

**Implementation of a Clinical Decision Support System for Peripheral Intravenous
Extravasation Management**

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Abstract

Problem & Purpose: Neonates are particularly vulnerable to peripheral intravenous (PIV) infiltration and extravasation that can lead to necrotic tissue injuries and long-term complications. In an urban mid-Atlantic Level IV Neonatal Intensive Care Unit (NICU), there has been a 2.2-fold increase in the rate of extravasations in the last five years with poor documentation compliance of a paper checklist as part of the unit's PIV extravasation guideline. Evidence shows that the use of clinical decision support systems (CDSS) improves compliance with unit-based protocols. The purpose of this quality improvement (QI) project is to implement and evaluate the utilization of a CDSS into the EHR to improve PIV extravasation detection and guide management in a Level IV NICU. **Methods:** This QI project was implemented over a 15-week period in Fall 2021. Interventions included integration of a nursing PIV flowsheet in the EHR with staging guidance and updated SmartText for provider documentation. Weekly data collection consisted of the number of infants with PIV access, monthly adverse event reporting system reports of extravasations and chart audits for nursing and provider documentation. **Results:** At the end of implementation, the data reflected a rise in documented extravasations indicating utilization of the CDSS. Compliance with all elements of the CDSS documentation demonstrated a trend of increased documentation by nurses. An increase in provider notes for injuries with CDSS documentation reflected improved early recognition and RN to provider notification of injuries. Standardized CDSS documentation led to a decrease in incidence of stage 3 and 4 extravasations in the NICU. **Conclusions:** The implementation of a PIV clinical decision support system in the electronic charting system improved early recognition of extravasations and decrease severe tissue injuries resulting from stage 3 and 4 injuries. The sustainability of this project was achieved by integrating the CDSS into the EHR and next steps include continued

refinement of the EHR-generated reports for data collection, addition of the educational module to annual nurse competencies and clarifying language for signs of different stages of injuries in the unit guideline.

Peripheral intravenous (PIV) cannulation is essential in the management of critically ill neonates to provide fluids, blood transfusions, parenteral nutrition, and medications (Liew, Zhou, Chin, Davis-Tuck, & Malhotra, 2021). Common complications of PIV use include infiltration, extravasation, spontaneous dislodgment, and catheter-associated blood stream infection (Legemaat, Carr, van Rens, van Dijk, Poslawsky, & van den Hoogen, 2016). The literature often uses infiltration and extravasation interchangeably, thus for the purposes of this paper, extravasation will be used to describe both PIV-related injuries. The neonate's poor venous integrity, risk of capillary leakage, and decreased peripheral circulation make them particularly vulnerable to injury (Desarno, Sandate, Green, & Chavez, 2018). Extravasation can cause permanent skin, nerve, and/or tendon damage that can result in loss of movement over joints, need for surgical skin grafts, physical or occupational therapy due to scarring, and potentially loss of limb (Legemaat et al., 2016; Driscoll, Langer, Burke & El Metwally, 2015). In a mid-Atlantic level IV Neonatal Intensive Care Unit (NICU), the average rate of PIV extravasations was 20 infiltrates per 1000-line days between September 2020 and December 2020. For comparison, the average monthly rate of PIV infiltrations was 9 per 1000-line days in 2015. Interviews with staff revealed a lack of compliance with the unit's existing PIV extravasation guideline due to lack of knowledge or perception of the importance of a paper checklist to guide assessment and management. The current process is outlined in Appendix A and the post-implementation process is outlined in Appendix B. Baltimore city has the highest rate of premature births in the state and many health disparities exist among the patient population including poverty, lack of health insurance, social disparities and more. Complications associated with PIV injuries can increase length of stay and costs, which can be a substantial burden on patient families.

There is significant evidence on management strategies to reduce extravasation in neonates. Clinical practice guidelines are an effective way to optimize patient care and outcomes, although achieving compliance may pose a challenge. A clinical decision support system (CDSS) can be developed in a variety of forms including standardized order sets, alerts to a specific protocol, reminders for testing, and more can increase compliance to a clinical practice guideline. The use of a CDSS in these variations has been shown to improve clinical practice compliance (Sutton, Pincock, Baumgart, Sadowski, Fedorak, & Kroeker, 2020). The purpose of this quality improvement project was to implement and evaluate an EHR-integrated PIV CDSS in a Level IV NICU. The intended effects of this practice change were increased early recognition of peripheral intravenous site extravasations, improved adherence to the clinical guideline and reduced incidence of stage 3 and 4 tissue injuries.

Literature Review

The feasibility and effectiveness of an EHR-integrated clinical decision support system in patient management is the focus of this evidence review. A review and synthesis of the evidence are presented in Table 1 and Table 2.

Two systematic reviews were identified that support the use of clinical decision support systems in clinical guideline adherence. Bright et al. (2020) conducted a systematic review and identified 148 RCTs to evaluate the impact of CDSSs on clinical outcomes, health care processes, workload and efficiency, patient satisfaction, cost and provider use and implementation. The review concluded that both commercially and locally developed CDSSs improved health care process measures related to performing preventive services, ordering clinical studies, and prescribing therapies. A systematic review completed by Jia et al. (2019) identified 24 RCTs that examined the impact of clinical decision support systems for insulin

practices on changes in glucose for diabetics. Measures of studies included in this review looked at mean blood glucose levels, HbA1c and number of hypoglycemia events. The review concluded that CDSS interventions can effectively change insulin dosing compared with paper-based insulin protocols.

A randomized controlled trial by Kharbanda et al. (2018) evaluated the implementation of an EHR-integrated CDSS on recognition of hypertension in adolescents. The CDSS included up to three best practice alerts (BPA) based on patient information (blood pressure and growth metrics) entered into the electronic medical record. If the entered data met alert criteria, the provider would receive a BPA with links to the CDSS and a patient-tailored order set with suggested diagnoses and orders. This study took place in 20 outpatient clinics and was integrated into the electronic health record to assist in hypertension recognition and intervention in a pediatric population. The results of the study showed that a linked CDSS tool was well accepted among providers and resulted in an improved recognition of hypertension. The CDSS also increased guideline-adherent care, including referrals to dietitians and cholesterol screening, but these occurred at rates below the target metrics despite showing an improvement in both groups (Kharbanda et al., 2018).

Two observational pre-post intervention studies were identified in the review of literature. Ebinger et al. (2019) assessed the effectiveness of the use of EHR-based tool and CDSS alerts on improving the use of bleeding avoidance strategies and bleeding event rates in adult patients who underwent percutaneous coronary intervention. It was concluded that integrating guideline recommendations into the electronic medical record to promote assessments of bleeding risk and use of bleeding avoidance strategies was feasible and associated with changes in clinical practice. Arain et al (2020) was a non-randomized pre-post intervention

study that evaluated the adoption of an EHR-integrated CDSS to improve adherence to hyperbilirubinemia management in infants from 27 to 34 weeks post menstrual age. Measures evaluated in the study included adherence to phototherapy initiation, number of times the CDSS was accessed via the EHR during the study period, and the rate of severe hyperbilirubinemia. Arain et al. (2020) supports the use of CDSS in the NICU setting to improve clinical outcomes for premature infants. The results of both studies conclude that the implementation of a CDSS to change clinical practice is feasible and improves adherence to clinical guidelines.

Across these studies, this evidence review demonstrates that EHR-integration and agreement with protocols by participants are elements necessary for successful CDSS implementation that leads to favorable patient outcomes.

Theoretical Framework

The Diffusion of Innovation Theory by E.M. Rogers explains how, over time, an innovation gains momentum and spreads/diffuses through a system, resulting in the adoption of something different than what is already established (Rogers 1962; Rogers, 2003). The main content of the theory includes innovation, communication, channels, time, and the social system (Rogers, 1962; Rogers, 2003). See Figure 1. The “innovation” of this project is the clinical decision support system flowsheet, communication about the project will be disseminated through established channels including mass emails, educational modules, the Epic “playground,” and presence of champions on the unit during go-live. The timeframe of this implementation project was September 2021-December 2021, and the “social system” is the identified NICU, and the different roles staff carries out on the unit. The theory establishes that adoption of the innovation is a process whereby the target population consists of five different adopter categories, including innovators, early adopters, early majority, late majority, and

laggards (Rogers, 1962; Rogers, 2003). Understanding the characteristics of these different types of adopters is important to identify strategies that appeal to each group and improve success of adoption. Strategies included identifying champions and stakeholders to establish a workgroup to support implementation, dissemination of outcomes to staff through mass emails, and maintaining open communication via email and in person interviews. The application of this theory to this implementation project contributed to successful adoption of the CDSS for PIV extravasations in the NICU.

