

Evaluation of Real-Time Clinical Decision Support Systems for Platelet and Cryoprecipitate Orders

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ABSTRACT

Objectives: To evaluate cryoprecipitate and platelet ordering practices after the implementation of real-time clinical decision support systems (CDSSs) in a computerized physician order entry (CPOE) system.

Methods: Uniform platelet and cryoprecipitate transfusion thresholds were implemented at 11 hospitals in a regional health care system with a common CPOE system. Over 6 months, a variety of information was collected on the ordering physicians and the number of alerts generated by the CDSSs when these products were ordered outside of the institutional guidelines.

Results: There were 1,889 orders for platelets and 152 orders for cryoprecipitate placed in 6 months. Of these, 1,102 (58.3%) platelet and 74 (48.7%) cryoprecipitate orders triggered an alert. The proportion of orders canceled after an alert was generated ranged from 13.5% to 17.9% for platelets and 0% to 50.0% for cryoprecipitate orders.

Conclusions: CDSS alerts reduce, but do not eliminate, platelet and cryoprecipitate transfusions that do not meet institutional guidelines.

Platelet (PLT) and cryoprecipitate (cryo) transfusions can be valuable in the treatment of bleeding patients. PLTs are indicated in patients with thrombocytopenia who are bleeding or are about to undergo an invasive procedure.¹⁻⁴ Cryo is efficacious in those patients with bleeding secondary to hypofibrinogenemia.^{2,5,6} Despite numerous studies and documented indications for the use of these products, many clinicians transfuse them using non-evidence-based, anecdotal thresholds.^{2,6,7} Given the cost and the potential for adverse events, it is desirable to reduce the unnecessary transfusion of these blood products.²

Numerous strategies have been tried in an attempt to reduce unnecessary transfusions. In addition to traditional “grand rounds”-style education forums presented by a transfusion medicine expert,^{8,9} some centers have begun using automated clinical decision support systems (CDSSs) to address the issue of unnecessary transfusion.¹⁰⁻¹⁷ These systems are built into the computerized physician order entry (CPOE) system and generate an on-screen alert when the patient’s antecedent laboratory values do not suggest that the order for transfusion is necessary. The prescriber can either heed the alert and cancel the order or override it and place the order depending on the patient’s clinical condition. In addition to generating alerts when apparently non-evidence-based orders are detected, another benefit of the CPOE system is that it provides the ability to track and monitor blood usage. These data are indispensable to the hospital’s transfusion committee in determining where and how blood products are used and in assessing where further education is needed.⁹

Previous studies have examined the impact of automated alerts on clinicians’ red cell, plasma, and PLT ordering practices.^{15,17-19} However, the lone study that examined the effect

of a CDSS on PLT transfusions involved newborn patients in the neonatal intensive care unit (NICU)¹⁸; in this study, improved compliance with the institution's PLT transfusion guidelines and a 12% decrease in PLT usage were observed after alert implementation. It is unknown, however, if compliance rates in the NICU are generalizable to other areas of the hospital or to other patient populations. The purpose of this study was twofold: to determine why clinicians were ordering PLT and cryo transfusions and to assess the impact of the CDSS alerts in improving compliance with the institutionally defined evidence-based transfusion thresholds.

Materials and Methods

Hospital System

Data for this project were obtained from the electronic medical records of a single health care system in southwestern Pennsylvania and included data from 11 separate hospitals, ranging in size from small community hospitals to large, quaternary care academic centers. These hospitals included two level 1 trauma centers, one that specializes in the care of women and another with an active cancer and stem cell transplant program. None of these hospitals specializes in children's inpatient care. All of these hospitals use the same electronic medical record (Cerner, Kansas City, MO) and the built-in CPOE module for placing blood bank orders. The CDSS and its automated alerts for PLT and cryo orders was implemented systemwide in December 2012, and data on the alerts generated in the first 6 months after its implementation (December 2012 through May 2013) were collected. Before the alerts were implemented, a short description of these alerts and a reminder of the institutional transfusion thresholds were published in the physician newsletter distributed to all physicians within the health care system. The same transfusion thresholds were in place systemwide. Urgent requests for blood products could be made by telephoning the blood bank, with the orders entered into the medical record after fulfillment. Of note, the CPOE system is not used for ordering blood products for patients in the operating room at any of these 11 hospitals, and thus these orders were not included in this analysis.

