Implementing the Early Onset Sepsis Calculator in a Neonatal Intensive Care Unit

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Abstract

Problem& Purpose: While intrapartum antibiotics have decreased the incidence of early onset sepsis (EOS) in infants > 34 weeks, there has not been an equal decrease in how often antibiotics are administered to treat suspected EOS. The use of an EOS calculator to help guide management has been shown to safely decrease the use of antibiotics. In this 52-bed neonatal intensive care unit (NICU), providers did not use an EOS calculator and the interpretation of the recommendations across providers greatly varied. There is no standard algorithm to stratify at risk infants for EOS in order to differentiate infants requiring antibiotics from those who can be safely observed. The purpose of this quality improvement project is to implement and evaluate the effectiveness of the early onset sepsis calculator in a level IV NICU for infants > 34 weeks gestational age on reducing antibiotics usage. **Methods:** Over a 15-week period in the fall of 2021, a multidisciplinary team implemented the EOS calculator to be utilized in the electronic health record (EHR). Data collection occurred through chart review of any infant > 34 weeks gestation that was admitted to the NICU. Data that was collected included gestational age, calculator use and recommendations, antibiotic administration, was a CBC and a blood culture obtained, and was there adherence to the calculator recommendations. **Results:** Post implementation 10% (n=110) of infants admitted to the NICU that were eligible for use of the EOS calculator had documentation of use within the EHR. The goal remains that 100% of infants > 34 weeks will have recommendations documented on the EOS calculator. Approximately, 50% of infants received antibiotics on admission. **Conclusions:** The education disseminated on the location and use of the EOS calculator has led more providers to utilize the calculator than prior to the implementation. The use of the EOS calculator has created better communication amongst providers about how to manage infants at risk for EOS.

Implementing the Early Onset Sepsis Calculator in a Neonatal Intensive Care Unit

Management of early onset sepsis (EOS) is a common diagnosis for providers in the neonatal intensive care unit (NICU) (Kuzniewicz, et al., 2016). Early onset sepsis is defined as blood or cerebral spinal fluid culture growing bacteria within 72 hours of birth. EOS is most commonly an infection of ascending colonization with infection involving the fetus/infant (Puopolo, et al., 2013). Early onset sepsis has decreased from three to four per 1,000 births to 0.5 cases per 1,000 births with the implementation of intrapartum antibiotics. However, implementing the current CDC guidelines for infants considered at risk for EOS results in a larger percentage of infants receiving antibiotics then may be needed (Puopolo, et al., 2013). In 2016, an algorithm-based calculator was created to help guide the management of infants greater than 34 weeks. Maternal and infant information entered into the EOS calculator provides a risk per 1000 live births based on three different clinical examination possibilities. Since then, research has shown that when utilizing an EOS calculator to help guide management and antibiotic usage in at risk infants, the number of infants who receive unnecessary antibiotics has been reduced. Antibiotic administration is not a benign event for infants. Antibiotics have been linked to an increased incidence of necrotizing enterocolitis, late onset sepsis, and may result in separation of mom from baby, thus negatively affecting breastfeeding initiation (Kuzniewicz, et al., 2016). Early administration of antibiotics has also been linked to an increased risk of asthma, obesity, allergic disorders and diabetes later in life (Kuzniewicz, et al., 2016). One downside to the use of this EOS calculator is that it is only studied in infants > 34 weeks, leaving other preterm infants without this guidance available.

Management of early onset sepsis is common in a level IV academic NICU in the mid-Atlantic region. Approximately 10 infants > 34 weeks are admitted weekly, with 7 receiving

antibiotics to treat suspected or proven EOS. Prior to implementation there was no standard algorithm to stratify infants at risk for early onset sepsis who need antibiotic therapy from those who could be safely observed (Appendix A). The lack of a standard process resulted in inconsistent practice patterns which unnecessarily exposed infants to antibiotics. The use of the early onset sepsis calculator would guide and standardize management of infants with suspected early onset sepsis in a level IV NICU. The purpose of this quality improvement project was to implement and evaluate the effectiveness of the early onset sepsis calculator in a level IV NICU for infants > 34 weeks gestational age on reducing antibiotic usage. The goal was that at the end of implementation, all infants >34 weeks gestational age would have the EOS calculator utilized and documented on admission to guide their EOS management and to lead to a decrease in antibiotic administration.

Literature Review

To provide evidence for the implementation of the EOS calculator, a literature search was completed. Articles included compared the use of the EOS calculator with conventional management options in infants as young as 34-36 weeks gestational. Well organized studies in neonatal academic locations, similar to this project site, with large sample sizes were utilized as evidence for this project. The evidence was then narrowed down to four articles that focused more similarly to the population and institution being studied. Two articles reviewed were quais-experimental trials without randomization, one article was a cohort study and finally a systematic review/meta-analysis that included thirteen studies and over 170,000 infants. In order to grade the literature in more detail Melnyk and Fineout-Overholt was utilized (2005). The literature and grading criteria are discussed in greater individual detail in Table 1.

The four studies reviewed concluded that implementation of the EOS calculator reduced the rate of antibiotics administered and the number of sepsis screens but avoided missing septic infants. All of the studies had similar inclusion criteria, infants ranging from 35-36 weeks and older who were considered at risk for EOS. The level of the evidence is graded utilizing the Newhouse grading criteria and further detailed in Table 2.

The first study reviewed was a systematic review/meta-analysis. In this systematic review of 13 studies, Atchen et al. (2019) evaluated the rate of antibiotic usage comparing implementation of an EOS calculator with standard therapy. Findings indicated that a 56% reduction in antibiotic usage was possible when the EOS calculator was implemented compared with standard therapy. Within the thirteen articles over 170,000 infants were included in the analysis. The analysis showed that across all the articles, there was a lower relative risk (range of 3-60%) of antibiotic use favoring the EOS calculator. When studies specifically addressed mothers with diagnosed chorioamnionitis there was a stronger relative risk reduction when following the EOS calculator recommendations (Atchen et al., 2019). While the systematic review included no randomized control trials the results across studies were clear and consistent.

Caroloa et al. (2017) conducted a cohort study with data collected through a chart review that evaluated infants previously born to mothers with chorioamnionitis and applied the calculator to their data. This allowed the researchers to compare the same exact group of infants who were treated with standard care versus if the calculator had been utilized. The study showed that two-thirds fewer infants would have received antibiotics while not missing any who did have a positive blood culture for EOS.