The Framework for Complex Innovations described by Helfrich et al. (2007) posits that innovation implementation is successful where there is the presence of an innovation champion and the fit between the innovation and the values of innovation users. The framework hypothesizes that effective innovation implementation is a function of management support and resource availability, mediated by the organization's specific implementation policies and practices and the ensuing implementation climate. The first focus used to leverage support for this project was garnering management support by presenting the practice problem and proposed solution at several organizational levels. Discussions with several clinicians and organizational leaders, including the NICU nurse manager and the director of the division all resulted in achieving buy-in for the implementation of a CDSS to improve recognition of PIV-related tissue injuries and decrease incidence of severe tissue injuries. Another key focus identified by Helfrich et al. (2007) is the importance of coordinated use of complex innovations by multiple organization members. Several stakeholders at different levels of the organization have been identified and are actively participating in data collection, education, IT support, and use of most updated evidence. This would ideally support the organizational climate for implementation by

including individuals who will directly utilize and support the use of the CDSS (Helfrich et al., 2007).

Methods

This QI Project was conducted over 15 weeks in Fall 2021 in a Level IV NICU located in a mid-Atlantic urban academic medical center. All infants in the NICU with a PIV were included for data collection and there were no exclusion criteria. During implementation, no patients or human subjects were at risk. The local Institutional Review Board approved this QI project and determined the project to be a Non-Human Subjects project.

The first structural change was the creation of the CDSS using the unit's "Neonatal Extravasation and Infiltration Management Guideline." To increase utilization, the CDSS was integrated into the EHR and designed to automatically populate in "Lines/Drains/Airway" flowsheets when "infiltration" or "extravasation" was documented for a PIV site assessment (see Appendix C). Organization policies require hourly assessment and documentation of PIVs, so incorporation into the EHR decreased interruptions to established nursing practices.

The practice change was promoted by a multidisciplinary team of champions made up of several nurses, the lead neonatal nurse practitioner, and the neonatal medical director and was led by the QI Project Leader (QI-PL). The QI-PL organized meetings with the multidisciplinary team and stakeholders such as IT personnel to develop the CDSS and disseminate data. Nurse champions were educated regarding project goals and changes to the EHR including the updated flowsheet and provider SmartText Notes. They played an important role in answering staff questions and communicating barriers and questions to the QI-PL throughout implementation.

During pre-implementation, baseline data was collected by the QI-PL including the number of infants with peripheral IV access and the number of reported PIV extravasations with

completed paper checklist and EHR documentation (see Appendix E). Meetings were held with champions to discuss goals of the project, data tracking plans during implementation, and an overview of the updates to the EHR, including the CDSS and SmartText notes.

During the 15-week implementation phase, the nursing flowsheet was integrated into the EHR, and an educational PowerPoint (Appendix D) was assigned to NICU staff through the organization's education platform. The project goals included 100% of staff educated on the implementation, 100% of identified extravasations having all elements of the CDSS documented, 100% of stage 3 and 4 injuries documented with the CDSS having a corresponding provider note and a decrease in stage 3 and 4 tissue injuries. The QI-PL completed weekly PIV counts using the daily charge nurse assignment sheet and weekly chart audits using an audit tool created to evaluate for nursing compliance of flowsheet use, assigned injury stage, management, and provider use of SmartText notes. Any protected health information collected by the QI-PL was only recorded and accessible to the QI-PL throughout the project timeline. Random codes were subsequently assigned to each patient and used for all other data collection. Staff names were not included in documentation to protect privacy. The QI-PL retrieved and recorded coded data manually in an excel database in a private office with the door closed for confidentiality. Descriptive analysis was completed for number of staff educated, rate of different stages of injuries per month, compliance with CDSS documentation and provider documentation. See Appendix E for the Data Collection Tools and Figures 3 to 6 for run charts and bar charts demonstrating trends in the data.

Results

Following activation of the nursing flowsheet, the educational module describing the changes and reviewing assessing and managing PIV-related injuries was assigned to all NICU nurses on staff.

By the end of implementation period, approximately 82% of staff had successfully completed the educational module. One challenge in achieving the process goal of 100% of staff being educated was that a delay in distribution of the education module resulting from several quality improvement projects being implemented at one time on the unit with several education modules needing to be assigned to staff. Throughout implementation, reminders were sent to staff via email and face to face conversations to discuss education and remind staff to complete the assigned education if they were actively employed. The data trends increased after reminders were sent indicating that the use of email reminders and face to face dialogue were useful strategies (Figure 3).

In the first several weeks of the implementation period, data trends showed an increase in documented stage 3 and 4 tissue injuries (Figure 6). Chart audits and in person interviews revealed that the clinical sign of “blanching” was often inappropriately documented for PIV assessments, which may have contributed to an increase in documented stage 3 injuries. To address this trend, the education PowerPoint was amended, and a mass email was sent to clarify the definition of this finding with examples of what to look for. The QI-PL discussed this finding with champions so that they could appropriately answer questions. By the end of implementation there was an increase in documentation of stage 1 and 2 injuries and a decrease in stage 3 and 4 injuries (Figure 6). These mass emails also reiterated proper use of the CDSS and reminders of choosing the correct site assessment for the CDSS to populate. This was a useful tactic which is demonstrated by the increase in CDSS use at weeks 7 and 10 demonstrated in figure 4.

At the beginning of data collection, the number of injuries and the stages were only being reported via the organization adverse event reporting system. If staff did not submit a report for an extravasation injury, it would not be formally reported for data collection purposes. This could lead to inaccuracies and misinterpretation of data. To address this barrier, the QI-PL and IT specialist met to create an EHR-generated report based on the CDSS flowsheet for patients in the NICU. Generating and refining these reports throughout implementation allowed for more accurate data collection and analysis. This also likely explains the increase in reported injuries in the last several weeks of implementation (Figure 6).

Data trends suggest that there has been an increase in documented PIV-related tissue injuries in the NICU, though no consistent documentation of these injuries were recorded prior to project implementation. There was an initial rise in stage 3 to 4 injuries in the first several weeks of the implementation phase, likely due to increased recognition and improved documentation practices. In the last several weeks, an increase in stage 2 injuries have been documented with a decrease in stage 3-4 injuries. This may reflect improving recognition of early signs of infiltration or extravasation with earlier management and removal in line with guideline recommendations via the CDSS. Throughout the project 76.7% of all infiltrates (23/30) had all elements of the CDSS documented in the EHR and 100% of stage 3 and 4 injuries with CDSS documentation had a corresponding provider note. Of all documented injuries, 72% had a corresponding provider note, despite the guideline only requiring provider notification for stage 3 and 4 injuries. These results suggest that the CDSS played a role in improving RN's notifying providers of injuries and prompted early treatment.

Discussion

The CDSS for PIV extravasation in the NICU brought increased awareness to extravasation tissue injuries and proper use of the unit guideline for assessment and management. This was demonstrated through increased use of CDSS for documentation of injuries, increased provider notes using the extravasation SmartText template in the EHR, a decrease in stage 3 and 4 injuries at the end of implementation compared to baseline, and appropriate medication administration for all documented stage 3 and 4 injuries.

Throughout the implementation period, 100% of documented stage 3 and 4 injuries received appropriate medication therapy. This result supports the findings outlined in Bright et al. (2020) concluding that CDSS's improve healthcare process measures related to performing preventative services and prescribing therapies. The project trend of increased CDSS use to 76% at the end of the implementation period supports the conclusions by Jia et al. (2019) that use of CDSS can change clinical practices when compared to paper-based protocols. By replacing the units paper checklist with the PIV CDSS, this NICU saw an increase in identification and documentation of tissue injuries, indicating appropriate and successful use. This also supports Kharbanda et al. (2018) conclusion that an EHR-integrated CDSS results in improved recognition of a diagnosis and increases guideline-adherent care. Lastly, the successful implementation of the CDSS in this NICU with a decrease in severe tissue injuries supports the conclusions of Arain et al. (2020) that the use of a CDSS improves clinical outcomes in the NICU.

It was anticipated that there would be an increase in total number of extravasations at the end of the project compared to baseline because there was poor compliance with documentation prior to implementation. Initially, nurses and providers had a different understanding of the definition of stages in the early stages of the implementation period. Collaboration and

communication led to identification of this barrier and allowed leaders to provide clarification for staging of injuries occurring during implementation. Formal dialogue for improvements and clarification in the guideline and CDSS can be addressed in future steps for this project. It was also not anticipated that there would be provider notes for injuries that were less than stage 3 or 4 injuries. However, many stage 1 and 2 injuries had corresponding provider notes which indicates that nurses were alerting providers of injuries more frequently compared to baseline. Nursing staff and providers reported satisfaction with the transition to the EHR-integrated CDSS compared to the paper checklist and reported that they were more cognizant of the guideline due to the CDSS auto populating in the EHR.

This project was limited due to a small sample size and difficulties with data collection prior to the creation of the EHR-generated reports. The results may be more generalizable if the CDSS is implemented across all NICUs within the medical system. However, this may not be applicable to other NICUs that do not have comparable number of PIV days and thus have a lower risk for vesicant injuries or NICUs that do not utilize a similar guideline. Establishing a NICU PIV Extravasation guideline that is used throughout the entire system would help to minimize this limitation.

