

A Prospective Quality Improvement Project Using the Neonatal Early-Onset Sepsis Calculator Among Late Preterm and Term Newborns at a Large Single-Center Neonatal Intensive Care Unit

C. Martin Begnaud Jr. DNP, APRN, NNP-BC; Jennifer Lemoine, Ph.D., DNP, APRN, NNP-BC; Lisa Broussard, RN, DNS, CNE; Roger Rhodon, DNP, APRN, CPNP-AC; Harshit Doshi, MD

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Introduction:

Problem Description:

Early-onset sepsis (EOS) is defined as a positive blood culture for a pathogenic organism within 72 hours of birth. (1) The non-discriminant symptomatology associated with EOS contributes to the difficulty in establishing a definitive diagnosis before blood culture results are known. (2) Therefore, to err on the side of caution, many providers initiate empiric antibiotic therapy regardless of newborn risk status and clinical presentation. (2)

“Early-onset sepsis (EOS) is defined as a positive blood culture for a pathogenic organism within 72 hours of birth. The non-discriminant symptomatology associated with EOS contributes to the difficulty in establishing a definitive diagnosis before blood culture results are known. Therefore, to err on the side of caution, many providers initiate empiric antibiotic therapy regardless of newborn risk status and clinical presentation.”

In 2010, the Centers for Disease Control and Prevention (CDC), the American Academy of Pediatrics (AAP), the National Institute for Health and Care Excellence (NICE), and the American Society of Microbiology (ASM) published reports and guidelines for best practices related to the management of EOS of the newborn.

Nevertheless, many providers continue to use outdated practices rooted in unit traditions or experiences to guide care decisions, which has resulted in variations in provider antimicrobial prescribing practices across and within neonatal intensive care units (NICUs) and escalated the use of unwarranted antibiotic therapy. (3–9) For example, Schulman and colleagues conducted a retrospective cohort study of 52,061 newborns diagnosed with unproven but suspected sepsis admitted to 127 NICUs across California. Findings of this multi-site study indicated variations in practice, including the initiation of EOS evaluations (complete blood count [CBC], C-reactive protein [CRP], and blood culture) and the administration of empiric antibiotics, with a 40-fold variation in antibiotic prescribing practices among units with similar numbers of proven infection. (10)

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Evidence suggests that the recognition of inconsistent antimicrobial prescribing practices has led antibiotic stewardship programs to develop a more evidence-based approach to caring for this vulnerable population. However, accepting and adopting these programs remain challenging, as providers must re-evaluate the systematic practice of initiating EOS evaluations and empiric antibiotic therapy during the immediate newborn period. (11)

Available Knowledge:

Incidence of EOS and Antibiotic Stewardship

Following the introduction of intrapartum antibiotic prophylaxis for group B-Streptococcus (GBS) two decades ago, the incidence of EOS in the United States (US) decreased from 0.77 to 1 per

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1,000 live births to 0.4–0.5 per 1,000 live births. (8, 12)While the incidence of EOS remains low, the initiation of antibiotic therapy remains high. (13)

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It has been widely reported that the unwarranted administration of antibiotics is associated with an increased risk of necrotizing enterocolitis (NEC), invasive candida infections, multi-resistant drug organisms, late-onset sepsis, and death. (14–18) Term newborns who have been exposed to antibiotics have a higher incidence of atopy, childhood obesity, and asthma. (19, 20) Moreover, indiscriminate EOS evaluations and antibiotic use can potentially affect the parent-newborn bond and breastfeeding success as well as increasing lengths of stay and healthcare expenditures. (21)

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Despite recommendations published by leading pediatric organizations and increasing evidence to support a more thorough, multifactorial approach to the management of EOS, many providers fail to employ antibiotic stewardship protocols and practices, which contributes to unnecessary EOS evaluations and unwarranted antibiotic therapy among late preterm (LPT) and term newborn infants. For example, in the US, it is estimated that approximately 400,000 term infants admitted to the NICU without a confirmed diagnosis of EOS will receive antibiotics at birth. (22–

24)

The philosophy of providers who “understand but don’t believe” the importance of antibiotic stewardship has contributed to newborns being treated ten times more for culture-negative sepsis than for blood cultures that are positive for pathogenic organisms. (11) The practice of treating clinical sepsis or suspected sepsis with negative culture results remains contentious and lacks consensus among providers. (13) Moreover, evidence suggests that providers continue to subscribe to high antibiotic utilization when the overall incidence of EOS remains low in high-income countries. (13)

Neonatal Early-Onset Sepsis (NEOS) Calculator:

Kaiser Permanente developed the NEOS calculator to estimate EOS risk per 1,000 live births in newborns greater than or equal to 34 weeks gestation utilizing applicable maternal delivery variables. (22) The calculator was tested and modified over 14 years using a large multi-center birth cohort that included over 600,000 newborns. (22, 25) This free web-based online tool is designed to provide guidance and management pathways for EOS evaluations and empiric antibiotic therapy based on maternal risk factors and clinical examinations (<https://neonatalesepsiscalculator.kaiserpermanente.org>).

