Quantifying Clinical Decision Support Across Pediatric Intensive Care Units

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Introduction: Clinical decision support (CDS) systems are intended to improve adherence to standard practices, improve clinician awareness, and ultimately increase the safety and quality of patient care.[1] CDS can be partitioned into passive support, such as order sets, documentation templates, or critical value highlighting, and active support, such as interruptive alerts. Excessive alerts can both reduce CDS effectiveness and contribute to dimensions of provider burnout. Across six academic pediatric institutions, the pediatric intensive care unit (PICU) has the highest burden of CDS alerts by the metric "alerts per encounter".[2] In a multi-national survey, PICU practitioners identify interruptive CDS as burdensome while agreeing that passive alerts are useful.[3] However, the extent of CDS use across PICUs is unknown. In this retrospective cross-sectional study, we estimate CDS penetrance across two large academic PICUs. By quantifying passive and active CDS use and estimating alert burden by provider role, we identify targets for CDS improvement to reduce alert fatigue and improve care.

Table 1. Cohort Demographics

		Site A	Site B
Cohort	ICU Enc	4,198	15,241
	Hospital Enc.	3,865	13,919
	Patients	2,946	9,778
Sex	Female	1,348 (46%)	4,264 (44%)
	Male	1,598 (54%)	5,514 (56%)
Age	0-2	1,255 (43%)	4,843 (50%)
	3-8	690 (23%)	2,207 (23%)
	9-12	326 (11%)	1,126 (11%)
	13-18	675 (23%)	1,602 (16%)
Dept	PICU	1,504 (36%)	11,906 (78%)
	PCICU	2,694 (64%)	3,335 (22%)
ICU LOS (hours)		47 [22, 116]	49 [26, 116]

PCICU: Pediatric Cardiac Intensive Care Unit

Methods: We conducted this study at 2 academic PICUs: Children's Hospital of Philadelphia (CHOP) and University of Rochester-Golisano Children's Hospital (GCH). Both use Epic Systems as their electronic health record (EHR) vendor. We included patients admitted between 9/1/2016 and 9/1/2019 and discharged by the time of data extraction. Similar to prior work, we collected and aggregated data using a federated query model where we developed queries at a single site (GCH), then extracted and independently verified each site's own data using custom data quality reports.[2] We identified practitioners as all providers who interacted with a patient's chart in the EHR while the patient was in the ICU and subdivided by role, as defined in the EHR. We used a custom report and semi-automated methods to identify ICU attending providers.

We divided CDS usage into passive and active metrics and report results per patient encounter and per provider. Passive metrics include: order set usage as a percentage of orders; abnormal vital sign and laboratory result highlighting across a set of common vital signs and laboratory results (with "abnormal" defined by site-specific EHR rules); and note text-automation tool usage. Active metrics include interruptive alerts. We calculated descriptive statistics and developed visualizations to examine variation among roles, metrics, and institutions. We modeled abnormal lab value likelihood using multivariable logistic regression and report adjusted odds ratios.

Results: Across two sites, we identified a total of 19,439 ICU encounters comprised of 12,724 unique patients. Age grouping, gender, and admission department are shown in Table 1. We identified 8,119 unique providers who accessed a patient's chart during the patient's ICU stay, of which 6,024 (74%) were nurses and 63 (0.7%) were ICU attendings. ICU length of stay was similar across both sites.

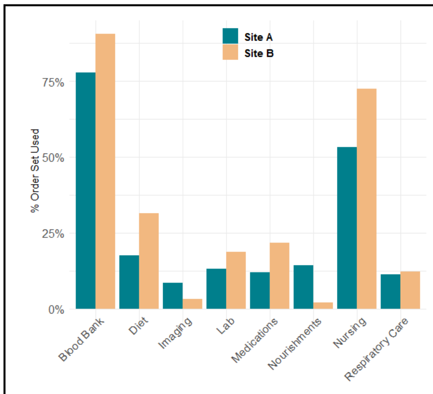

Figure 1. Percent of orders using an order set, by type and site.