Conclusion

Implementation of an EHR-integrated PIV CDSS improved recognition and management of extravasations in this NICU. Buy-in from management, IT, nursing staff and providers was essential in the success of this project. While there was an overall increase in rate of extravasations by the end of this project, there was a decrease in severe tissue injuries for the patients in the NICU. This is extremely beneficial to patient outcomes and decreasing the related cost of care from these injuries including length of stay, medication and need for additional

therapies. The use of change champions for this project was crucial to success as this is a very large unit with a lot of staff. Having champions that were regularly present on the unit allowed for gaps to be identified quickly and for barriers to be addressed and relayed to the QI-PL.

Barriers related to the language of the guideline and educating all staff are being addressed by continuing to update the educational module with feedback from staff. The lead advanced practice provider and a senior clinical nurse are working together with the clinical educator to ensure that education is included in annual competencies and that each new hire is assigned the education when they start their orientation process. More research is needed in the neonatal population to define the stages of injuries so a consensus can be reached for the clinical practice guideline.

The success of this project supports the use of a CDSS to improve adherence to clinical practice guidelines. As other gaps in practice are identified, unit leaders are aware that the use of a CDSS is a feasible, cost effective and useful tool in improving clinical processes and outcomes.

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Tables

Table 1.

Evidence Review Table

<p>Citation: Kharbanda, E. O., Asche, S. E., Sinaiko, A. R., Ekstrom, H. L., Nordin, J. D., Sherwood, N. E., Fontaine, P. L., Dehmer, S. P., Appana, D., & O’Connor, P. (2018). Clinical decision support for recognition and management of hypertension: A randomized trial. <i>Pediatrics</i>, 141(2), e20172954. https://doi.org/10.1542/peds.2017-2954</p>					Level II
Purpose/Hypothesis	Design	Sample	Intervention	Outcomes	Results
<p>“We evaluated whether an electronic health record–linked clinical decision support (CDS) tool could improve the recognition and management of hypertension in adolescents.”</p>	<p>Nonrandomized cluster-randomized trial</p>	<p>Sampling Technique: Convenience, primary care clinics within an integrated care system</p> <p>Inclusion criteria: Patients between the ages of 10 and 17 years who met clinical criteria for incident hypertension during primary care visits at study sites between April 15, 2014 and April 14, 2016 were eligible for inclusion</p> <p>Exclusion Criteria: Patients who were pregnant or ≤12 weeks postpartum were excluded. Accepted: 31,579 patients 10 to 17 years of age with at least 1 BP recorded</p>	<p>Control: Usual care group (10 clinics)</p> <p>Intervention: Clinical decision support group (10 clinics)</p> <p>At intervention sites, the CDS displayed BPs and percentiles, identified incident hypertension based on current or previous BPs, and offered tailored order sets. The recognition of hypertension was identified by an automated review of diagnoses and problem lists and a manual review of clinical notes, antihypertensive medication prescriptions, and diagnostic testing.</p> <p>Intervention fidelity: Generalized linear mixed models were used to test</p>	<p>The primary outcome was the recognition of hypertension. This was a composite outcome based on at least 1 of the following: (1) outpatient discharge diagnosis of hypertension (ICD-9 401-405 and ICD-10 I10) or elevated BP (ICD-9 796.2 and ICD-10 R03.0), (2) hypertension or elevated BP documented in the clinical note, (3) hypertension or elevated BP documented in the after-visit summary, (4) hypertension or elevated BP added to the problem list, (5) a workup for secondary causes of hypertension or end-organ damage, or (6) antihypertensive</p>	<p>Among the 10 TeenBP CDS clinics and between April 15, 2014 and April 14, 2016, there were 17 037 patients 10 to 17 years of age with at least 1 BP recorded. Of these, 296 (1.7%) had incident hypertension. At the 10 UC clinics over the same time period, there were 14 542 patients 10 to 17 years of age with at least 1 BP recorded and 226 (1.6%) with incident hypertension</p> <p>Within 6 months of meeting the criteria for incident hypertension, 54.9% of the CDS patients versus 21.3% of the UC patients were clinically recognized ($P < .001$). Recognition was most commonly</p>

		<p>Group Homogeneity: Of the 31 579 patients with at least 1 BP, the majority (63.5%) were white, non-Hispanic (94.2%), and privately insured (92.6%). The final population meeting the criteria for incident hypertension was similar to the larger cohort with the exception of having a higher proportion of girls (56.7% vs 49.7%). Patient and visit characteristics did not vary significantly between the CDS and usual care groups</p>	<p>the effect of the intervention. Exact BP percentiles were calculated consistent with the Fourth Report and the Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents, the guidelines that were in use during the time of the study. Differences by study arm in baseline characteristics were tested with Pearson’s χ^2 test, Fisher’s exact tests, and independent sample <i>t</i> tests. Generalized linear mixed models with a logit link and a random intercept for clinic were used to test the effect of the intervention on binary outcomes of the clinical recognition of hypertension. Each model included a binary indicator for study arm and the following a priori-selected covariates: SBP percentile at the index visit, BMI percentile at the index visit, and index visit type (well-child or acute and/or follow-up visit). Adjusted, model-predicted proportions and</p>	<p>medication being prescribed.</p>	<p>achieved by having hypertension or elevated BP as a discharge diagnosis at an outpatient encounter, in a clinical note, or in the patient discharge instructions. Only 10.1% of patients at intervention clinics and 5.2% of patients at UC sites had hypertension or elevated BP added to their problem lists.</p> <p>Referrals to dietitians or weight loss or exercise programs were more common in CDS patients (17.1%) versus UC patients (3.9%; <i>P</i> = .001). Among the 256 CDS patients and 205 UC patients who were eligible for lipid screening, 14.4% of CDS versus 5.3% of UC patients had lipid screenings completed (<i>P</i> = .03). The provision of antihypertensive medication within 6 months of meeting the criteria occurred in 1% of intervention patients and 0.4% of UC patients (<i>P</i> = .48).</p>
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			95% confidence intervals are reported for each outcome. Similar models were developed to evaluate differences in diagnostic workups, referrals, and lipid screenings by study arm. All analyses were 2 sided, and <i>P</i> values of <.05 were considered statistically significant. Corrections for multiple comparisons were not conducted. All analyses were conducted with SAS version 9.4 (SAS Institute, Inc, Cary, NC). Survey results were evaluated by using descriptive statistics.		The implementation of the TeenBP EHR-linked CDS across the 10 CDS intervention clinics increased hypertension recognition to 54.9%.
<p>Citation: Bright, T. J., Wong, A., Dhurjati, R., Bristow, E., Bastian, L., Coeytaux, R. R., Samsa, G., Hasselblad, V., Williams, J. W., Musty, M. D., Liz Wing, Kendrick, A. S., Sanders, G. D., & Lobach, D. (2012). Effect of clinical decision-support systems. <i>Annals of Internal Medicine</i>, 157(1), 29–43. doi: 10.7326/0003-4819-157-1-201207030-00450</p>					Level I
Purpose/Hypothesis	Design	Sample	Intervention	Outcomes	Results
“To evaluate the effect of CDSSs on clinical outcomes, health care processes, workload and efficiency, patient satisfaction, cost, and provider use and implementation.”	Systematic review (SR) with meta-analysis	<p>Search Strategy: A search was conducted for studies done between January 1976 and January 2011 in MEDLINE accessed through PubMed, CINAHL, PsycINFO, and Web of Science.</p> <p>Data related to study setting and design,</p>	<p>Control: The controls of the studies included in the SR were usual care or no CDSS, or the same CDSS with additional features.</p> <p>Intervention: Interventions in the studies in the SR were predominantly automatically delivered, system-initiated</p>	<p>Dependent Variable: Outcomes of the studies included in the SR include health care process measures (performing preventative services, ordering clinical studies, and prescribing therapies) clinical outcomes, and costs.</p>	<p>Level of Measurement: Meta-analysis of studies conducted using the DerSimonian and Laird Random Effects Model. Researchers used narrative analysis and descriptive statistics where meta-analysis was not possible.</p>