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The calculator utilizes a multivariate assessment risk of EOS in newborns greater than or equal to 34 weeks gestation. (30) The summation of risk factor variables includes:

- An incidence of EOS per 1000 live births (0.5 per 1000 live births is the CDC incidence or unit-specific EOS incidence)
- Gestational age of the newborn
- Highest maternal intrapartum temperature

- Length of time of rupture of membranes
- Maternal GBS status
- And initiation of intrapartum antibiotic prophylaxis before delivery (22)

Additionally, the calculator allows the provider to enter a physical examination assessment. Based on the assessment findings, the clinical state of the newborn is characterized into one of the following hierarchical, mutually exclusive categories according to predetermined criteria: (1) well-appearing, (2) equivocal, or (3) clinical illness. (22)

The developers of the NEOS calculator recommend utilizing the tool from birth up to 24 hours of age, which is a conservative approach but would likely detect clinical changes in the newborn. (22) There are four progressive tiers of recommendations based on risk scores and clinical symptomology to help guide providers: (1) observe without evaluation, (2) observe and evaluate (obtain blood culture), (3) evaluate and strongly consider antibiotics, and (4) evaluate and treat with empiric antibiotics. Multiple studies have reported fewer EOS evaluations and a 44% to 78% reduction in empiric antimicrobial therapies with the implementation of the NEOS calculator over extended periods. (26–29)

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In the seminal study conducted by Escobar et al. using the NEOS calculator, a newborn who presents with clinical illness per physical examination and sepsis risk factors present, a score of ≥ 1.54 per 1000/births, or having a combination of an equivocal presentation with risk factors and a score of $\geq .065$ per 1000/births would constitute a high-risk newborn requiring further evaluation.

(22) This supports the assumption that as the probability of sepsis risk increases, so does the NEOS risk score per 1000/births.

Rationale:

Over the past 12 years, the CDC, AAP, and NICE published guidelines and reports regarding the appraisal and management of EOS in newborns. (3–9, 30) These directives have inspired progressive clinicians to adopt evidence-based practices in managing EOS to limit newborn exposure to unwarranted antibiotic administration and mitigate adverse outcomes. As previously stated, providers, including those working in the NICU of interest for this Quality Improvement Project (QIP), continue to practice based on knowledge acquisition from initial programs of study or local unit traditions where historical viewpoints outweigh the current trends toward evidence-based antibiotic stewardship in the NICU. The mean incidence of EOS within the NICU of interest for this QIP was 1.44 cases per 1,000 live births over nine years, 2010–2018. Moreover, 65% of newborns over or equal to 34 weeks gestation received empiric antibiotic therapy. These figures supported the need for providers to critically examine current unit practices and consider adopting an evidence-based approach to decreasing antibiotic exposure among newborns classified as low-risk for developing EOS.

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Specific Aims:

This QIP aimed to reduce EOS evaluations and empiric antibiotic use by 20% in newborns greater than or equal to 34 weeks admitted to the NICU by implementing an evidence-based protocol using the NEOS calculator. A 20% reduction was deemed an achievable goal within the time frame of the QIP.

The secondary aims of this project included examining provider adherence rates following the implementation of the NEOS calculator and estimating the potential reduction of EOS evaluations and empiric antibiotic use retrospectively (July–December 2016) before the implementation of the NEOS calculator in 2018. Additional outcome measures included evaluating NEOS calculator recommendations with actual cases of EOS and the stratification of antibiotic use based on the clinical presentation compared to the recommendations from the NEOS calculator.

Methods:

Context:

The setting for the project was a 50-bed, level III regional transport designated NICU, admitting approximately 600 to 700 newborns annually. Referral newborns comprise 20% of the annual admissions from the surrounding communities. A private group of six neonatologists and neonatal nurse practitioners support this unit, along with several pediatric subspecialists.

Inclusion criteria for the QIP were newborns greater than or equal to 34 weeks gestation with a complete maternal history. Exclusion criteria included newborns under 34 weeks gestation and those with missing maternal data (i.e., maternal temperature, variables factored into the NEOS calculator).

Needs Assessment and Stakeholder Buy-In:

Before implementing this project, stakeholder buy-in was garnered by identifying the historical antibiotic prescribing practices and the number of EOS evaluations among newborns greater than or equal to 34 weeks' gestation admitted to the NICU between July through December 2016. The pre-implementation evaluation was discussed and analyzed with one of the country's leading clinical researchers in neonatology to establish credibility for the project among the NICU providers. Data related to 203 newborns who met inclusion criteria were processed using the NEOS calculator. NEOS scores were retrospectively applied to compare empiric antibiotic use and EOS evaluations to the NEOS calculator recommendations using the CDC incidence of EOS of 0.5 per 1000 live births. Findings were presented to the providers and key stakeholders. The initial presentation included the outcomes of the baseline analysis, which supported the need to implement new unit EOS protocols/guidelines with the application of the NEOS calculator. Moreover, this data served as the comparison or baseline group for post-implementation data analysis.