Similarly, Dhudasia et al. (2018) and Atchen et al. (2018) both utilized a cohort study design. Like Caroloa, et al (2017), these studies reviewed historical patients to view antibiotic

usage, and then compared this to data collected following the implementation of the EOS calculator. These studies also showed that the EOS calculator had fewer infants receiving antibiotics. Dhudasia et al. (2018) showed a 42% decrease in antibiotic use when compared with standard CDC recommendations. Across all studies included as evidence for this quality improvement project, implementation of the EOS calculator showed a decrease in antibiotic usage.

Theoretical Framework

R. W. Roger created the Protection Motivation Theory (PMT) which aims at helping describe behavioral changes as they relate to threats and threat appraisals (Figure 1.) (Floyd, et al., 2000). There are two sources of information that influence a person's assessment of a situation. These sources are environmental and intrapersonal. This information then influences whether a person views a situation through the lens of fear or coping. The fear lens usually produces maladaptive behaviors, while the coping lens leads to more adaptive responses. When applying this theory to the quality improvement project at hand, the situation being assessed was cases of early onset sepsis. A provider would intake the information about the situation and assess it looking at environmental and intrapersonal information available to them. Environmental information included information about maternal risk factors for neonatal sepsis as well as the clinical presentation of the infant. Intrapersonal information that may be influencing a provider's decisions are previous cases of EOS they have treated and their outcomes. The situation was then viewed through either the lens of fear, being a missed case of early onset sepsis, or coping, how can the provider adequately treat those who need it while also not overtreating. By addressing the fear of missed cases of EOS with the implementation of the early onset sepsis calculator, a provider may choose to make a more adaptive decision.

Helfrich et al., (2007) identified an implementation framework which helps to guide healthcare related innovations (Figure 2.). The framework focuses on a limited number of variables that can be taken into consideration and addressed, like manager support, innovation champions and the environmental readiness for change. This framework uses these assessed variables to make sure that an innovation change aligns with the organization's values (Helfrich et al., 2007). Helfrich's implementation framework was used to guide the implementation of this quality improvement (QI) project. Project planning included obtaining management commitment for the practice change and implementing the sepsis calculator. Management support already existed for the EOS calculator since it is already utilized on other units in the hospital. This ties directly into the financial resources factor. The early onset sepsis calculator was previously built into the electronic health record, so there was no financial barrier. As there was no management or financial barrier to address, the implementation could move forward. In terms of the implementation climate at this organization, the hospital at large was working to reduce antibiotic usage, which is supported by the use of the EOS calculator. Unit change champions worked to support staff training on signs and symptoms of sepsis to help support the implementation of this project. Implementation effectiveness was assessed weekly through collection and analysis of data metrics.

Methods

This QI project implemented the early onset sepsis calculator on a 52-bed NICU in an urban academic institution. The utilization of the EOS calculator was aimed at infants admitted to the NICU greater than 34 weeks gestational age. The calculator has been studied and validated on infants greater than 34 weeks with insufficient data to support its use on infants less than 34

weeks gestation (Kuzniewicz, et al., 2016). This vulnerable population was excluded from participation in this QI project.

The EOS calculator is a risk prediction model that neonatal care providers use when determining an infant's risk for EOS. The calculator utilizes maternal risk factors and the infant's clinical appearance to help determine the management plan. The EOS calculator is used to guide the management of infants at risk for early onset sepsis with the goal of judicious antibiotic prescribing but not missing infants with sepsis. A decision-making algorithm was then created so providers could utilize the recommendations from the EOS calculator. The information technology (IT) department at the project site was contacted to facilitate implementation of the EOS calculator and algorithm. After the initial meeting, it was discovered that the EOS calculator was embedded into the electronic health record (EHR) and available for use by providers in the NICU at the time of implementation.

Utilizing the decision-making algorithm, the provider must determine if the infant is considered well appearing, equivocal or clinically ill and determines a management strategy based on the recommendation. The differentiation between these well-appearing and clinical illness is further explained in appendix B. The recommendations for treatment (provided by the calculator) per 1000 live births is further differentiated (appendix C). These recommendations are discussed by the interdisciplinary team to determine management of the infant.

To facilitate implementation of the calculator, education was developed for providers and bedside nurses to improve knowledge on the EOS calculator. The education was created by the project lead and was reviewed by an interdisciplinary team for feedback. There were 25 advanced practice providers and 120 bedside nurses who were active care providers on the unit that were included in the education roll-out. Education to staff was provided through an online

education system which included a post education quiz. A binder was placed at the front desk that included the presentations in hard copy as well as the quiz with answer results for staff reference. Due to a delay in the roll out of the online education, additional in-person, small group- education was conducted by the project lead.

Strategies used to improve adherence included candy as an incentive. Change champions were also educated prior to implementation of the project and were there to be references for staff if they had questions. The project lead and change champions reminded staff during admissions to utilize the EOS calculator and decision-making algorithm whenever possible to guide their management decisions. The education supplied to the nurses educated them on what and where the EOS calculator is as well as signs and symptoms of sepsis. This education was created to help combat the possible balancing measure of missing a case of sepsis. The education provided to the advanced practice team also explained the location of the EOS calculator and, provided more detail on how to utilize and interpret the results of the calculator through a decision-making algorithm supplied to them.

Data collected for this QI project included gestational age of the infant, calculator utilization in the EHR, antibiotic initiation, sepsis evaluation, and EOS calculator- risk determination. The main goal of this QI project was to see a decrease in antibiotic usage in infants admitted to the NICU greater than 34 weeks gestation.

For data collection, protected health information was coded through a patient code book that was kept separate from the rest of the data. Each patient was provided a unique identifier in order to keep anonymity. Weekly, the QI project lead collected and entered this de-identified data on a password protected data management Excel sheet (Appendix D). This data collection was completed in a private room in the NICU. All staff education completion was reported to the

project lead as a percentage obtained through the online education system, thus maintaining anonymity of the staff participation. When provided education, other staff members would sign off that they had completed the training on a sheet kept in a locked cabinet in the NICU. Each staff member was also provided a unique code identifier. Data was entered into run charts and was analyzed for run, trends and shifts in the data.

Results

Approximately 90% of bedside nurses completed the education provided to them for the early onset sepsis calculator. Nearly, 77% of advanced practice providers completed the education provided to them as well. Through informal conversations throughout implementation there was an agreement that the calculator was useful, but this did not seem to translate to the documentation.

Conversations with staff throughout implementation noted that despite education, the location and how to functionally use the calculator within the EHR, there was difficulty and confusion. Providers did not find the location to be obvious when doing admission documentation. There was also a missed step of refreshing the flowsheet once information was entered that pulled through the recommendations. Once staff was shown this in person improved adherence. To address this, one on one sessions were held to help increase staffs comfort with the calculator. Staff also said that there was continued confusion on how to interpret recommendations from the calculator. A resource card was provided half way through implementation to help staff (Appendix B and C). The data collected after this implementation of a resource card does not suggest that this further improved documentation of the EOS calculator.