		<p>sample characteristics, intervention characteristics, comparators, and outcomes were extracted by 1 reviewer and confirmed by another. Two reviewers used a standardized approach to independently categorize the quality of individual studies as good, fair, or poor and evaluated the overall strength of evidence for each outcome as high, moderate, low, or insufficient. Reviewers also identified issues related to study setting, interventions, and outcomes that limited applicability of evidence.</p> <p>Eligible: RCTs of CDSSs implemented in a real clinical setting and used by health care providers to aid decision making at the point of care or for a specific care situation. Studies had to report at least one of the following types of outcomes: clinical, health care process, user workload and</p>	<p>recommendations provided synchronously at the point of care to enable decision making during the health care provider–patient encounter. Some studies required a mandatory response by the provider or justification for not adhering to the recommendation.</p> <p>Protocol: Not applicable to SR critique</p>	<p>Measure: Length of stay, morbidity, mortality, health-related quality of life, adverse events; health care processes (recommended preventative care, clinical study, or treatment ordered or completed); user knowledge, number of patients seen, clinician workload, and efficiency; patient satisfaction; cost and cost effectiveness; acceptance, satisfaction, use and implementation by health care provider</p>	<p>A priori–defined outcomes believed to be important in measuring the effect of CDSSs in improving clinical practice guided the synthesis process. Studies with a common outcome were grouped together to facilitate qualitative analysis. Quantitative analysis was done where 4 or more studies assessed the same outcome in the same manner, regardless of the specific CDSS intervention.</p> <p>Outcome Data Retrieval: Researchers pooled data from all selected articles.</p> <p>Analysis: Both commercially and locally developed CDSSs improved health care process measures related to performing preventive services ($n = 25$; odds ratio [OR], 1.42 [95% CI, 1.27 to 1.58]), ordering clinical studies ($n = 20$; OR, 1.72 [CI, 1.47 to 2.00]), and prescribing</p>
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		<p>efficiency, relationship-centered, economic, or use and implementation by a health care provider.</p> <p>Excluded: Studies that described nonelectronic CDSSs, included fewer than 50 participants, were not published in English, described closed-loop systems that did not involve a provider, evaluated systems that required mandatory compliance with the CDSS, or evaluated only the performance of the system as opposed to its effect on clinical practice.</p> <p>Included: 148 randomized control trials were included. A total of 128 studies (86%) assessed health care process measures, 29 (20%) assessed clinical outcomes, and 22 (15%) measured costs. Many studies ($n = 51$) were performed in environments with established health information technology (IT); many were multisite studies in-</p>			<p>therapies ($n = 46$; OR, 1.57 [CI, 1.35 to 1.82]).</p> <p>Conclusions: Clinical decision support had a favorable effect on prescribing treatments, facilitating preventive care services, and ordering clinical studies across diverse venues and systems.</p> <p>SR Bias Risk: based on the methodology described, bias risk is low</p>
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		<p>volving multiple institutions ($n = 46$). Studies were primarily conducted outside of institutions with an established health IT infrastructure.</p> <p>PRISMA: Included detailing decision-making criteria for retaining/omitting studies from the SR</p> <p>Power analysis: Not applicable to SR critique</p>			
<p>Citation: Ebinger, J., Henry, T., Sungjin Kim, Moira Inkelas, Cheng, S., Nuckols, T., Kim, S., & Inkelas, M. (2019). Development and evaluation of novel electronic medical record tools for avoiding bleeding after percutaneous coronary intervention. <i>Journal of the American Heart Association</i>, 8(22), 1–11. doi: 10.1161/JAHA.119.013954</p>					Level IV
Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results
<p>“Our institution, having observed that post-PCI bleeding event rates were above the national average, thus established a quality improvement (QI) initiative with 3 basic components: (1) An established risk prediction model was used to create a bleeding risk calculator in the EMR; (2) clinical decision alerts were created to notify physicians before PCI if patients were high</p>	<p>Quasi experimental study; nonrandomized, pre-post intervention study</p>	<p>Sampling Technique: Convenience</p> <p>Inclusion criteria: Any percutaneous coronary angioplasty, with or without stent placement, performed by either a faculty or private practice physician.</p> <p>Exclusion Criteria: patient < 18 years at time of PCI; hemoglobin <8 or >16 g/dL before PCI; unplanned placement</p>	<p>Control: Pre intervention implementation measures</p> <p>Intervention: A voluntary clinical decision alert to assess bleeding risk before percutaneous coronary intervention (PCI), a bleeding risk calculator tool, and when indicated, a second alert to consider 4 bleeding avoidance strategies.</p> <p>Intervention fidelity: Given that this an order must be placed in the</p>	<p>Dependent Variable: (1) use of the electronic medical record-based intervention tool (2) Use of bleeding avoidance strategies and bleeding event rates before and after implementation</p> <p>Time: For the before versus after analyses, the independent variable was whether the PCI was performed before (September 30, 2014 to February 9, 2016) or after</p>	<p>Statistical Procedures(s) and Results: Data are presented as frequency (percentage, %) for categorical variables and mean (SD) for continuous variables. Correlated data from the same subject were taken into account in all analyses. Patient characteristics were compared for eligible PCIs before versus after implementation of the BRC, as well as for</p>

<p>risk; and (3) a system was created to monitor changes in care processes and outcomes related to PCI and bleeding events. In the current analysis, we sought to examine the feasibility and effectiveness of this QI initiative. We specifically assessed adherence to the new EMR-based tool and also performed pre-post analyses that included 2 outcomes: (1) use of bleeding avoidance strategies and (2) bleeding event rates. Given that attention has traditionally been focused on high- risk patients, who represent a minority of those undergoing PCI, we stratified analyses of care and outcomes by level of risk for bleeding.</p>		<p>on extracorporeal membrane oxygen before or during PCI; coronary artery bypass graft during the same hospitalization or within 30 day of PCI; or death on the same day as the PCI. Accepted: 4867 met eligibility criteria, including 1965 before and 2902 after implementation of the intervention. Control: No control, nonrandomized study. Group Homogeneity: Patients were similar in regard to bleeding risk, age, male sex, preprocedural creatinine, preprocedural hemoglobin and other clinical covariates.</p>	<p>EMR before all PCIs, placing this order was used as the trigger for the BRC tool, which prompted users to input the required data to calculate a bleeding risk score based on the NCDR risk prediction model. The risk score could be calculated by any member of the cardiology team involved in a patient’s care, with the result provided to the attending interventional cardiologist. The alert was not a “hard stop,” allowing providers to skip risk stratification. The resultant score from the BRC tool subsequently posted to the patient’s chart in the EMR (in the title bar and nursing flow sheet). For patients found to have a high- or intermediate-risk score, the CDS alert prompted the user to consider use of the bleeding avoidance strategies. If a user did not use the BRC tool to generate a score, no CDS alert fired for that patient.</p>	<p>implementation of the intervention (February 9, 2016 to September 30, 2017). For analyses examining associations between adherence to the tool and care processes and outcomes, use versus nonuse of the BRC tool after implementation (February 9, 2016 to September 30, 2017). The use of the BRC tool and bleeding rates were tracked weekly by the Division of Cardiology’s Director of Quality and Physician Outreach. Providers with low performance in BRC tool use or high bleeding event rates were notified by e-mail or in-person meeting. Both use rates of the BRC tool and bleeding event rates were reported quarterly to the Quality Council. Measurement: (1) use of the BRC tool (yes or no); (2) use of any of 4 specific bleeding avoidance strategies (yes or no); and (3) the occurrence</p>	<p>PCIs in the implementation period in which the BRC was used versus not used, with logistic regression models accommodating correlated data using generalized estimating equations, assuming exchangeable correlation between observations on the same patient. Logistic regression models considering correlated data were further used in univariate and multivariable analyses of bleeding events. 2 sets of multivariable analyses of bleeding events with predictor variables were completed, before versus after implementation and use versus nonuse of the BRC tool after implementation. Multivariable analyses were carried out by entering covariates into the model and using a backward variable selection method with an alpha level of removal of 0.1 while a predictor variable was forced into the model. All analyses were done</p>
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				<p>of a bleeding event (yes or no). In the latter 2 analyses, a secondary analysis stratified patient by risk of bleeding (low risk, intermediate risk, high risk).</p> <p>Reliability and Validity: Not reported</p>	<p>using SAS software (version 9.4; SAS Institute Inc., Cary, NC) with 2- sided tests and a significant level of 0.05.</p> <p><i>Before vs After Implementation:</i> Near universal use of at least 1 bleeding avoidance strategy occurred both before and after implementation (99.7% versus 99.9%; P=0.143). Following introduction of the BRC tool and CDS alert, the use of individual bleeding avoidance strategies changed on univariate analyses, with an increase in radial access (47.6% versus 64.8%; P<0.001) and a decrease in glycoprotein IIb/IIIa inhibitor use (12.8% versus 3.17%; P<0.001). There was no difference in use of femoral closure devices among femoral procedures (95.3% versus 94.5%; P=0.408). Use of bivalirudin declined (1.48% versus 0.59%; P=0.004). Use of radial</p>
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					<p>access and avoidance of IIb/ IIIa inhibitors increased across all bleeding risk categories. The unadjusted bleeding event rate was 5.5% before implementation and 4.4% after (P=0.08). Stratification by bleeding risk did not change these findings. In multivariable analysis after adjusting for bleeding risk, preprocedural hemoglobin, smoking status, dyslipidemia, and previous CABG, bleeding event rates were similar before and after implementation (odds ratio, 0.82; 95% CI, 0.63–1.08; P=0.164;). Comparing the types of qualifying bleeding events before versus after implementation, the percentage of PCIs followed by a drop in hemoglobin declined (3.3% versus 2.3%; P=0.05) whereas the percentage associated with frank bleeds within 72 hours rose (1.5% versus 2.4%; P=0.03).</p>
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					<p>In univariate analyses, the bleeding event rate was significantly lower for PCIs involving use of the BRC tool versus nonuse (3.5% versus 5.1%; P=0.040; Figure 4). Stratified by bleeding risk, use of the BRC tool was only associated with a reduction in the unadjusted bleeding event rate among intermediate-risk PCIs (low risk, 0.4% versus 1.2%; P=0.281; intermediate risk, 3.5% versus 1.8%; P=0.041; high risk, 10.5% versus 9.3%; P=0.560). In multivariable analyses after adjusting for bleeding risk, preprocedure hemoglobin, smoking status, and previous coronary artery bypass grafting, the bleeding event rate was similar when physicians used versus did not use the BRC tool (odds ratio, 0.71; 95% CI, 0.48–1.04; P=0.079).</p>
<p>Citation: Jia, P., Jia, P., Chen, J., Zhao, P., & Zhang, M. (2020). The effects of clinical decision support systems on insulin use: A systematic review. <i>Journal of Evaluation in Clinical Practice</i>, 26(4), 1292–1301. doi: 10.1111/jep.13291</p>					<p>Level I</p>
<p>Purpose/ Hypothesis</p>	<p>Design</p>	<p>Sample</p>	<p>Intervention</p>	<p>Outcomes</p>	<p>Results</p>