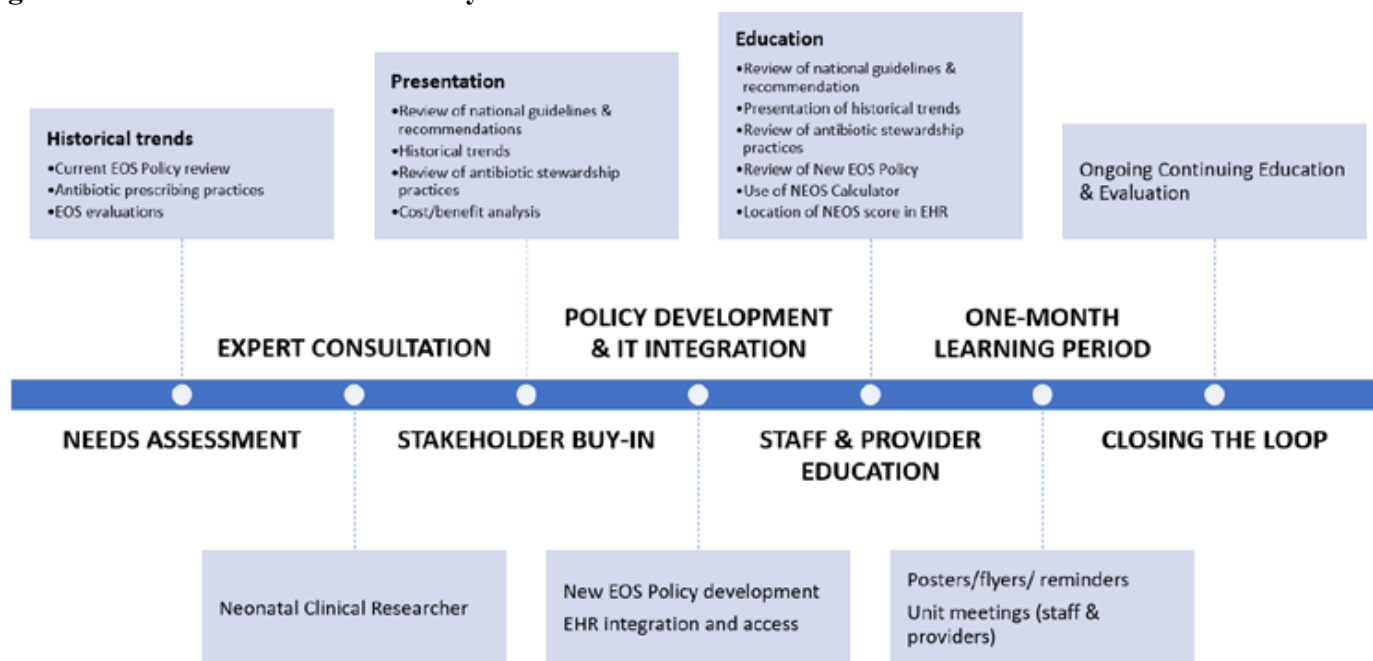
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A new unit EOS policy was developed and integrated into the existing electronic medical record (EMR) system. Staff and provider education related to the current national guidelines and recommendations, a review of antibiotic stewardship practices and best recommendations, the use of the NEOS calculator, and the goals of the QIP were presented. Posters, flyers, and reminders were displayed on the unit, and the investigator frequently attended staff and provider unit meetings to provide continuing education and answer any questions. The post-implementation phase began after a one-month learning period (see Figure 1).

Intervention:

Implementation of the NEOS calculator with the revised EOS protocol occurred over nine months, from June 2018 to February 2019. Before the QIP was implemented, educational sessions were conducted for providers and NICU staff nurses, including PowerPoint presentations and interactive, hands-on scenarios from the NEOS calculator website. This antibiotic stewardship QIP's purpose was to transform the providers' behavior and

Figure 1. Timeline of Stakeholder Buy-in



the unit's culture toward a more evidence-based perspective of EOS within the NICU. Pre- versus post-implementation unit EOS guidelines were as follows:

Pre-implementation

- Blood culture at birth.
- CBC, CRP at birth.
- Empiric antibiotics based on risk factors.
- CBC, CRP at 24 hours of age.

Post-Implementation

- Evaluation per the NEOS calc.
- CBC between 6 to 12 hours of age.
- Empiric antibiotics per the NEOS calc.
- Repeat CBC as needed.

Additionally, two algorithms were created for newborns < and ≥34 weeks gestation, including new parameters for observation of late preterm and term newborns exposed to chorioamnionitis. Algorithms and NEOS calculator instructions were inserted into the unit's practice guideline binder. Also, a NEOS calculator shortcut was created on the desktops of each computer system in the NICU for easy reference.

Study of Intervention:

As previously noted, before project implementation, the mean incidence of EOS within the QIP facility was 1.44 cases per 1000 live births. Therefore, NEOS scores were collected prospectively utilizing two EOS incidences: 0.5 per 1000 live births (per CDC recommendations) and one per 1000 live births (consistent with unit cases). The intent was to compare the recommendations from the calculator on EOS evaluations (i.e., recommendations to obtain a blood culture) and initiation of empiric antibiotics. After the fifth month of data collection, a change was made to restrict incidence calculation parameters to one per 1000 live births, more representative of the local EOS incidence. Baseline data collected and analyzed during the needs assessment of this project served as the comparison group to examine the effectiveness of the intervention following implementation.