Prior to implementation of this quality improvement project, zero infants had documentation of the EOS calculator within the EHR. After implementation, of the infants eligible for use of the calculator, 10% (n=10) over the 15-week period had documentation. That is a weekly average of 9% (ranging from 0-42% each week) of infants who had documentation within the EHR of the EOS calculator (Figure 3). For sepsis screens on admission, prior to implementation, sepsis screens were completed on anywhere from 70-80% of infants on a weekly basis. The average after implementation was 65% (ranging from 0-100% each week) of infants admitted in this age range. Towards the end of implementation as staff became more aware of and comfortable with the implementation of the calculator, use increased and the sepsis screens steadily went down. By the last week of implementation, the number of infants who received a sepsis screen on admission was down to 36% (Figure 4). Prior to implementation 40-60% of infants received antibiotics on admission. After implementation, antibiotics prescribed on admission averaged 49% for the implementation range (Figure 5). As to why there was a downtrend in the sepsis screens and not the antibiotic usage there may be a few reasons. Infants admitted to the NICU may have had sepsis screens completed at outside facilities that were not documented in the results in the EHR. There are also infants admitted who are placed on prophylactic antibiotics (like an infant with gastroschisis) that did not receive a sepsis screen done prior.

Discussion

Overall, the documentation of the early onset sepsis increased very marginally from prior to implementation from zero infants to an average of 9% of infants. The data collected looked at all infants greater than 34 weeks gestation and if there was documentation of the calculator usage. If providers utilized the calculator which is available on the internet, and none within the

EHR, then there would be no way to track this usage. The small increase in documentation is likely related to the education provided to staff members.

While staff expressed appreciation of the online education, possibly having in-person education sessions where staff could practice finding and using the EOS calculator would have been more beneficial. While change champions were identified to help with the roll out of education, further utilization of them could be useful for these in person education sessions. Prior to this quality improvement project, zero infants had documentation within the EHR on their EOS risk. While there was no consistent trend upwards, there was an improvement from baseline.

The implementation of the EOS calculator showed a decrease in sepsis screens conducted on admission. Sepsis screen management is an aspect of the EOS calculator that continues to be studied. Kuzniewicz, et al. (2016), recommended that sepsis screens should be individualized and based on clinical findings as well as objective data.

Despite implementation of the EOS calculator into the EHR and the roll out of the decision-making algorithm, antibiotic administration did not change during the implementation phase. While this did not align with the goals of this project or literature reviewed prior, there were possible reasons that explain this disparity. Infants of this age, admitted to the NICU, may be more likely to be deemed “equivocal” or “clinical illness” then an infant admitted to a full-term nursery. If a full-term infant is admitted to the NICU, they are more likely to have needed resuscitation, require FI02 or be hemodynamically unstable, thus likely requiring a sepsis screen and antibiotic administration. Infants admitted to the full-term nursery on the other hand usually do not require interventions based on recommendations from the EOS calculator. This can

explain why the NICU may not see the same decrease in antibiotic usage as in the literature for full-term nursery infants.

During the implementation time period, there several factors that may have played into the outcomes described. While this project was implemented, many other quality improvement projects were also being implemented at the same time. This did not allow for staff to give their full attention to just one project. A large staff turnover was also happening, resulting in missed educational opportunities within the unit. As previously stated, there was staff confusion on the EHR documentation which likely played into the lack of significant results collected.

Conclusion

The use of the EOS calculator within the EHR is beneficial to infants greater than 34 weeks gestation in reducing sepsis screens and antibiotic usage. While there was not a documented decrease in antibiotic usage, there was a decrease in sepsis screens. This likely means that there is an increased conversation occurring surrounding EOS management of at-risk infants. With continued education on how to interpret the recommendations of the calculator, management of these infants at risk for EOS can continue to be consistent across providers.

In order to sustain this quality improvement project, there needs to be continued buy-in from staff members. Utilizing groups on the unit who are working on antibiotic stewardship and EOS education will be useful moving forward. These groups have already been updated on the education provided to staff and are ready to continue data collection. Further sustainability efforts may include requiring the input of the EOS recommendations into an admission note or an initial daily progress note. Another sustainability measure would be to create a best practice alert for all admissions > 34 weeks gestation when antibiotics are ordered. This would help

remind providers to utilize the EOS calculator to guide their management of possible EOS. This would be streamlined with the utilization of a dot phrase that all providers would use. This would allow staff to identify the recommendations with the physical exam all in one place.

In general, the use of the EOS calculator within the EHR is beneficial for staff and patients alike. It helps to increase interdisciplinary conversation surrounding EOS which leads to decrease in sepsis screens and better conversation around antibiotic usage. Further steps are required to help sustain this quality improvement project as noted above. This quality improvement project did help to bring attention to the use of the calculator and improve conversation surrounding EOS management.

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Table 1

Evidence Review Table

Citation: Dhudasia, M., Mukhopadhyay, S., & Puopolo, K. (2018). Implementation of the sepsis risk calculator at an academic birth hospital. *Hospital Pediatrics*, 8(5), 243-250. http://doi.org/10.1542/hpeds.2017-0180					Level (Melnyk): III
Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results
"Our object in this study was to describe the implementation of the SRC [sepsis risk calculator] in obstetric and newborn care practice and quantify the proportion of infants born at ≥ 36 weeks' gestation who were administered empirical antibiotics and/or subjected to laboratory testing for risk of EOS before and after the use of the SRC-based approach"	Retrospective and prospective	**Sampling Technique:** Convenience **# Eligible:** 11,782; All infants ≥ 36 weeks gestation eligible for care in the newborn nursery; anyone younger is automatically admitted to the NICU **# Accepted:** 11,782 **# Control (pre):** 5,692; all infants ≥ 36 weeks gestation looked at retrospectively; 22 infants were missing data **# Intervention (post):** 6,090; all	**Control:** Pre-implementation, neonatal risk assessment was done based on CDC GBS prevention guidelines as well as recommendations by the AAP. **Intervention:** At delivery, nurses calculate the infant's sepsis risk utilizing the sepsis calculator. Based on the results different steps were followed per an algorithm posted in labor and delivery.	**DV:** Early on set sepsis (EOS) is defined as "blood or cerebrospinal fluid cultures with positive results for pathogenic bacteria or fungi." Empirical antibiotic use was defined as "any antibiotic use administered at ≤ 72 hours of age that were initiated before culture results were known. EOS evaluation was defined as "any combination of CBC, CRP, and blood culture performed at ≤ 72 hours of age."	**Statistical Procedures(s) and Results:** A Chi-square test was run. Non statistical difference was notes between birth gestation and delivery mode, nor among infants admitted to the NICU during the 2 periods. Antibiotic use was reduced during the post SRC implementation from 6.3% to 3.7 % (P<.001) with a relative risk of antibiotic exposure at 0.58. This is a 42% reduction in antibiotic initiation