<p>“To determine whether CDSS can facilitate better insulin use and increase satisfaction of the process of managing glucose control.”</p>	<p>Systematic review (SR)</p>	<p>Search Strategy: A comprehensive search was conducted in PubMed, Embase, and Cochrane Central Register of Controlled Trials (CENTRAL) from their inception to October 2018 and selected English-only publications. ClinicalTrials.gov was searched to identify additional eligible clinical trials. Multiple keywords and Medical Subject Headings (MeSH) terms for the interventions including, but not limited to, “decision support systems, clinical,” “diagnosis, computer assisted,” “therapy, computer assisted,” “drug-therapy, computer assisted,” and “expert system.” The search terms were customized for different databases No limitations were made on the outcomes.</p> <p>Eligible: Randomized control trials involving CDSSs interacting with users to generate tailored content that aimed to improve one</p>	<p>Control: The control of the studies included in the SR was users did not undergo any CDSS interventions</p> <p>Intervention: Interventions of the studies included in the SR were that the CDSSs interacted with users to generate tailored content that aimed to improve one or more insulin treatment domains.</p> <p>Protocol: Not applicable to SR critique.</p>	<p>DV: Researchers selected articles with outcomes related to the beneficial or harmful effect of the CDSS in relation to the use of insulin, glucose control, health-related quality of life and economic outcome.</p> <p>Measure: Daily insulin requirements (dose), mean blood glucose levels, HbA1c, hypoglycemic events, self-reported understanding of treatment and quality of interaction with physician, length of hospital stay</p>	<p>Level of Measurement: Meta-analysis was not undertaken because of the heterogeneity in the studies in this SR. Mean, standard deviations (SDs), median, or interquartile range (IQR) was used for continuous variables, and dichotomous variables were presented as odds ratio or rate ratio. Researchers presented results in narrative and tabular form based on the interventions and the textual description clustered based on outcome.</p> <p>Outcome Data Retrieval: Researchers pooled data from all selected articles.</p> <p>Analysis: Researchers reviewed results from all studies included in the SR and presented them in narrative and tabular form based on the interventions and the textual description clustered based on outcome.</p>
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		<p>of more insulin treatment domains through alerting, interpreting, critiquing, assisting, diagnosing, and managing. Populations of studies included consisted of patients who were expected to require an insulin treatment.</p> <p>Excluded: Studies were excluded from the SR if they were (1) non-RCTs (2) no CDSS (3) no insulin (4) analysis of factors that influence the use of CDSS (5) behavior change interventions (6) review (7) health information technology.</p> <p>Included: 24 RCTs with a total of 7653 participants were included. The studies were conducted in diverse settings including intensive care units, outpatient clinics, and hospitals. Most studies were completed in developed countries, 6 of which were in the United Kingdom and remainder were in</p>			<p>Conclusions: CDSSs have potential for improving insulin use and blood glucose control, as the patients in the computerized insulin dose adjustment group experienced a reduction in mean blood glucose levels and the HbA1c.</p> <p>SR Bias Risk: Based on criteria described, the bias risk is low.</p>
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		<p>America, Germany, Italy and Spain. 17 trials were supported by public funding.</p> <p>PRISMA: Included detailing decision-making criteria for retaining/omitting studies from the SR</p> <p>Power analysis: Not applicable to SR critique</p>			
<p>Citation: Arain, Y., Banda, J.M., Faulkenberry, J. <i>et al.</i> (2020). Clinical decision support tool for phototherapy initiation in preterm infants. <i>Journal of Perinatology</i>, 40(10), 1518–1523. https://doi.org/10.1038/s41372-020-00782-0</p>					Level IV
Purpose/Hypothesis	Design	Sample	Intervention	Outcomes	Results
<p>“We hypothesized that adoption of an electronic health record integrated clinical decision support (CDS) tool would improve adherence to phototherapy guidelines.”</p>	<p>Quasi experimental study; nonrandomized, pre-post intervention study</p>	<p>Sampling Technique: Convenience</p> <p>Inclusion criteria: premature infants with chronologic age greater than 48 hours and post menstrual age of 27 weeks and 0 days through 34 weeks and 6 days</p> <p>Exclusion Criteria: Infants with PMA > 34 weeks and 6 days</p>	<p>Control: Pre intervention implementation measures</p> <p>Intervention: Premie BiliRecs™ (PBR, pbr.stanfordchildrens.org) is a freely available web-based CDS tool for phototherapy initiation and exchange transfusion in preterm infants from 27 through 34 weeks PMA. The process included (1) extrapolation of expert consensus guidelines into a discrete, computable form; (2) development of the web tool; (3) definition of the</p>	<p>Dependent variable: Adherence to guidelines for initiation of phototherapy</p> <p>Measures: In the pre-intervention period, adherence was defined as the proportion of phototherapy initiation events associated with TB values meeting the more conservative (lower TB) consensus-based guideline treatment threshold. In the post-intervention period, adherence was</p>	<p>Adoption: Adoption of PBR was rapid and sustained over time; during the intervention period, the CDS tool was accessed a total of 3372 times from the EHR by an average of 42 unique users per month. PBR was used on an average of 20 unique patients per month</p> <p>Guideline adherence: In the pre-intervention period, the adherence rate to consensus-based</p>

		<p>Accepted: 509 patients; 202 in the 12-month pre-intervention period and 307 in the 24-month post-intervention period.</p> <p>Control: No control, nonrandomized study.</p> <p>Group Homogeneity: Patients in the pre and post-intervention study populations were similar in gestational age, birth weight, gender, and race</p>	<p>target population of the tool; and (4) EHR-integration of the CDS tool.</p> <p>Intervention fidelity: PBR was integrated into our commercial EHR by displaying a PBR icon for patients in the target population. This icon serves as a hyperlink that passes the most recent TB value and corresponding PMA to PBR, allowing the provider direct access to treatment recommendations on the PBR results page without the need for manual data entry.</p>	<p>defined as the proportion of phototherapy initiation events associated with TB values meeting the increased-risk (lower TB) CDS tool guideline treatment threshold. A phototherapy initiation event was defined as nursing documentation of phototherapy initiation in the EHR in combination with the most recent TB value in the preceding 6 h. This time interval was selected based on the potential period between a lab result and documentation of phototherapy initiation. assessment of CDS tool adoption and the incidence of severe hyperbilirubinemia.</p>	<p>thresholds for phototherapy initiation was 39.4%; the post-intervention adherence rate to CDS tool thresholds for phototherapy initiation was 69.8%, $p < 0.001$ Cross-application of the CDS tool thresholds to pre-intervention data yielded a similar adherence rate of 38.4%, $p = 0.87$; and cross-application of the consensus guideline thresholds to post-intervention data also yielded a similar adherence rate of 68%, $p = 0.67$</p> <p>Incidence of severe hyperbilirubinemia: During the pre-intervention period, 5/202 patients (2.48%) had TB values that exceeded the increased-risk (lower TB) exchange transfusion threshold. In the post-intervention period, 2/307 patients (0.65%) had TB values that exceeded the increased-risk exchange transfusion threshold, $p = 0.12$. The majority of these</p>
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					<p>patients responded to intensive phototherapy and did not require exchange transfusion: only one exchange transfusion was performed in the study population during the pre-intervention period, and none were performed in the post-intervention period, $p = 0.4$</p>
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Table 2.