Providers' practices were examined for adherence to the NEOS calculator recommendations. Documentation included the NEOS calculator birth score and clinical exam score were included within the EMR under an appropriate diagnosis.

Measures and Analysis:

A convenience sample obtained from a single tertiary NICU was used for this project. All vital healthcare information was deidentified, converted into 69 variables, and stored in a password-protected database. The primary outcome of the QIP was to examine the effectiveness of implementing an evidence-based EOS protocol using the NEOS calculator in reducing EOS evaluations and empiric antibiotics use.

A secondary outcome measure was provider adherence rates. The NEOS calculator recommendations with actual cases of EOS and the stratification of antibiotic use based upon the clinical presentation to the recommendations from the NEOS calculator served as additional outcome measures.

SPSS 27 was used for data analysis. Descriptive statistics were employed to assess frequencies and percentages across group demographic characteristics and other variables of interest, including provider adherence. Independent sample *t*-tests were used to evaluate the mean differences between EOS evaluations and empiric antibiotics between pre- and post-implementation periods. The significance level was set at 0.5.

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Ethical Considerations:

A local public university granted Institutional Review Board (IRB) approval before the QIP started. The participating hospital accepted this IRB approval. Data de-identification, collection, and documentation utilized a corresponding ID number for each newborn to protect confidentiality. The findings of this project have been limited to the reporting of aggregate data.

Results:

Pre-Implementation Demographic Characteristics:

The retrospective analysis included 203 newborns scored through the NEOS calculator. Demographics for this group were mostly Caucasian 56.2% (n = 114) and male 62.1% (n = 126), with an average gestational age of 37.4 weeks and birthweight of 2932 grams. Cesarean section (CS) deliveries accounted for 53% (n = 108) of deliveries. Positive maternal GBS status was 17.7% (n = 36), while 37.4% (n = 76) were unknown at delivery time. Additionally, 7.9% (n = 16) were born to mothers with a temperature ≥ 38° Celsius. Table 1 summarizes the demographic characteristics associated with the pre-implementation group.

Table 1. Pre vs. Post-Implementation Demographic Characteristics

	Pre-Implementation N=203	Post-implementation N=357	P value
Mean gestational age (weeks)	37.4	37.1	.10
Mean birthweight (grams)	2932g	2934g	.98
Term	119 (58.6)	195 (54.6)	.36
Late preterm	84 (41.4)	162 (45.4)	.36
Male	126 (62.1)	196 (54.9)	.09
Female	104 (37.9)	161(45.1)	.05
Caucasian	114 (56.2)	198 (55.5)	.87
African-American	79 (38.9)	133 (37.3)	.72
Hispanic	4 (2%)	16 (4.5)	.13
C-section	108 (53.2)	195 (54.6)	.75
SVD	95 (46.8)	162 (45.4)	.75
Maternal fever (>38.0 C)	16 (7.9)	32 (9)	.66
Maternal GBS positivity	36 (17.7)	64 (17.9)	.95
Maternal GBS unknown	76 (37.4)	129 (36.1)	.76

EOS Evaluations and Empiric Antibiotic Administration:

Among participants in the pre-implementation group, empiric antibiotics were administered to 65% (n = 132), and EOS evaluations were obtained on 99% (n = 201) of newborns. Clinical examination findings revealed that 51.7% (n = 105) were well-appearing, and 48.3% (n = 98) were characterized as clinical illnesses. Clinical illness was defined as receiving any respiratory support, from a nasal cannula to full ventilator support. Due to the retrospective nature of the evaluation, no newborns were classified as equivocal. See Tables 2 and 3.

Of the 203 newborns scored using the NEOS calculator, recommendations revealed that three newborns should have received an EOS evaluation, and only one recommendation was made to initiate an EOS evaluation and empiric antibiotics. Contrary to these recommendations, 61.9% (n = 65) of newborns were treated with empiric antibiotics. Seven newborns categorized as well-appearing had a positive blood culture; one culture was positive for GBS, and the remaining six were colonized with other bacteria. Of the seven positive cultures, only the newborn with GBS bacteremia and another with positive blood and cerebral spinal fluid (CSF) cultures for *Bacillus cereus* were treated with a full course of antibiotics. The newborn with meningitis was treated with ampicillin and gentamicin for 19 days. Five positive blood cultures were considered contaminants, and these newborns received less than five days of antibiotic therapy. In comparison, one newborn received seven days of treatment for possible sepsis. It is important to note that the NEOS calculator would have recommended “observation without evaluation” for all seven newborns with positive blood cultures who had a well-appearing clinical examination using the CDC EOS incidence of 0.5 per 1000.