		infants ≥ 36 weeks during implementation period from March 2014-May 2015 and July 2015-October 2015. 2 infants post implementation were missing data **Group Homogeneity:** Some statistically significant difference was notes between groups; however only minor differences were noted in birth gestation and delivery mode. There was not statistically significant difference of infants admitted to the NICU between the two groups.	**Intervention fidelity** (describe the protocol): Multidisciplinary team created sepsis risk calculator policy. Labor and delivery staff were educated and the EMR was updated to provide a link to the calculator. Labor and delivery nurses were instructed to 1) calculates sepsis risk at birth 2) record value in the EMR 3) contact NICU team to evaluate and sepsis risk ≥ 0.7 per 1,000 live births in accordance with the calculator's definition of clinical status. All subsequent assessments of clinical status and antibiotic decisions were made by the NICU team. All	**Measure:** Measure of the dependent variables were measured through EMR data analysis. This information was gathered by the labor and delivery nurses. Further assessment of infant was done by NICU clinicians when indicated. Compliance to utilization of the calculator was measured with EMR reports. No instrument (beyond the calculator itself) was used for measures. No inter-rater reliability documented.	in the post SRC period. Laboratory test use declined 82% in the post SRC period with 26.9% pre and 4.9% post implementation, relative risk of 0.18.

			information from the EMR was generated into a report daily for quality- assurance.		
Citation: Atchen, N., Dorigo-Zetsma, W., van der Linden, P., van Barkel, M., & Plotz, F. (2018). Sepsis calculator implementation reduces empiric antibiotics for suspected early-onset sepsis. *European Journal of Pediatrics*, 177, 741-746. http://doi.org/10.1007/s00431-018-3113-2					Level: III
Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results
"Therefore, the aim of this study was to prospectively evaluate the feasibility and impact of using the sepsis calculator to help guide antibiotic use in children born ≥ 35 weeks of gestational age at risk for EOS in a Dutch teaching hospital. We hypothesized that antibiotic use can be significantly reduced compared to historical birth cohort."	Retrospective and stratified prospective	**Sampling Technique:** Convenience **# Eligible:** 2,076 pre, 1,877 post; all born ≥ 35 weeks **# Accepted:** 100 Retrospectively, 208 prospectively included based on EOS risk factors **# Control:** 100, born ≥35 weeks gestation treated empirically for suspected EOS; retrospectively establishing estimated EOS risk using the calculator	**Control:** Prior to implementation, infants ≥ 35 weeks were evaluated within 72 hours based on either maternal EOS risk or infant clinical presentation. Decisions based on existing protocols as it relates to EOS. **Intervention:** Utilization of sepsis calculator to guide clinical management decisions. **Intervention fidelity:**	**DV:** Maternal EOS risk or EOS clinical presentation within 72 hours. Maternal EOS risk includes: maternal fever > 38 during labor, + GBS status, ROM >24 hour, presumed chorioamnionitis with or without adequate intrapartum antibiotics. Clinical EOS is defined as "potential EOS case by attending physician after clinical examination."	**Statistical Procedures(s) and Results:** An independent t test was used for normally distributed data. A Mann-Whitney U test or ordinal and non-normal data. After implementation of the sepsis calculator, the use or empiric antibiotics for suspected EOS reduced from 4.8% to 2.7%, P< 0.001, relative risk reduction of 44%.

		# Intervention: 208 infants included based on EOS risk factors **Group Homogeneity:** Some statistically significant differences noted among pre/post groups, but weeks gestation was not among them.	Each infant was evaluated using the study protocol. If one or more of maternal EOS risk factors were met, clinical evaluations of the newborn by a pediatric resident or pediatrician followed. Using the EOS calculator, along with the physical exam, each infant was assigned a risk category. The calculator helped guide clinical management about diagnostic workup and antibiotic usages or a conservative approach with routine clinical monitoring. At any time, the clinician could opt for different clinical management.	**Measure:** Measures of data were gathered by looking at pharmacy data, microbiology results and clinical note of whether calculator was utilized. In both retrospective and prospective groups, EOS calculated risk was stratified into low, intermediate and high risk and were compared as such.	The reduction was seen most in the low EOS risk category, relative risk reduction of 70% in this group.
Citation:					Level VI

Carola, D., Vasconcellos, M., Sloane, A., McElwee, D., Edwards, C., Greenspan, J., & Aghai, Z. (2017). Utility of early-onset sepsis risk calculator of neonates born to mothers with chorioamnionitis. *The Journal of Pediatrics*, 195, 45-52. http://doi.org/10.1016/j.peds.2017.11.045					
Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results
"Our first objective was to evaluate the predictive value of the EOS calculator in identifying neonates born to mothers with clinical chorioamnionitis. Our second objective was to determine the incidence of abnormal laboratory tests at 6-12 hours of age in chorioamnionitis exposed neonates."	Retrospective Study	**Sampling Technique:** Convenience retrospective sample **# Eligible:** 17,908 born $\geq$ 35 weeks; 1,159 exposed to clinical maternal chorioamnionitis **# Accepted:** Sufficient data for 896 to calculate EOS risk **# Excluded:** 263 were missing data required for EOS calculator **# Control:** The 896 infants identify retrospectively were included; Infants were treated based on CDC and AAP guidelines. **# Intervention:** The EOS calculator was retrospectively	**Control:** Infants treated based on hospital protocol per CDC and AAP guidelines with relationship to maternal chorioamnionitis, which by nature over treats healthy infants. **Intervention:** EOS calculator retrospectively applied to infants included to see who would have received empiric antibiotics and laboratory studies; this allowed the team to see who would have been treated compared to who actually needed treatment.	**Dependent variable:** The dependent variable for this study is the retrospective data from applying the EOS calculator. The infants were then stratified into low, intermediate and high-risk groups. **Measures:** The measures of this study were comparing the infants who were treated based on standard protocol and how that might have changed if the EOS calculator was being used.	**Statistical Procedures(s) and Results:** Comparisons between the groups were performed using the student t test and the Mann-Whitney rank sum test. For continuous data the chi square or Fisher exact test for categorical data was used. Of the infants exposed to chorioamnionitis only 0.43% of infants had culture positive EOS. Utilizing the CDC treatment 231 patients were treated with antibiotics. Utilization of the calculator would