Evidence Synthesis

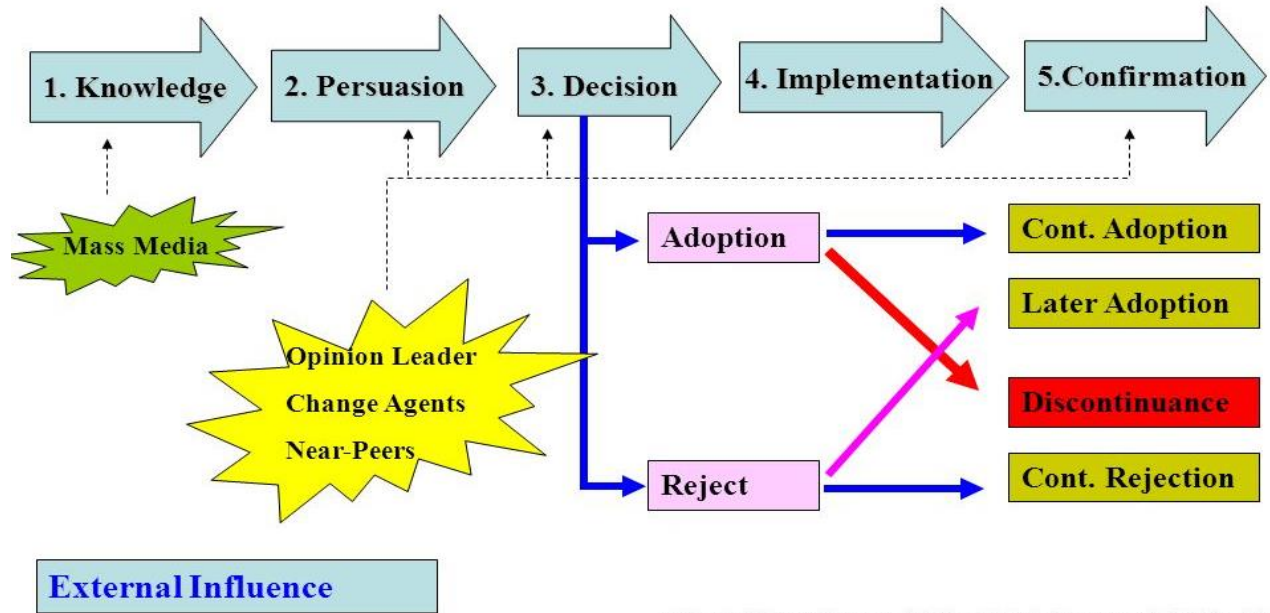
Evidence Based Practice Question (PICO): In a level IV Neonatal Intensive Care Unit, does the incorporation of a clinical decision support system (CDSS) in the electronic charting system compared to the current use of a paper algorithm guideline, lead to reduced stage 3 and 4 tissue injuries in infants with peripheral intravenous access?			
Level of Evidence	# of Studies	Summary of Findings	Overall Quality
I	2	<p>Systematic review by Jia et al (2020) identified 24 RCTs including 7653 participants. Thirteen of those trials (54.2%) used a computerized algorithm or a computer-assisted insulin protocol for insulin dose and therapy adjustment, of which 30.8% (four of 13) found significant changes. Of 10 trials that measured mean blood glucose levels and the 11 trials reported HbA1c, the computerized insulin dose adjustment resulted in lower mean blood glucose levels in 70.0% (seven of 10) and 36.4% (four of 11) of RCTs, respectively. Additionally, a significant reduction of hyperglycemia events was reported in three of six RCTs.</p> <p>Bright et al (2020) conducted a systematic review and identified 148 RCTs. The review concluded that both commercially and locally developed CDSSs improved health care process measures related to performing preventive services, ordering clinical studies and prescribing therapies.</p>	<p>B Good Quality: Well-defined reproducible search strategies for each systematic review. Reasonably consistent results and fairly definitive conclusions from both reviews. Comprehensive review of sufficient number of studies. Recommendations from each review are based on fairly comprehensive literature review that includes references to scientific evidence. Studies in both reviews were of mixed quality. The strengths and limitations of each review were discussed.</p>
II	1	<p>Kharbanda et al (2018) conducted a cluster-randomized trial evaluating the use of an EHR-linked CDS tool to improve hypertension recognition in pediatric outpatient clinics. The implementation of the TeenBP EHR-linked CDS across the 10 CDS intervention clinics increased hypertension recognition to 54.9%. The CDS also increased guideline-adherent care, including referrals to dieticians and cholesterol screening, but these occurred at suboptimal rates in both the intervention and UC populations.</p>	<p>B Good Quality: Reasonably consistent results and sufficient sample size (20 clinics, 31579 patients 10 to 17 years old) Control was present, although not double blinded. Evaluation of strengths and limitations of the study were included. Statistically significant results produced. Interpretation of the results leads to fairly definitive conclusions because of confounding factors identified that may have impacted outcomes. Although, sufficient sample size indicates the ability for definitive conclusions.</p>
IV	2	<p>Observational pre-post intervention study. Ebinger et al (2019) and Arain et al (2020) assessed the effectiveness of the use of EMR-based tool and CDS alert on improving clinical practice. Ebinger et al measured the use of bleeding avoidance strategies and bleeding event rates in patients who</p>	<p>B Good Quality: Reasonably consistent results indicating the use of the tool decreased bleeding event rates, while it increased only some bleeding avoidance strategies. Statistically significant results reported.</p>

		<p>underwent PCI and Arain et al (2020) assessed for phototherapy initiation guideline adherence. Both studies concluded that integrating guideline recommendations into the electronic medical record was feasible, safe, and associated with changes in clinical practice</p>	<p>Significant sample sizes (1965 and 2902 patients) indicate ability for fairly definitive conclusions. Measurement tools reliability and validity not reported in this study. Lack of contemporaneous control group because of observational before-after design.</p> <p>Recommendations based on literature review touching on different strategies used to prevent post PCI bleeding, as well as physicians' perceptions of EMR based tools with reference to scientific evidence and burden on the health care system.</p>
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Figures

Figure 1.

Diffusion of Innovation Theory



Adapted from Rogers, 2003 p.170 & Chamard, 2003 p.19

Figure 2.

The Framework for Complex Innovation

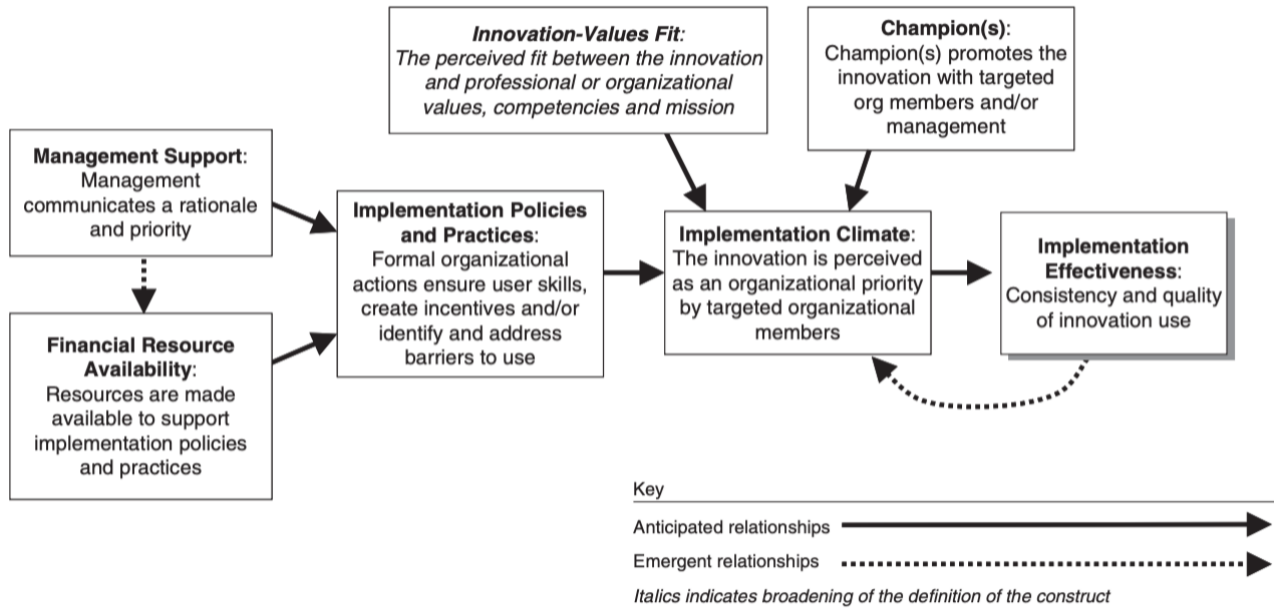


Figure 3.