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Of those 98 newborns categorized as clinical illness, 68.4% (n = 67) received empiric antibiotic administration, and all were evaluated for EOS, including the collection of blood cultures. Conversely, the NEOS calculator recommended that 100% of newborns be evaluated, suggested the initiation of empiric antibiotics on 37.7% (n = 25), and recommended that providers strongly consider empiric antibiotic administration on newborns’ remaining 62.3% (n = 42). Finally, only one blood culture was positive for *E. coli*, and this newborn received 17 days of antibiotic therapy. The calculator’s recommendations were to evaluate and strongly consider antibiotics for this newborn with *E. coli* sepsis.

Risk Stratification of Antibiotic Use and Physical Examination:

Quantitative risk stratification was analyzed for antibiotic use in

relation to the physical examination findings. Of the 105 well-appearing newborns, all received an EOS evaluation, and empiric antibiotics were initiated on 56.2% (n = 59) despite being in the two lowest birth risk scores when scored using the NEOS calculator. Moreover, the NEOS calculator recommended obtaining blood cultures on only five of the 99 newborns within these lower-tiered categories, while withholding empiric antibiotics was recommended for all. The newborns categorized as well-appearing with birth scores > 1.54 (high-risk) received an EOS evaluation and were treated empirically, mirroring the NEOS calculator recommendations. Of the 98 newborns whose physical examination was categorized as clinical illness, all were evaluated, and 68.3% (n = 67) were treated empirically.

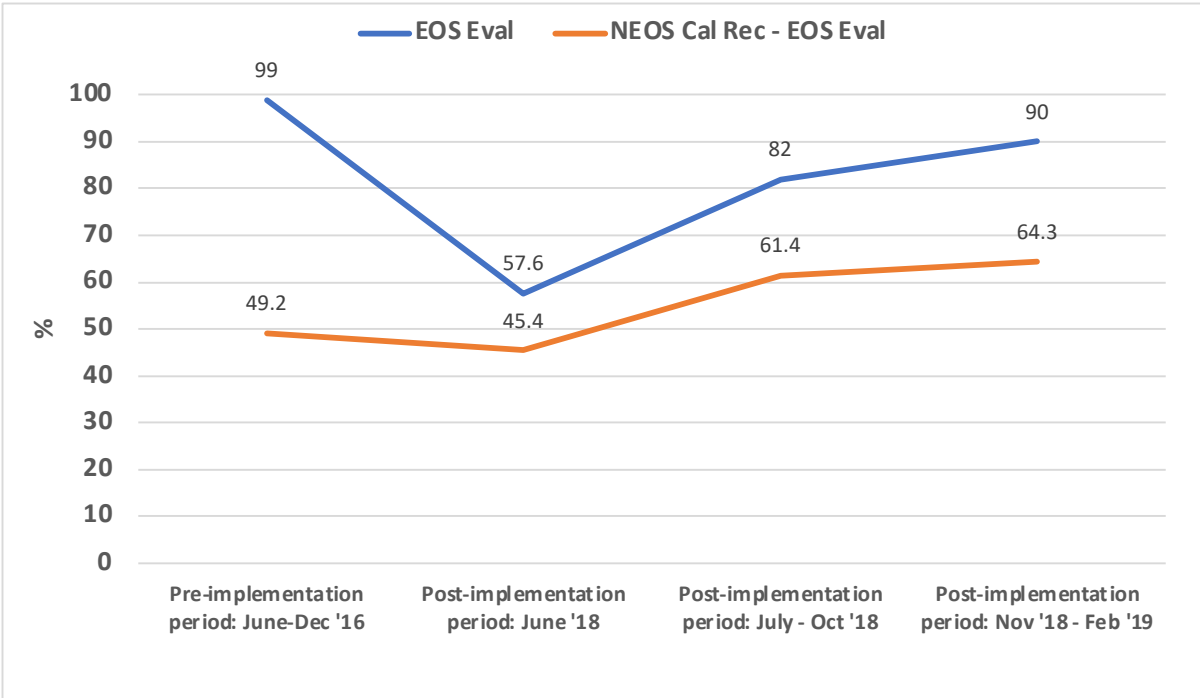
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The NEOS calculator could reduce empiric antibiotic administration by 71.2% among the well-appearing and clinical illness groups. Furthermore, the strongly considered recommendation reduces empiric therapy if the provider evaluates high-risk maternal factors while excluding respiratory distress disorders like transient tachypnea of the newborn and respiratory distress syndrome in the LPT and term population. Only one newborn was diagnosed with NEC, and there were no readmissions or deaths related to EOS.

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Post-Implementation:
Timeframe and Demographic Characteristics:
The post-implementation period consisted of nine months of data collection within the unit and scored 357 newborns prospectively

Table 2. EOS evaluations actual vs NEOS calculator recommendations.



using the NEOS calculator. Of the 357 newborns, 15.6% (n = 56) were referral newborns from outlying facilities. Participants were mostly Caucasian 55.5% (n = 198), male 54.9% (n = 196), with a mean birthweight of 2934 grams and gestational age of 37.1 days. Cesarean section accounted for 54.6% (n = 195) of deliveries. Maternal GBS positivity was 17.9% (n = 64), while unknown status included 36% (n = 129). Maternal fever above 38 degrees Celsius applied to 9% (n = 32) of the participants. See Table 1.