		applied based on clinical data to all 896 infants. **Group Homogeneity:** There was no statistically significant baseline demographic data between included and excluded infants.	**Intervention fidelity:** Neonates were identified through a national database as to who was exposed to maternal chorioamnionitis. All infants were admitted to the NICU, had a blood culture, CBC and CRP drawn as well as started on antibiotics. Data was collected and entered into the EOS calculator.		have reduced antibiotic use by 2/3's. All 5 infants who were culture positive would have been screened or started on antibiotics.
Citation: Achten, N., Klingenberg, C., Benitz, W., Stocker, M., Schlapbach, L., Giannoni, E., Bokelaar, R., Driessen, G., Brodin, P., Uthaya, S., van Rossum, A., & Plotz, F. (2019). Association of use of the neonatal early-onset sepsis calculator with reduction in antibiotic therapy and safety a systematic review and meta-analysis. *JAMA Pediatrics*, 173(11), 1032-1040. http://doi.org/10.1001/jamapediatrics.2019.2825					Level: I
Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results
"The purpose of the current systematic review and meta-analysis was to identify, critically appraise, and synthesize evidence from studies	Systematic review with meta-analysis;	A systematic search was done for all available literature describing EOS calculator in Cochrane, Embase, and PubMed/MEDLINE	**Control:** Conventional EOS management strategies **Intervention:** Management of EOS guided by EOS calculator	**Dependent variable:** All 13 studies included looked at the use of the calculator to reduce rates of empirical antibiotics	**Level of measurement:** Meta-analysis compared using the Cochran-Mantel-Haenszel method to test for significance.

comparing management guided by the EOS calculator with conventional management strategies, and report the rates of empirical antibiotic therapy for suspected EOS."		data bases from 2011- January 31, 2019. Search terms included "EOS calculator", "EOS risk calculator", "sepsis calculator", or "sepsis risk calculator" Title and abstracts were searched for "predictive, risk, quantitative or stratification, combined with model or algorithm and early onset sepsis, early onset neonatal sepsis, or EOS". Only limits applied were peer review and dates (due to 2011 being when the calculator was first published). Search results were independently screened by two researchers for predetermined inclusion and exclusion criteria. In the case of		prescribed for EOS as the main outcome **Measure:** Reduced rate of antibiotic prescription	Quantified inconsistencies between the results of the studies using the I^2 test. **Outcomes data retrieval:** Researchers pooled all the data from the articles included. **Analysis:** All studies found lower RR for antibiotic therapy, favoring the use of the calculator (range 3-60%). Analysis showed that studies looking at mother with chorioamnionitis alone found stronger reductions (RR 3-39%). In before and after studies, there was a 56% reduction in antibiotics use (95% CI, 53-59%). **SR Bias Risk:** judged high for 9 studies, low 2 and unclear for 2

		disagreement, a third researcher was the decisive vote. **Eligible Studies:** 354 unique results Cohort studies for pre and post design as well as hypothetical analysis of newborn data. Original data including use of the calculator. **Excluded:** 341 excluded Exclusion due to no calculator, not original data, not peer reviewed, or being a developmental study. **Included:** 13 studies included. 175,752 newborns included in total; 3 studies were confined to well-appearing infants while the other 10 included symptomatic newborns. 6 limited			

		inclusion to infants born to mothers diagnosed with chorioamnionitis; 2 limited to infants treated with antibiotics. **PRISMA:** Included information for inclusion/exclusion articles from SR.			

Table 2

Synthesis Review Table

Evidence Based Practice Question (PICO): Does the use of the EOS calculator reduce the use of antibiotics and sepsis screens in infants ≥ 35 weeks as compared to the current standard management?			
Level of Evidence	**# of Studies**	**Summary of Findings**	**Overall Quality**
I	**I**	Achten, et al. (2019), systematic review and meta-analysis showed that the use of the EOS calculator reduces the percentage of infants treated with empiric antibiotics for suspected or proven EOS as compared to conventional strategies. Antibiotic use was decreased by 56% in before and after studies included.	B, the review had a decent sample size. All the literature included came to the same conclusions. There was no RCT's included. The results were consistent and clear.
III	**2**	Dhudasia et al. (2018), and Atchen et al. (2017), were both retrospective-prospective study designs, comparing historical data to post implementation of the EOS calculator data. Each study saw a 42-44 decrease in antibiotic usage when the EOS calculator was implemented. Dhudasia et al., did have a slightly clearer design implementation regarding the use of the calculator.	B, both studies had large sample sizes. The results were consistent with the rest of the literature. Both articles provided the algorithms utilized, however Dhudasia et al., was easier to follow. Both were prospective-retrospective study designs which is a natural limitation lending to a lower quality grade.
VI	**1**	Carola, et al. (2017), was a retrospective study. The EOS calculator was applied retrospectively to infant's data to see if the conventional management	B, the study included a large data sample. The results were consistent with previous studies in recommending the use of the EOS calculator. As the study is retrospective in nature, there was

		used would have aligned with the EOS recommendations. 67% of the infants who received antibiotics would not have based on the EOS calculator results.	no ability to randomize. The inclusion and exclusion data was clear.

Figure 1.