Staff Education

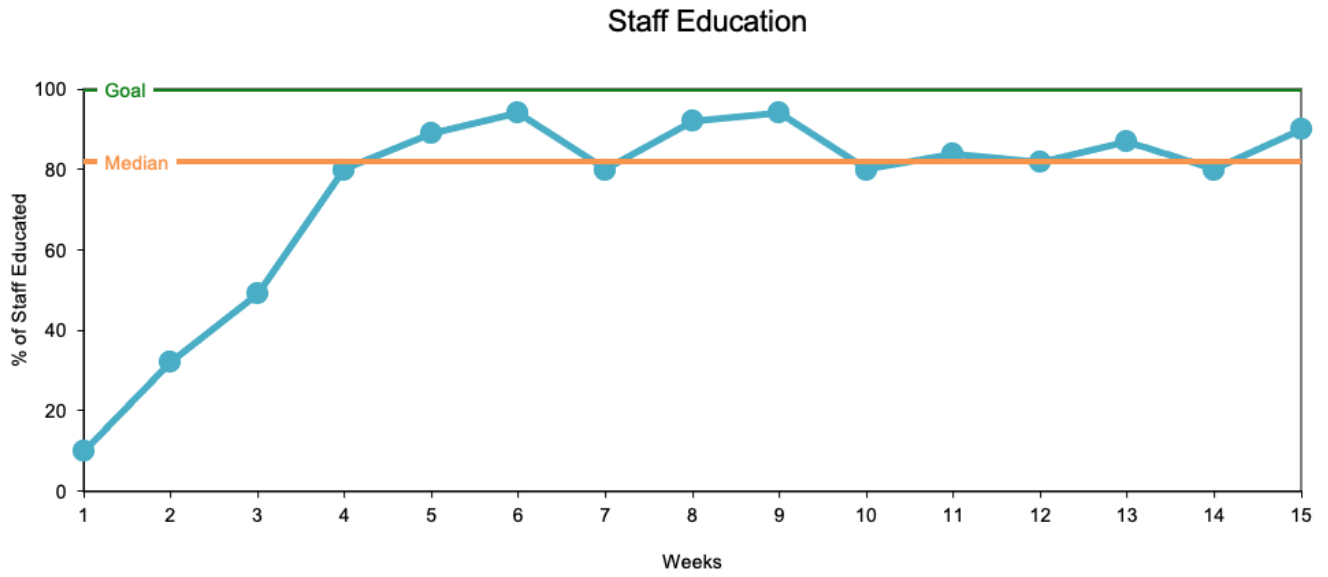


Figure 4.

CDSS Use by Nursing

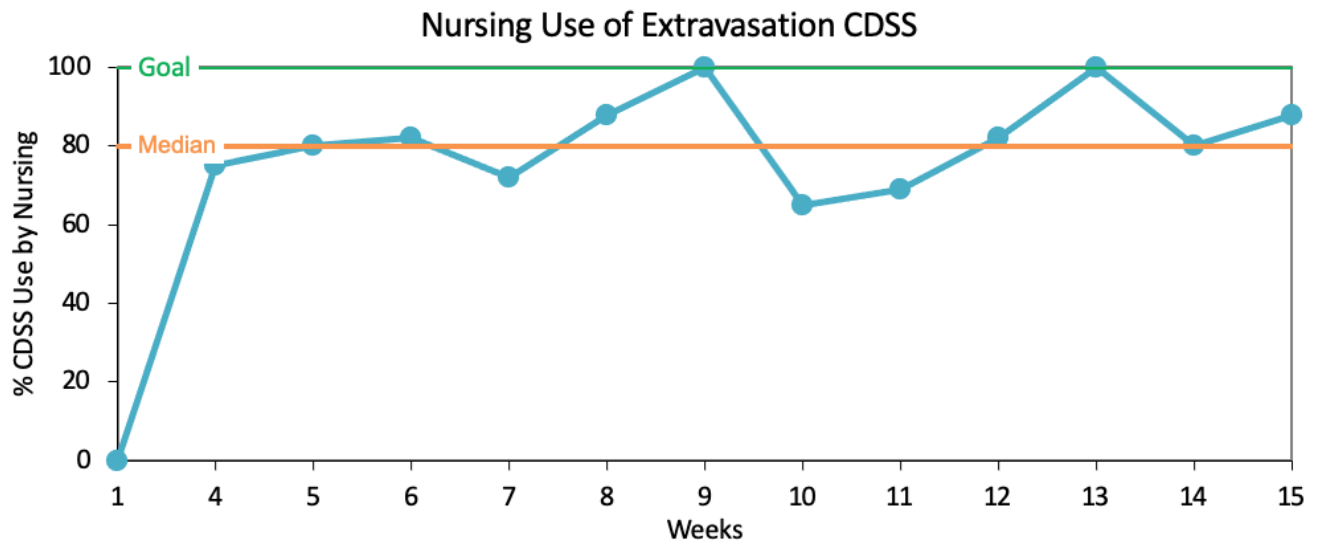


Figure 5.

Provider Notes

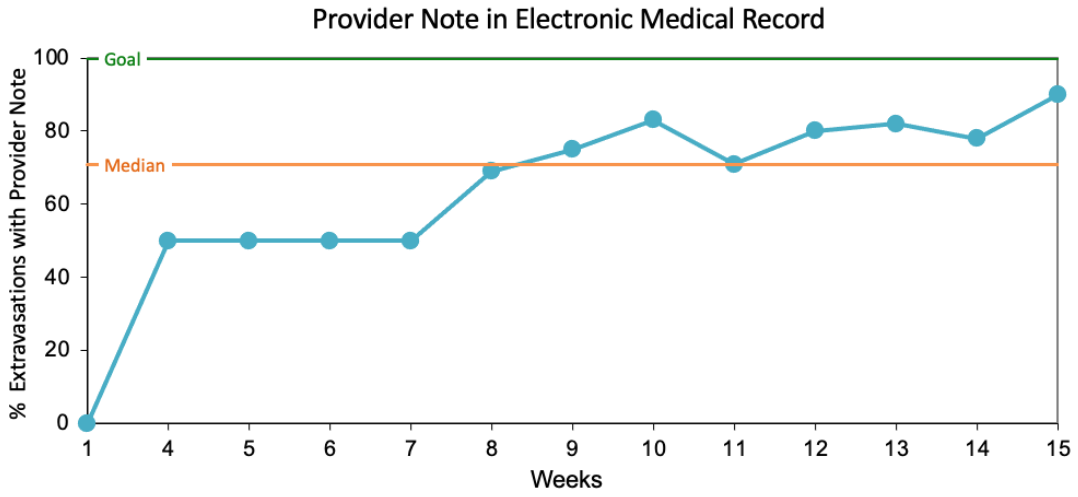
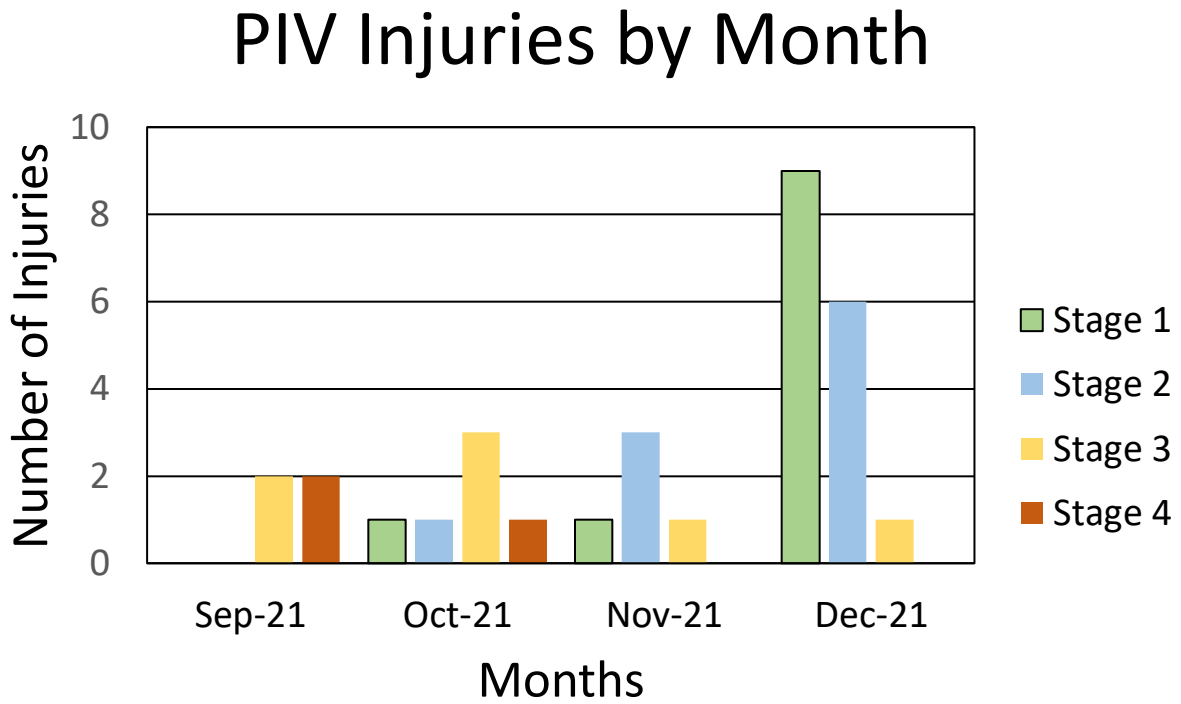