NEOS Calculator

For the first five months following the implementation of the calculator, the incidence of EOS risk was set at 0.5/1000 births to determine scores, recommendations, and direct treatment measures. For the remaining four months of the project, the incidence was increased to one per 1000 live births to resemble the facility's local EOS incidence more closely.

Empiric Antibiotic Administration:

During the nine-month collection period, 81.8% (n = 292) of newborns were evaluated for EOS, a decrease of 17.4% from the pre-implementation period, $\chi^2 (1, n=560) = 36.28, p < .001$. Empiric antibiotics were prescribed for 51.5% (n = 184) of newborns, a decrease of 20.3% prior to implementing the NEOS calculator $\chi^2 (1, n = 560) = 9.16, p < .003$. Of the 357 newborns, the clinical exam within the NEOS calculator resulted in a distribution as follows: 39.2% (n = 140) were categorized as well-appearing, 9% (n = 32) as equivocal, and 51.8% (n = 185) as clinical illness.

Incidence of Risk 0.5 per 1000 live births

As previously stated, during the first five months of the post-implementation period NEOS calculator was set using an incidence of risk of 0.5 per 1000 live births. Of the 357 newborns observed during the entire project, 217 were scored during the first five months; 40.1% (n = 87) were categorized as well-appearing, 9.7% (n = 21) as equivocal, and the remaining 50.2% (n = 109) as clinical illness.

Well-appearing physical examination

Of the 87 well-appearing newborns, 18.4% (n = 16) were treated with empiric antibiotics. Conversely, the NEOS calculator recommended obtaining an EOS evaluation for six newborns,

while empiric antibiotic administration was recommended for only one newborn. Subsequently, three well-appearing newborns developed suspected EOS for GBS (treated x 10 days) and *Enterococcus faecalis* (treated x 10 days), although a repeat blood culture and lumbar puncture (LP) obtained before the initiation of antibiotics were negative, and *E. coli*. In the case of *E. coli*, the initial blood culture drawn at birth was negative. However, a repeat blood culture was drawn just before 72 hours of age due to NEC symptomology and was consequently positive, as noted above.

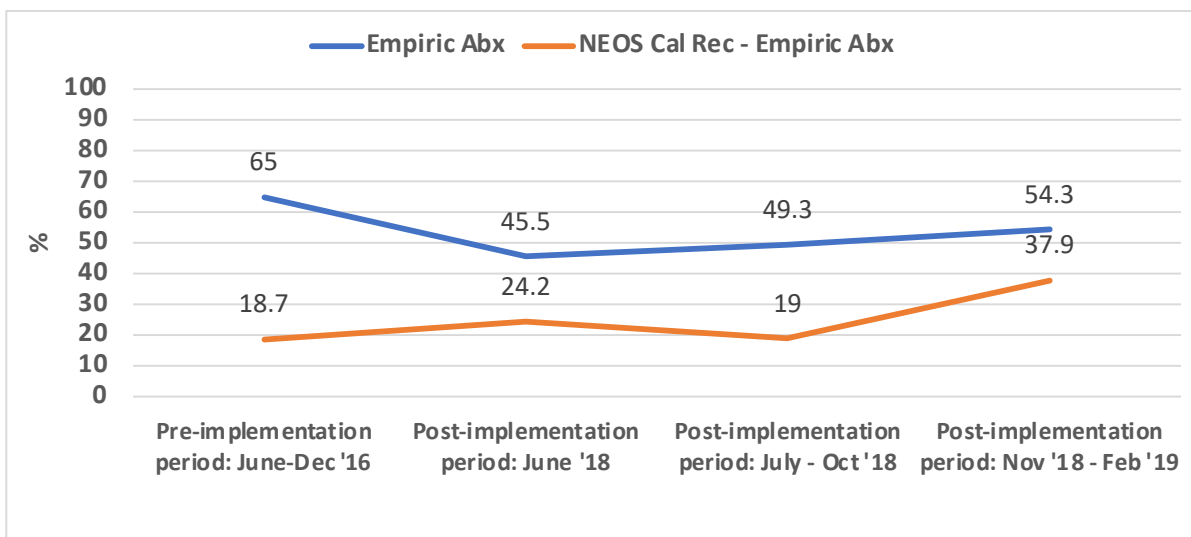
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Additionally, two positive blood cultures were considered contaminants. The NEOS calculator did not recommend a blood culture for these cases of EOS using the 0.5 per 1000 incidence. However, if the 1.0 per 1000 incidence were utilized, the calculator would have recommended a screening blood culture for two (67%) positive cultures.

Equivocal physical examination

The equivocal presentation consisted of 21 newborns, of which 14.3% (n = 3) received empiric antibiotics. The NEOS calculator suggested that three newborns receive EOS evaluations and one to be treated empirically. One blood culture was a positive culture for GBS, and this newborn received a 13-day regimen of antibiotic therapy. This was another example of an ambiguous case of EOS,

Table 3. Empiric antibiotics actual vs. NEOS calculator recommendations



as both a repeat blood culture and LP were negative and obtained less than 18 hours from the initial culture. The NEOS calculator recommended “observe without evaluation” for the 0.5 and 1.0 per 1000 EOS incidences with an equivocal presentation in this newborn.