Roger's Protection Motivation Theory

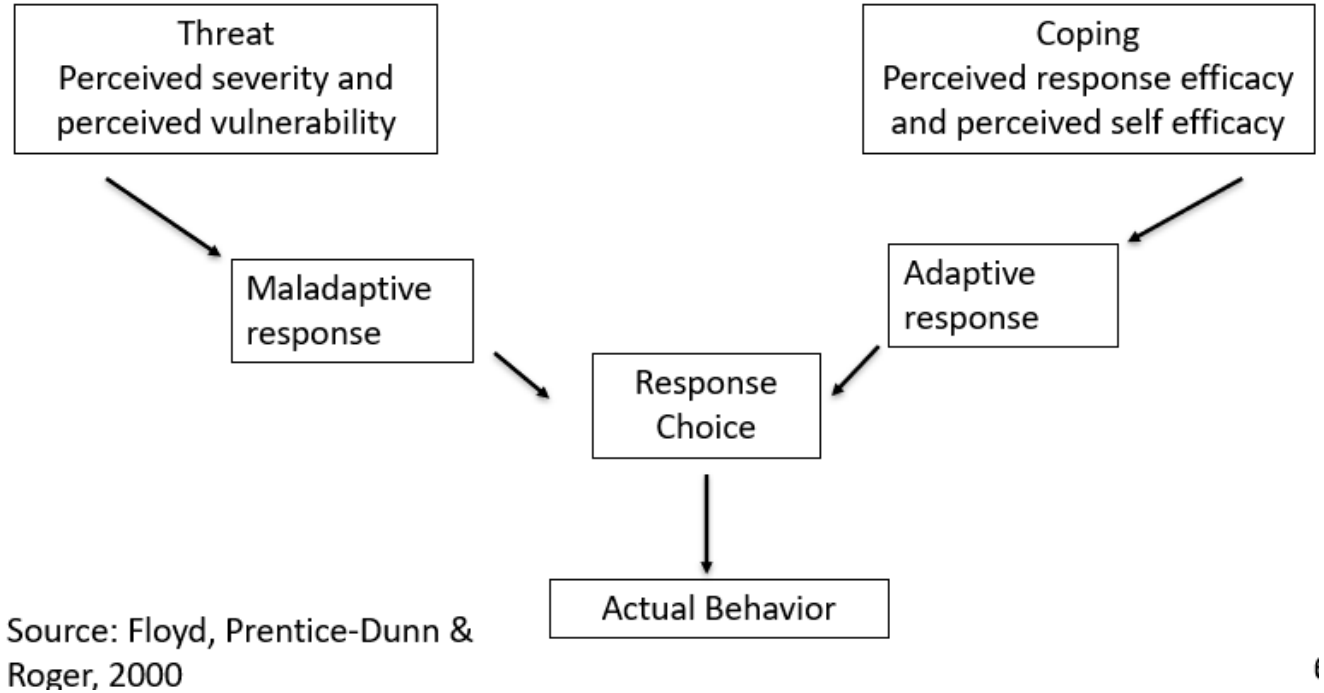
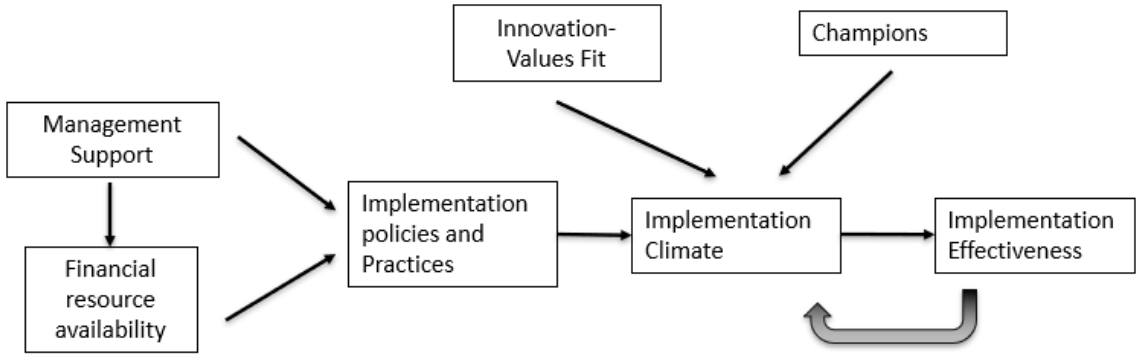


Figure 2.

Helfrich's Determinants of Implementation Framework



Source: Helfrich, Weiner, McKinney and Minasian, 2007

7

Figure 3.

Early Onset Sepsis Calculator Use

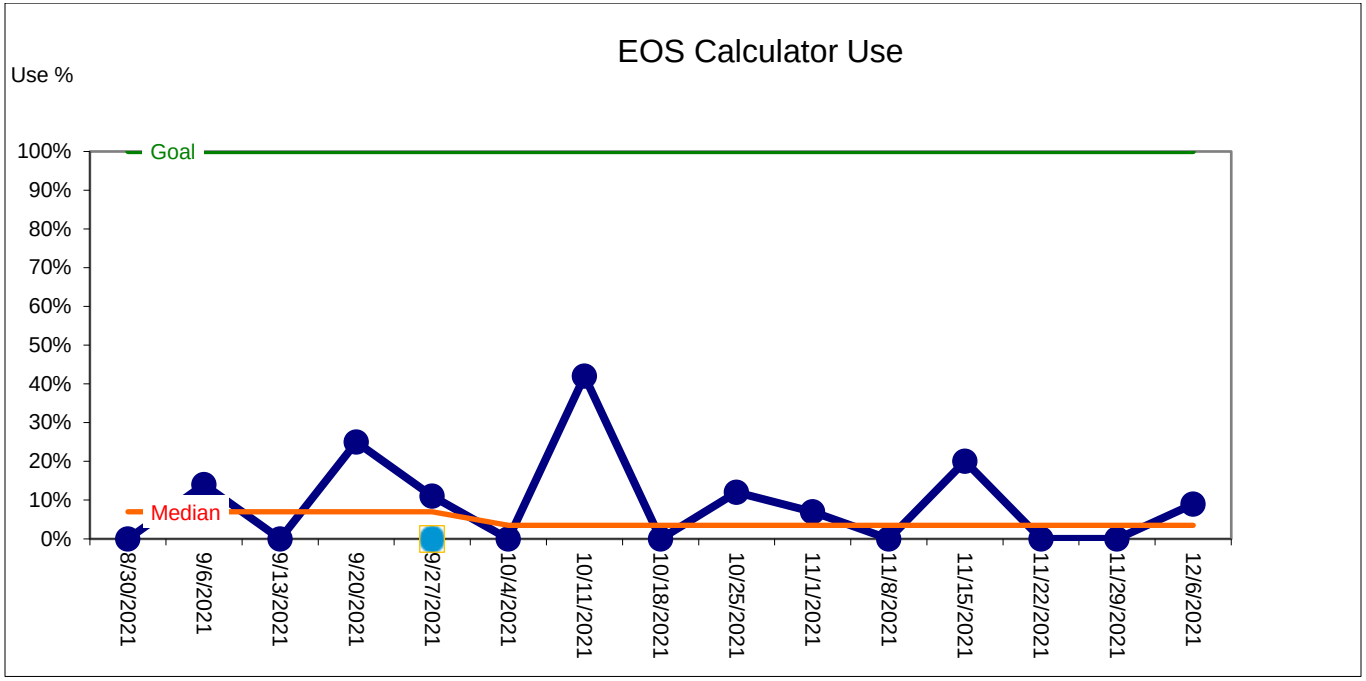


Figure 4.