Platelet CPOE Alerts

Before an order for a PLT transfusion could be entered in the CPOE system, the prescriber had to select one of the following indications: PLTs less than 10,000/ μ L in stable patients, PLTs less than 20,000/ μ L in patients with PLT consumption, PLTs less than 50,000/ μ L in patients prior to the procedure, or PLTs less than 50,000/ μ L for patients with the following indications: bleeding, on anti-PLT medication prior to a procedure, bleeding on anti-PLT medication,

and massive bleeding. An Other option was also provided, and the ordering clinician was encouraged to input free-text justification for the PLT order. After the order was entered, the CPOE system queried the laboratory information system (LIS) to determine the patient's PLT count within the 24 hours prior to placing the order. The CDSS then automatically compared this count with the PLT count threshold in the indication selected by the prescriber. If the patient's antecedent PLT count in the LIS exceeded that in the indication for transfusion, an alert appeared on screen notifying the clinician of this discrepancy. Alerts were not generated if the selected indication was either a patient on anti-PLT medications or a patient experiencing massive bleeding. If the Other indication was selected, then an alert would be generated if the antecedent PLT count was more than 50,000/ μ L. After viewing the alert, the clinician could cancel the order (ie, heed the alert) or dismiss the alert and proceed with the order for transfusion. If the patient did not have a PLT count within the most recent 24-hour period, a different alert was displayed offering to order a PLT count and cancel the transfusion order. This alert could also be dismissed by the clinician, and the order for transfusion would be sent to the blood bank. Data on the PLT transfusions using the Other indication were compiled post hoc and categorized into nine categories to understand why physicians were ordering PLTs using this indication.

These hospitals use mainly pools of whole blood PLTs. Depending on the patient's clinical situation and PLT inventory, the pool sizes ranged from three to five whole blood PLTs. Thus, the actual number of transfused PLT doses is unknown. Therefore, the number of whole blood PLT equivalents, calculated by multiplying the number of apheresis PLT units by 5 and then adding that value to the number of individual whole blood PLT units issued, is reported.

Cryoprecipitate CPOE Alerts

Prescribers also had to specify one of the following clinical indications when ordering cryo: active bleeding, fibrinogen 100 mg/dL or less prior to the procedure, and other. Similar to the PLT CDSS described above, the CPOE system queried the LIS as an order for cryo was being entered; if the most recent fibrinogen value drawn within the preceding 24 hours was above 100 mg/dL and the latter two indications had been selected, an alert would be triggered. An alert was not triggered for orders placed using the active bleeding indication. As with the PLT alert, clinicians could cancel the order after seeing the alert or dismiss the alert and proceed with the order. Likewise, if the patient did not have a fibrinogen level within the most recent 24-hour period, an alert was displayed that offered to order a fibrinogen concentration and cancel the transfusion order. This alert could also be dismissed.

Since the cryo pool size is variable (typically six units per dose), the number of transfused individual cryo units is reported.

Data Collection

Due to a limitation of the CPOE system, when an order was canceled following an alert, only the date/time of the order, antecedent PLT or fibrinogen counts, and the hospital service of the ordering clinician were captured. For all orders actually placed either after dismissing an alert or if one was not generated, the following information was collected: date/time of order, indication for ordering (as described above), number of alerts that were triggered, number of alerts that were overridden, medical service of the ordering clinician, credentials of the ordering clinician (physician, resident, or advanced practice nurse), antecedent PLT or fibrinogen level (from the LIS), and any free text entered by the clinician at the time of ordering. The number of PLT and cryo units transfused was available from nine of 11 of these hospitals; the two hospitals from which data were not available do not have active trauma or oncology programs and would thus not have been expected to have used significant quantities of these products.

This protocol was approved by the Total Quality Council, which is a section of the Institutional Review Board of the University of Pittsburgh.

Statistical Analysis

Continuous variables were analyzed using descriptive statistics. Categorical values were analyzed using the χ^2 or Fisher exact test (GraphPad Prism 6.02; GraphPad Software, San Diego, CA).

Results

Platelet Orders

During the six-month study period, a total of 1,889 PLT orders were placed among these 11 hospitals, with a total of 33,209 whole blood PLT equivalent units issued. Most of the PLT orders, 1,089 (57.6%) of 1,889, were placed at two of the large tertiary care facilities. Overall, 1,102 (58.3%) of 1,889 orders triggered an alert, and 168 (15.2%) of 1,102 of the alerted orders were subsequently canceled **Figure 1A**. Note that even if an order was canceled, it was still counted