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Clinical illness physical examination

There were 109 newborns classified as clinical illness. Approximately 80% (n = 88) of these were treated empirically. However, this group had only three positive cultures: one GBS and the others categorized as not GBS or *E. coli*. Treatment consisted of 10 days for the GBS EOS case, while the other two newborns received seven and eight days of antibiotics for possible sepsis. The NEOS calculator recommended an evaluation and empiric antibiotics for two (67%) positive blood cultures using the 0.5 per 1000 EOS incidence. The calculator recommendations for these three EOS cases were the same despite a change in the EOS incidence to 1.0 per 1000 live births.

“Overall, for the first five months after the implementation of the NEOS calculator, 50% (n = 107) of newborns were treated empirically. In sharp contrast, NEOS calculator recommendations suggested initiating empiric antibiotics on only 19.4% (n = 42). Additionally, 78.3% (n = 170) of newborns received an EOS evaluation versus 54.4% (n = 118) based on calculated scores.”

Overall, for the first five months after the implementation of the NEOS calculator, 49.3% (n = 107) of 217 newborns were treated empirically. In sharp contrast, NEOS calculator recommendations suggested initiating empiric antibiotics on only 19.4% (n = 42). Additionally, 78.3% (n = 170) of newborns received an EOS evaluation versus 54.4% (n = 118) based on calculated scores (Table 2, Table 3).

Stratification of Antibiotic Use and Physical Examination:

There were 150 newborns who were identified under the lowest risk stratifications for the calculator (birth score of < 0.64 with well or equivocal exam and birth score of 0.65–1.54 with well exam). EOS evaluations were done on 53.5% (n = 80), while only 6% (n = 9) were recommended. Furthermore, 16.2% (n = 24) of newborns were treated with antibiotics within the lowest risk stratifications. The most challenging decision from the NEOS calculator is to evaluate and strongly consider antibiotics. In this group, 72.5% of newborns received antibiotics. There was the potential to reduce EOS evaluations by 30.5% and empiric antibiotics by 61.4% per the recommendations from the calculator.

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Incidence of Risk 1 per 1000 live births

The remaining four months of the project included 140 newborns scored through the NEOS calculator with one per 1000 live births to resemble the local incidence of EOS more closely within the tertiary facility. Of these 140 newborns, 37.8% (n = 53) were categorized as well-appearing, with 15.1% (n = 8) receiving empiric antibiotics. The NEOS calculator suggested evaluating eight newborns and starting antibiotics for only one well-appearing newborn. There was one positive culture during the latter four months, which was considered a contaminant. This newborn received 48 hours of antibiotic therapy while the calculator recommended to “observe without evaluation.”

There were 11 newborns with an equivocal physical examination, and 45.5% (n = 5) were treated empirically. In contrast, recommendations were to evaluate six of these newborns while initiating empiric antibiotics on only one.

Fifty-four percent (n = 76) of newborns were characterized as clinical illness; 82.9% (n = 63) received antimicrobials. In this same group, the NEOS calculator recommendations were to obtain EOS evaluations on all 76 patients, strongly consider antibiotic administration for 32.9% (n = 25), and initiate empiric antibiotic therapy on the remaining 67.1% (n = 51) of newborns.

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During the latter four months, the NEOS calculator recommended that 64.3% (n = 90) of newborns receive an EOS evaluation, while providers evaluated 90% (n = 126). Furthermore, the recommendations from the calculator suggested treating 37.9% (n = 53) with antibiotics, but 54.3% (n = 76) were treated empirically (Table 2, Table 3).

Provider Adherence

During the post-implementation phase, provider adherence, or lack thereof, was operationalized as two separate outcome measures: recommended EOS evaluation and unwarranted antibiotic utilization. The first measure of adherence was analyzed based on the number of calculator recommendations made to obtain an EOS evaluation compared to the number of EOS evaluations ordered by providers. Of the 357 newborns scored using the NEOS calculator during this period, providers obtained EOS evaluations on 82.9% (n = 295), despite recommendations made to evaluate only 208 newborns, indicating an overall adherence rate to this measure of only 58.2%. The second measure, unwarranted antibiotic administration, was defined as the number of newborns treated with antibiotics despite calculator recommendations to “observe” or “strongly consider” empiric antibiotics without the presence of additional risk factors such as a chest x-ray consistent with meconium aspiration syndrome. Of the 185 newborns treated with empiric antibiotics, provider adherence to the NEOS calculator recommendations was 51.6% (n = 95).

Discussion:

Summary and interpretation:

An overall decrease in empiric antibiotics by 20.3% was noted following the NEOS calculator’s implementation. Additionally, EOS evaluations declined by 17.4% during the post-implementation period, approaching the goal of 20% established for the QIP. Although these findings indicate improvement, they are less substantial than similar studies, which reported favorable results in reducing laboratory testing and a 38 to over 50% potential

reduction in antibiotic use with the introduction of the NEOS calculator over time. (26, 28, 31) These results may be attributed to the limited timeframe and the stepwise approach taken by the investigators to target a gradual reduction to assess the impact and feasibility of this intervention before projecting more substantial reductions.