Sepsis Screens on Admission

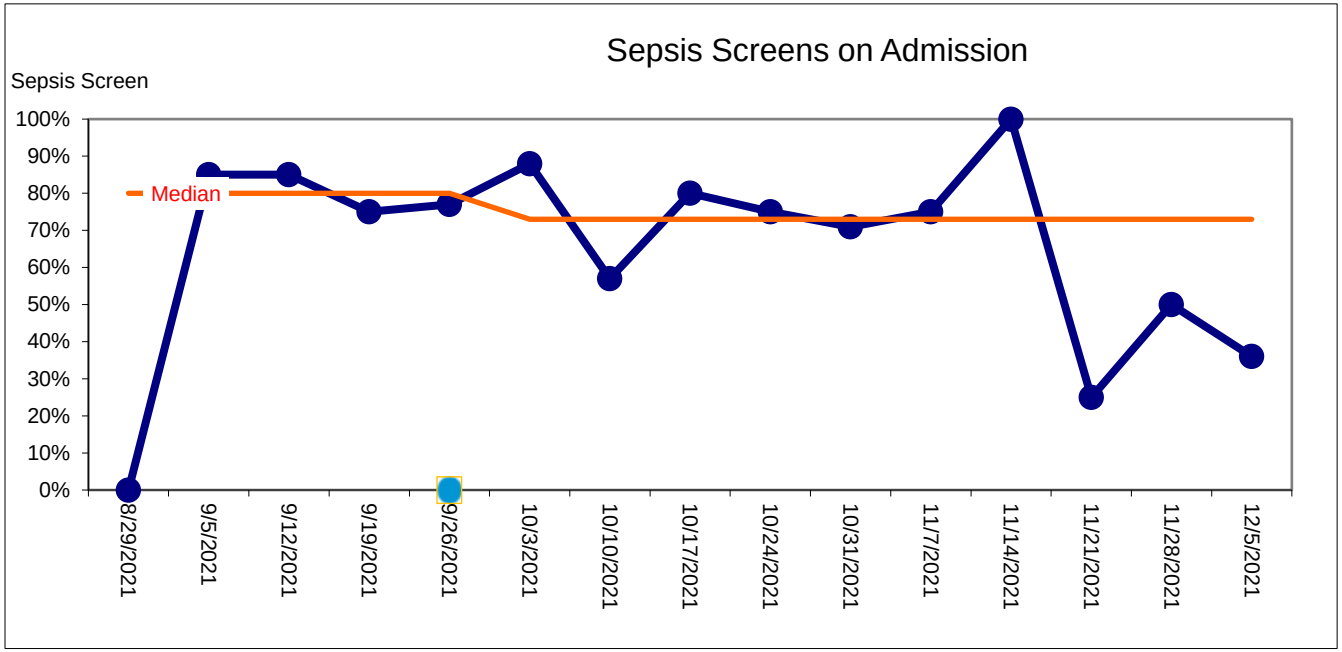
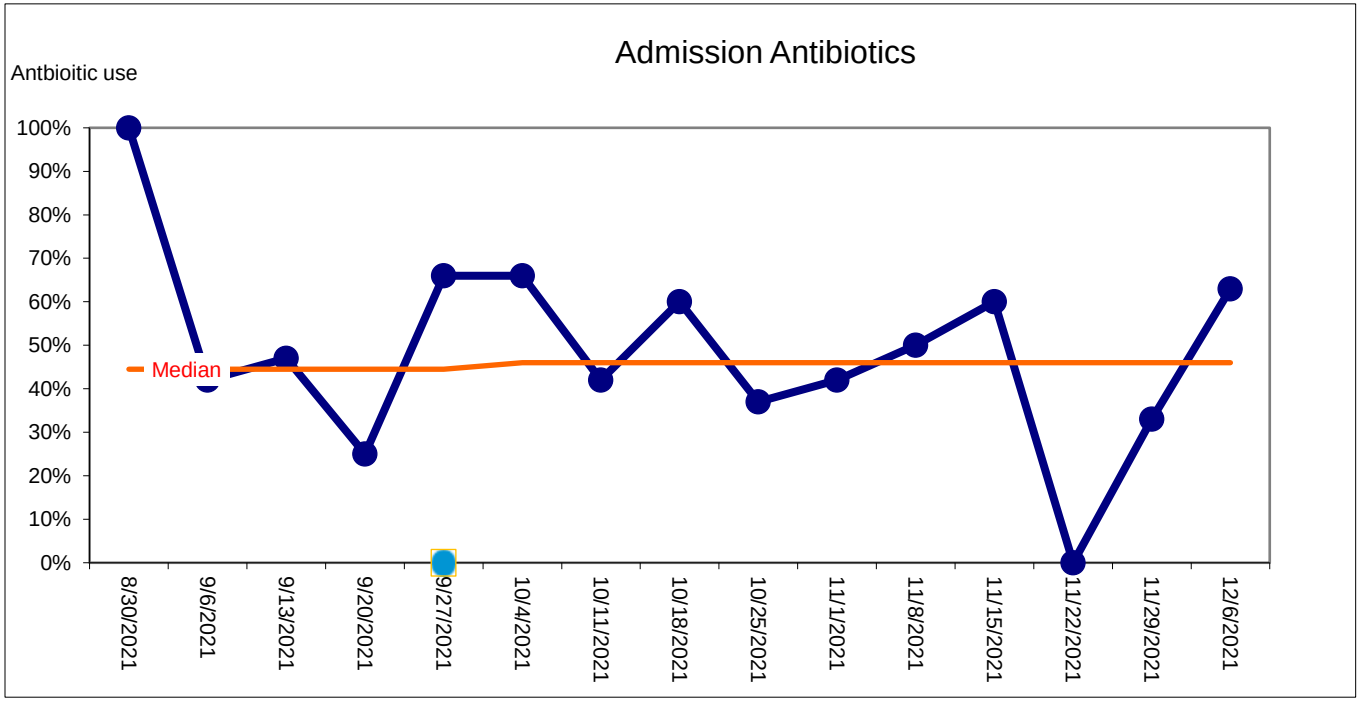


Figure 5.