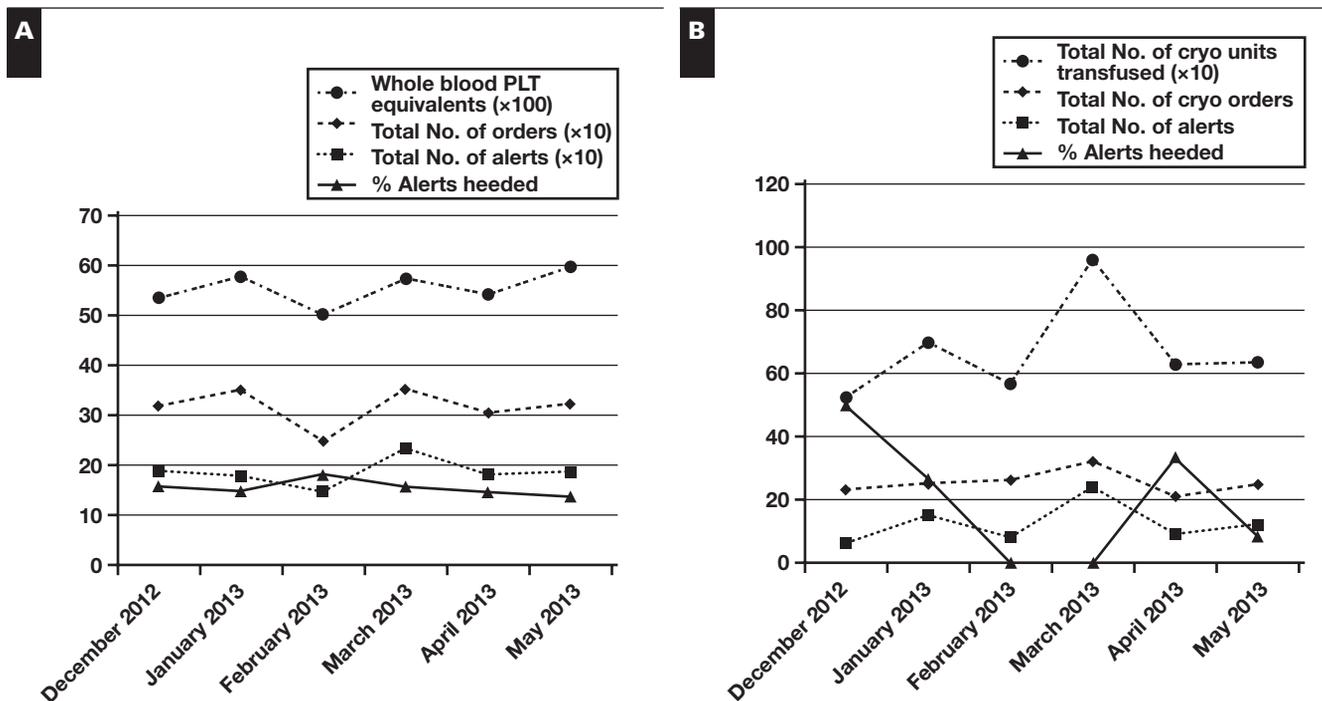


Figure 1 **A**, Number of platelet (PLT) orders and alerts, percent alert heed rate, and the number of whole blood PLT equivalents transfused by month. To estimate the number of PLT doses transfused per month, divide the number of whole blood PLT equivalents by approximately 5. **B**, Number of cryoprecipitate (cryo) orders and alerts, percent alert heed rate, and the number of individual cryo units transfused by month. To estimate the number of cryo doses transfused per month, divide the number of cryo units issued by approximately 6.

in the total number of orders. There was no statistically significant difference between the number of alerts generated in the first month of the study compared with the last month ($P = .75$). The alert heed rate was also not significantly different between the first and last months of the study ($P = .65$) (Figure 1A).

Figure 2A demonstrates the ordering indications selected for the PLT orders. Figure 3A shows the mean antecedent PLT values for these ordering indications and the alert generation rate between indications. The Other indication was selected for 32.8% of the total number of orders. A post hoc analysis of the free-text explanations that accompanied these orders revealed several broad indications for its use Figure 4. Approximately 9.9% of the Other orders were inappropriately categorized by the ordering physician. An order in this subcategory of the Other orders could, for example, have been placed on a stable patient whose antecedent PLT count was less than 10,000/ μL , and therefore it should have been placed using the appropriate indication. A prominent portion (7.8%) of the Other orders were placed on pre- or postoperative neurosurgical patients, in whom a PLT count of more than 100,000/ μL was desired.