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One phenomenon that was discussed among the investigators before the implementation of the NEOS calculator was that providers would possibly follow the recommendations from the calculator regardless of assessing EOS risk factors for each newborn. For example, a 36-week infant delivered by repeat C-section requiring CPAP with minimal risk of infection would still be classified as “clinical illness,” suggesting “strongly consider” or “begin” empiric antibiotics. In contrast, this newborn would have been evaluated while withholding empiric antibiotics before implementing the NEOS calculator. Subsequently, 82.2% of newborns treated during the post-implementation period and 68.3% during the pre-implementation period were categorized under clinical illness. This could be interpreted as the providers following the NEOS calculator suggestions indiscriminately rather than considering EOS risk factors in practice during the pre-implementation period.

The biggest quandary for providers during the QIP was trusting the recommendations of the NEOS calculator in two specific scenarios: observe without evaluation and evaluate and strongly consider antibiotics. More newborns received an EOS evaluation in the first scenario by a large margin, while most antibiotics administered under the second scenario could have been withheld initially. It is essential to highlight that many of the newborns categorized as clinical illnesses with minimal maternal risk factors for an infection

subsequently received empirical therapy. It is postulated that provider skepticism about the accuracy of the NEOS calculator contributed to unnecessary antibiotic administration. There was no evidence of increased severity of EOS with improved antibiotic stewardship utilizing the NEOS calculator. This further supports the findings of Cantey and Baird, who reported that providers' decisions to treat empirically might be related to concerns about false-negative blood culture results. (11)

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Limitations:

The major limitation of this QIP was the timeframe between the pre-implementation and post-implementation periods. Other limitations include a smaller sample size when compared to multi-site studies, as data were obtained from a convenience sample and limited to a single tertiary NICU. Another consideration related to sample size was the lack of inclusion of newborns with incomplete maternal records (n = 81), particularly for those admitted from outlying centers.

In addition, during the post-implementation period, there was a lack of ability to differentiate decision-making between the neonatologist and the NNP. Therefore, the physician of record on each admission note was utilized to assess adherence to the calculator. This lends to possible discrepancies in the decision-making process with the calculator among providers.

The sustainability of the NEOS calculator within the NICU was not evaluated beyond the QIP due to the facility’s change of ownership, the introduction of new EMR systems, and provider relocation. In 2020, there was a perception of periodic provider abandonment from the newly established EOS guidelines and indifference to the NEOS calculator despite the noted improvements in antibiotic stewardship without adverse outcomes.

Conclusions:

There is a utility for NEOS calculator use if providers are willing to accept an evidence-based guideline that utilizes maternal risk factors and close observation during the initial 12 to 24 hours

of life to guide treatment plans; however, resistance to change is expected in the NICU environment. Therefore, providers must address outdated unit practices and embedded beliefs to effectively implement and adopt best practices to improve patient outcomes and mitigate the adverse effects of unnecessary laboratory testing and unwarranted antibiotic administration in this vulnerable population.

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Since the most recent publications of guidelines for EOS of the newborn by the AAP in 2018, considerations to utilize an evidence-based protocol with close clinical assessment remains a sensible approach, especially considering that less than 1% of newborns admitted to the NICU are diagnosed with EOS. Another critical factor is to examine management practices and EOS incidence within individual units to facilitate a customizable option for practice. These decisions can be enhanced by providers carefully assessing maternal delivery attributes with newborns who fall under the clinical illness category.

Nursing and medical staff buy-in, or lack thereof, contribute significantly to the successful implementation, evaluation, and sustainability of QIPs within the NICU. Finally, the importance of provider accountability in establishing practices that improve the quality of care for patients, consumers, and healthcare organizations acceptable to the level of expenditures accompanying each NICU

admission cannot be underestimated.

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Corresponding Author



C. Martin Begnaud Jr. DNP, APRN, NNP-BC
Neonatal Nurse Practitioner
Our Lady of Lourdes Women's and Children's Hospital and
Pediatrix Medical Group
University of Louisiana at Lafayette, College of Nursing and
Health Sciences
411 E. St. Mary Blvd.
Lafayette, LA 70503
Email: begnaudjr@gmail.com



Jennifer Lemoine, Ph.D., DNP, APRN, NNP-BC
Professor and Interim Associate Dean
University of Louisiana at Lafayette
College of Nursing and Health Sciences
411 E. St. Mary Blvd.
Lafayette, LA 70503



Lisa Broussard, RN, DNS, CNE
Professor and Interim Dean
University of Louisiana at Lafayette
College of Nursing and Health Sciences
411 E. St. Mary Blvd.
Lafayette, LA 70503



*Roger Rholdon, DNP, APRN, CPNP-AC
Associate Professor
University of Louisiana at Lafayette
College of Nursing and Health Sciences
411 E. St. Mary Blvd.
Lafayette, LA 70503*



*Harshit Doshi, MD
Neonatologist
Golisano Childrens Hospital of Southwest FL
9981 S. Healthpark Dr.
Fort Myers, FL 33908*