Antibiotic Use on Admission

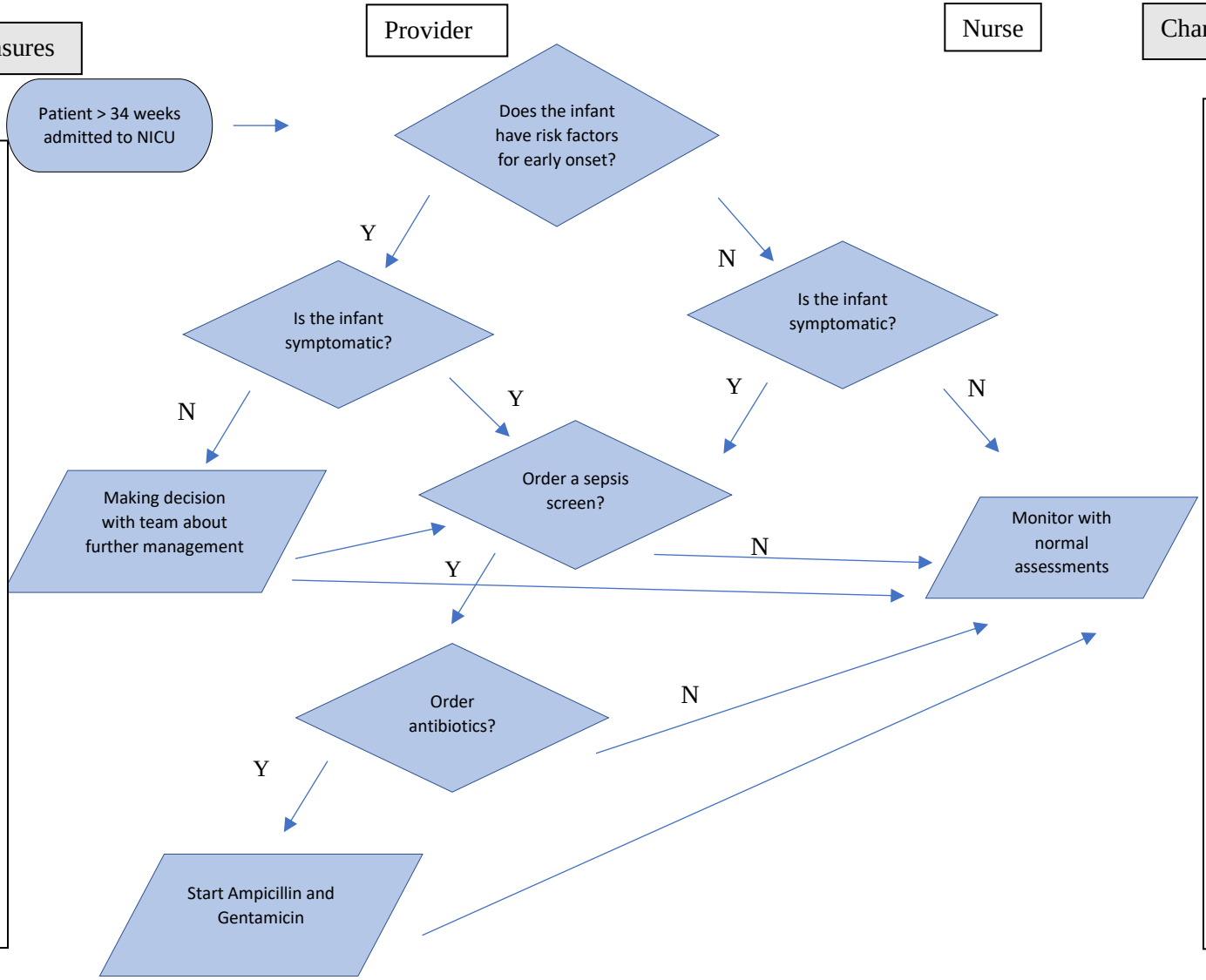


Appendix A

Possible Measures

- # of patients identified as:
  - Admissions to NICU
  - At risk for sepsis
- How often team must make this decision?
- How many infants get a sepsis screen?
- How many infants get started on antibiotics?

Current Process



Change Opportunities

- All infants > 34 weeks utilize the early onset sepsis calculator to guide management.
- Outcome of calculator put into H&P of infant to show use

Appendix B

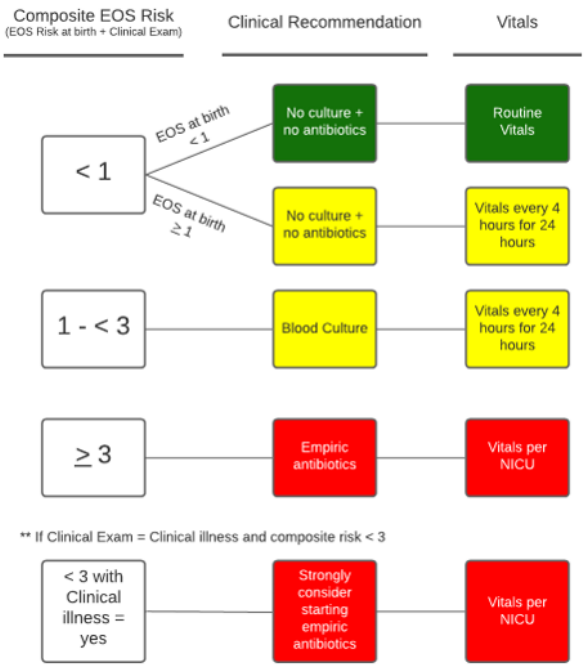
Well Appearing	• No persistent physiologic abnormalities

Equivocal	• Single persistent physiologic abnormality lasting > 4 hrs or two or more physiologic abnormalities lasting > 2 hours
	  ○ Tachycardia (HR > 160)
	  ○ Tachypnea (RR > 60)
	  ○ Temperature instability (> 100.4˚F or < 97.5˚F)
	  ○ Respiratory distress (grunting, flaring, or retracting) not requiring supplemental O2

Clinical Illness	• Persistent need for NCPAP/HFNC/mechanical ventilation
	• Hemodynamic instability requiring vasoactive drugs
	• Neonatal encephalopathy / Perinatal depression
	  ○ Seizure
	  ○ Apgar Score @ 5 minutes < 5
	• Need for supplemental O2 > 2 hours to maintain oxygen saturations > 90%

Education on how to clinically assess the infants from further interpretation of the sepsis calculator. This was adapted from the Kaiser Permanente education.

Appendix C



Note: Adapted from Kaiser Permanente EMR Implementation Guidance.

This is the education provided to staff to help better understand how to interpret the results of the early onset sepsis calculator. This was adapted from the Kaiser Permanente education.

Appendix D

Data Collection Tools

MRN Number	Assigned Code
3000000000	801

Code	Staff Member Name	Date	Signature
001	Jane Doe	8/30/21	Jane Doe

Data Management Tool

Infant admitted to the NICU (assigned number)	Gestational Age	Utilization of EOS calculator in EHR?	EOS Calculator outcome	Antiboitics in first 48 hours?	Antibiotics used > 48 hours?	CBC sent within first 48 hours?	Blood Culture Sent in first 48 hours?	Positive blood culture result?	Outcome
801	35.4	Yes	Start abx	Yes	No	Yes	Yes	No	Calcuator used correctly
802	37.2								Data incomplete

Yes
No

Appendix E

The PowerPoint above was created to present information to the bedside nurses describing the early onset sepsis calculator and re-educating them on signs and symptoms of sepsis. The presentation also provided information on how to locate the sepsis calculator in the EHR (specifically for nurses). At the end of the presentation was a quiz to assess staff's knowledge.

The above PowerPoint was created for providers. It differed slightly from the nurses as it provided more education on the use of the early onset sepsis calculator. The presentation also provided information on how to locate the sepsis calculator in the EHR (specifically for providers). At the end of the presentation there was a quiz to assess staff's knowledge.