Most PLT orders were placed by attending physicians (55.7%), with house staff such as residents, fellows, and nurse practitioners comprising the remainder. Attending physicians had a higher PLT order alert rate than did resident

physicians (61.0% vs 44.7%; $P < .001$). Surgical (31.8%) and medical (33.2%) specialties placed most PLT orders, with one-fourth of the orders placed by the hematology/oncology service (26.7%). Family practice and emergency department physicians ordered the remainder. Hematology/oncology physicians generated alerts most frequently compared with all other specialties (73.7%; $P < .001$), and there was a wide range of alert rates between specialties (range, 36.7%-73.7%). Family physicians and internists heeded slightly but not significantly more alerts (22.2% and 19.1%, respectively; $P = .10$) than the other specialties, but overall, all specialties had a similarly low alert heed rate (range, 12.1%-22.2%).

Cryoprecipitate Orders

During the study period, 152 orders were placed in the CPOE system for cryo. Of these orders, 74 (48.7%) triggered alerts, and 11 (14.9%) alerted orders were subsequently canceled Figure 1B. There was no statistically significant difference in the alert generation rate ($P = .14$) or the alert heed rate ($P = .08$) between the first and last months of the study. Figure 2B demonstrates the selected ordering indications for cryo orders. Free-text justification for Other orders included patients with abnormal thromboelastograms or other undefined coagulopathy. Figure 3B shows the mean antecedent fibrinogen values of the different cryo ordering indications, along with their respective alert generation rates.

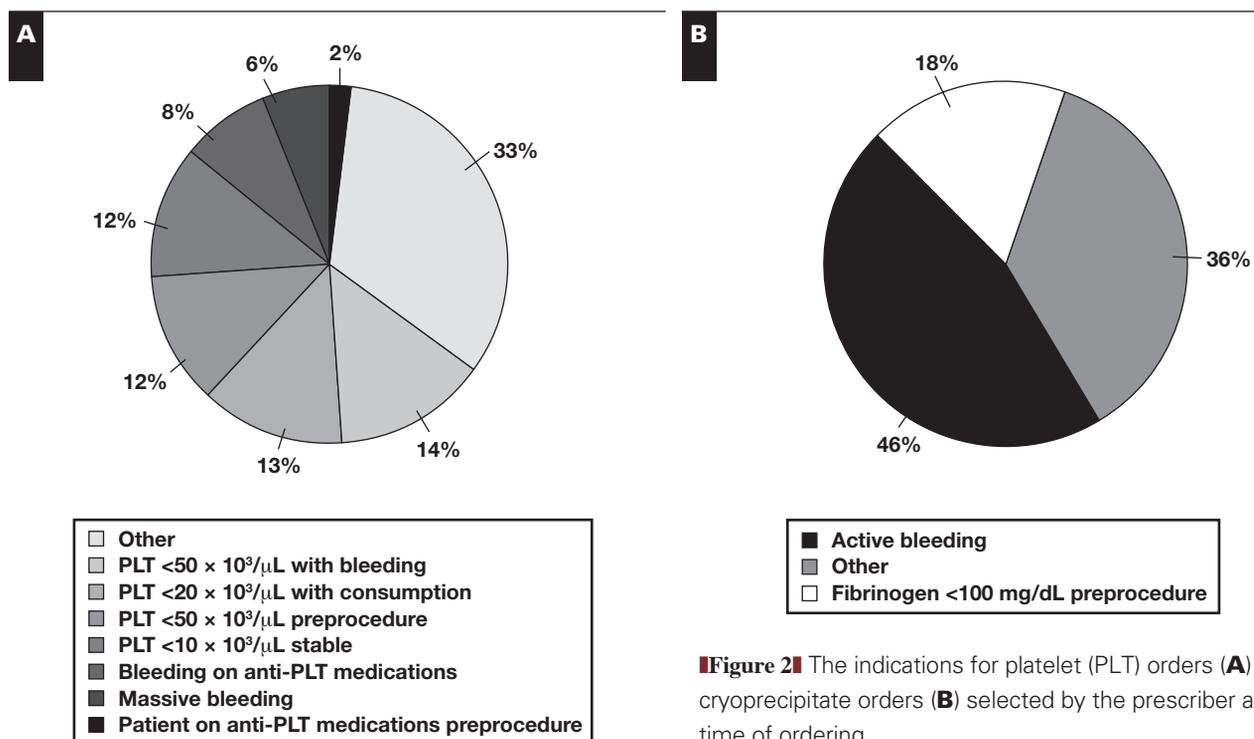


Figure 2 The indications for platelet (PLT) orders (A) and cryoprecipitate orders (B) selected by the prescriber at the time of ordering.