There was a significant relationship between order set usage and institution (Site A: 21.1%, Site B: 28.2%; χ^2 p<0.001). Figure 1 shows the percent of orders placed through an order set, by order type. At both institutions, blood bank and nursing orders were most frequently placed using an order set while imaging studies were least frequently placed

Lab Group	Site A	Site B
Basic Chemistry	47 %	43 %
Hepatic Function	52 %	60 %
Coagulation	77 %	36 %
Blood Counts	62 %	56 %
Blood Gases	60 %	57 %

Table 2. Abnormal result highlighting by group

using an order set. Orders placed within one hour of ICU admission were more frequently placed using an order set (Site A: 48%, Site B: 59%). The frequency of abnormal laboratory result highlighting significantly differed by institution (Site A: 54%, Site B: 50%; χ^2 p<0.001). The percent of abnormal results by laboratory group are shown in Table 2. We used a logistic regression model to analyze the relationship of abnormal result highlighting to age, department, and labs within 24 hours of admission. The only significant variable consistent across sites was labs 24 hours of admission, for which the odds of an abnormal result decreased compared to labs after the first 24 hours of admission [Site A: 12% decrease (95% CI 0.87, 0.89), Site B: 15% decrease (95% CI 0.85, 0.86)]. The frequency of abnormal vital sign highlighting differed significantly by institution (Site A: 21%, Site B: 18%; χ^2 p<0.001). Similar frequencies of abnormal values were seen among most, but not all, vital signs: heart rate (A: 16% vs B: 19%), respirations (A: 36% vs B: 28%), pulse oximetry (A: 15% vs B: 14%), temperature (A: 9% vs B: 11%), and blood pressure (A: 33% vs B: 10%).

EHR text-automation tool use frequency significantly differed by institution (Site A: 79%, Site B: 73%, χ^2 p<0.001). Text-automation tool use also varied among practitioner types: providers used text-automation tools frequently (A: 88%, B: 96%) whereas nurses used text-automation tools less frequently (A: 62%, B: 16%). Attending providers wrote the longest notes (median characters: A: 8,304, B: 5,724) but used a text-automation tool >99% of the time.

Interruptive alerts were common during the study period (Site A: 1.2×10^6, Site B: 1.3×10^7 total alerts). Alert type varied by institution, with medication administration record alerts most common at Site A (37% of total) and custom interruptive alerts most common at Site B (64% of total). Average alerts per encounter per day increased through the study period and varied significantly by institution (Figure 2).

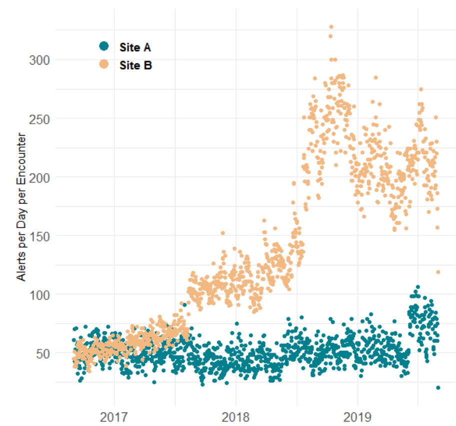

Figure 2. Interruptive alerts per ICU encounter per day, by site.

Discussion: CDS is present in many forms within the two academic PICUs. Consistent with prior studies, interruptive alerts occur frequently and may be burdensome to all providers, including nurses, pharmacists, and physicians. Passive CDS use is different across sites and is also applied heterogeneously within a site (e.g., order sets with different order types). These differences provide natural experiments to measure CDS effectiveness. Alternatively, by leveraging these CDS successes, we can share best practices and lessons learned. One specific area of focus identified in this work includes the potential opportunity to increase text-automation tool use in nurse workflows, which may improve documentation efficiency and increase reusability. Additionally, improving lab result or vital sign highlighting could decrease the abnormal result "noise" (e.g., 77% of coagulation studies at Site A flagged as abnormal) to better allow providers to identify the signal. Lastly, using aggregated time-varying data (e.g., interruptive alerts per day) allows for trending analyses of CDS alerts effected by operational changes within each system. This study is limited in that it was only completed at two sites and was retrospective by design. We did not classify specific CDS elements into clinical content areas (e.g., sedation order sets) as this would require manual processes, though it would add power by specifically highlighting content areas of need. Additionally, the federated nature of this analysis made row-level cross-institutional comparisons impossible. Future work focuses on disseminating queries and aggregating analyses from all sites in the Pediatric CDS Collaborative. This work is just the first step toward uncovering PICU CDS uses, successes, and challenges, all to support the goal of improving critical care quality while reducing provider fatigue.

References

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