DT= dwell time; EFs= exposition factors; FT= fisher test; HAIs= hospital acquired infections; HR= Hazards rate; HR*= high risk; HBM=health belieft model; H/I: hematologic/ immunologic; IMD=Invasive medical device; IF= intrinsic factor; IF*= intestinal failure; KMA= Kaplan-Meier analysis; K-W H test= Kruskal-wallis H test; LT= life tables; LR= logistic regression; MS= monocentric study; MPS= multicenter prospective studyMWUT= Mann-Whitney U Test; M=Mean; MW-UT= mann-whitney U test; MA= multivariate analysis; MV LR= multivariate analyses with logistic regression; Nicu= neonatal intensive care unit; O= observational study; OHS= open heart surgery; OR= odds ratio; Pedi=pediatric; Picu= Pediatric intensive care unit; PT=Pearson test; PICU= pediatric intensive care unit; PS= pediatric surgery; Pts=patients; QI= quality improvement; R= retrospective; RS= retrospective study; RMCS= retrospective matched case-control study; RV= risk value; -SA= staphylococcus aureus; SD= standard deviation; SS= sample size; SPICU= Surgical pediatric intensive care unit; TLD= total line day; TC= tunneled catheter; TSA= time series analysis; UA= univariate analysis; WRS= wilcoxin rank-sum; WRST= Wilcoxon rank sum test; YO=years old; ZB= zero bundle

Appendix B

Flow Chart



Appendix C

Smiley Risk-Factor CLABSI Sign

Appendix D

Post-implementation questionnaire

1. Were patients who met criteria as “high-risk” easily identified with the smiley picture?
    - Not at all
    - Sometimes
    - Most of the time
    - Always
2. When a patient was identified early on if they were high-risk for developing CLABSIs were you more mindful in your central line care?
    - Not at all
    - Sometimes
    - Most of the time
    - Always
3. Was it useful to have patients identified as high-risk?
    - Not at all
    - Sometimes
    - Most of the time
    - Always
4. Do you think this project is beneficial to the unit?
    - Not at all
    - Some
    - Most of the time
    - Always