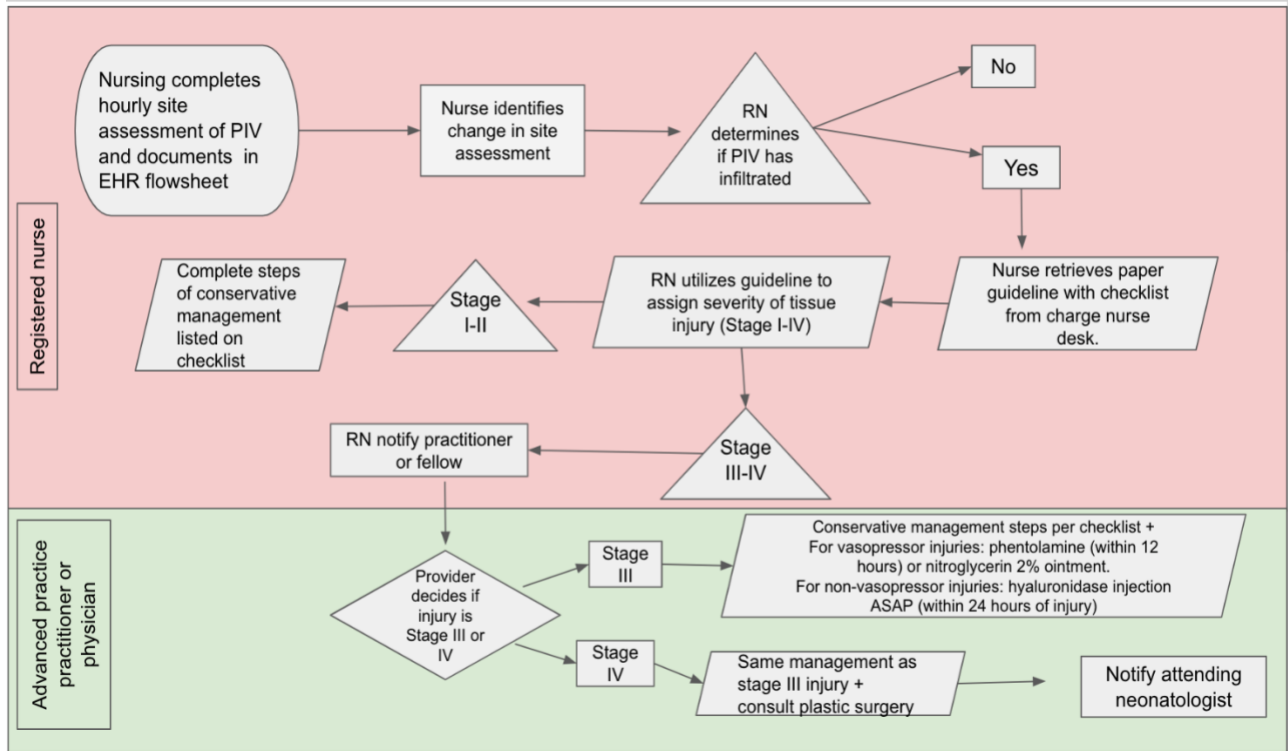
Figure 6.

PIV Injuries by Month



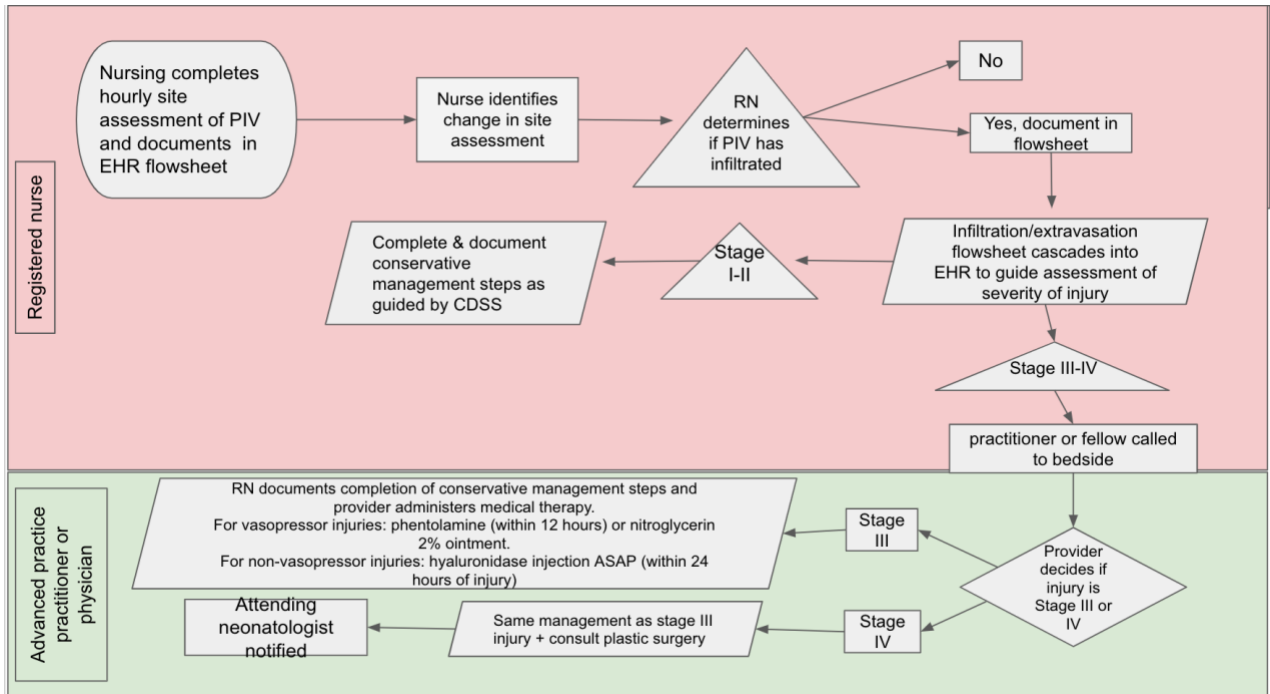
Appendix A

Pre-implementation Process



Appendix B

Post-implementation Process



Appendix C

CDSS Flowsheet

This screenshot shows the Epic EHR interface for a patient named BabyBoy B Nicuiv Testing. The interface includes a patient summary on the left, a central flowsheet, and a right-hand panel with assessment details. The 'Suspected Extravasation' section is highlighted with a red box, and the 'Site Assessment' section is highlighted with a blue box.

Suspected Extravasation Section:

- IV Site Location
- Stage
- Orientation
- Time Healthcare Provider
- Name of Provider Notified
- Agent Extravasated
- Extravasation Diluent
- Suspected Amount of Fluid
- Symptoms
- Management of Extravasation
- Extravasation Comments

Site Assessment Section:

- Peripheral IV 09/28/21 0726 Anterior, Left, Proximal Forearm
- IV Properties
- Site Assessment
- Line Status
- Additional Activities
- Dressing Status
- Dressing Intervention
- Dressing Type
- IV Site Change Due
- Reason Not Rotated
- OTHER
- LDA Staff

This screenshot shows the Epic EHR interface for the same patient, BabyBoy B Nicuiv Testing. The 'Suspected Extravasation' section is highlighted with a yellow box, and the 'Stage' dropdown menu is highlighted with a blue box.

Suspected Extravasation Section:

- IV Site Location
- Stage
- Orientation
- Time Healthcare Provider
- Name of Provider Notified
- Agent Extravasated
- Extravasation Diluent
- Suspected Amount of Fluid
- Symptoms
- Management of Extravasation
- Extravasation Comments

Stage Dropdown Menu:

- 1=Stage 1
- 2=Stage 2
- 3=Stage 3
- 4=Stage 4

Row Information:

- Stage I: Painful IV site, No erythema, No swelling
- Stage II: Painful IV site, Slight swelling (5%-20%), No blanching, Good pulse below infiltrate site, Break capillary refill before infiltrate site
- Stage III: Painful IV site, Marked swelling (20%-50%), Blanching, Skin cool to touch, Good pulse below infiltrate site, Break capillary refill before infiltrate site
- Stage IV: Painful IV site, Very marked swelling (>50%), Blanching, Skin cool to touch, Decreased or absent pulse, Capillary refill >4 seconds, Skin temperature no warmer

Appendix D

Educational PowerPoint

Utilize the "row information" to assist in appropriately staging the PIV injury!