Most cryoprecipitate transfusion orders were placed by attending physicians (61.7%), with residents and fellows ordering the remainder. Attending physicians generated fewer alerts (41.4%) compared with resident physicians (50.0%), but this was not statistically significant ($P = .38$). Most cryoprecipitate orders were placed by surgeons (50.7%), with hematology/oncology and internal medicine clinicians comprising the majority of the remaining orders. Hematology/oncology physicians were the most likely to generate alerts compared with all other specialists (80.0%; $P = .01$). The alert heading rate was low regardless of specialty (range, 0%-20.0%).

Discussion

It is evident that many clinicians are currently ordering PLT and cryo transfusions based on criteria that are not evidence based, despite seeing the CPOE alerts. More than 50% of the PLT orders generated an alert, with few cancellations after seeing the alert. It is interesting that the PLT order alert rate was relatively constant over the study period; thus, the alerts generated by the CDSS alone are apparently not sufficient to substantially reduce the number of orders placed outside of the institution's thresholds. Also, almost one-third of PLT orders were placed under the Other indication. Based on the post hoc analysis, around 10% of these Other orders

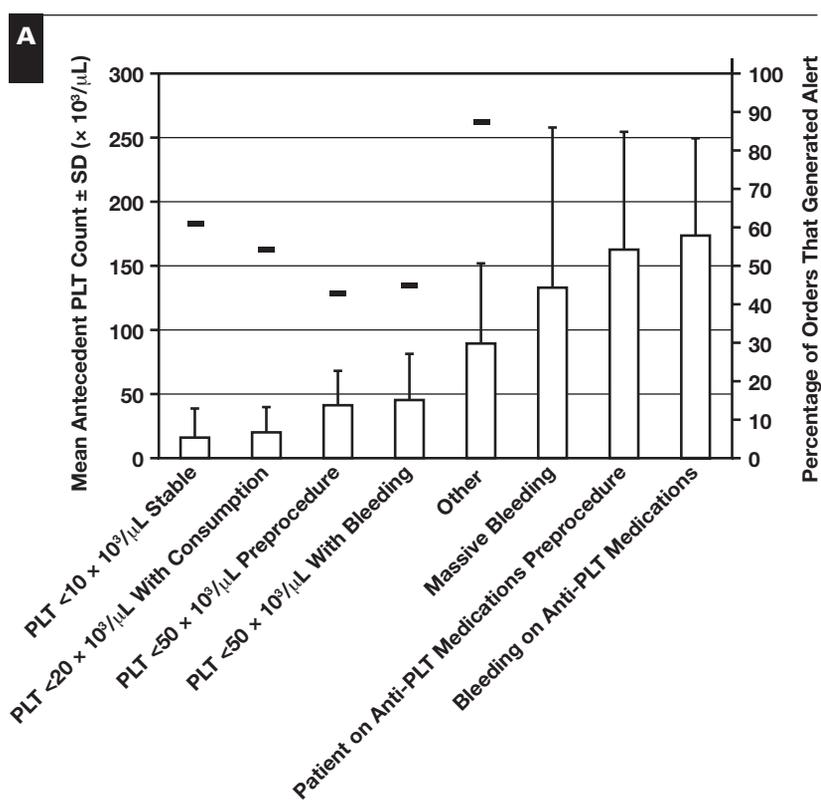
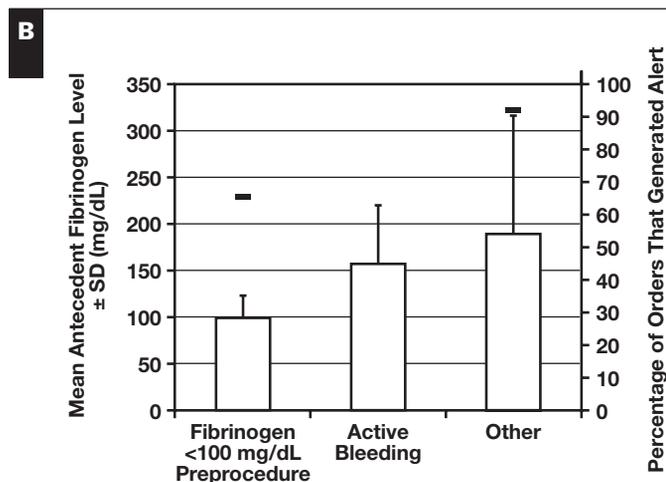


Figure 3 **A**, Mean ± SD antecedent platelet (PLT) count (column) and percent alert rate (dark bar) for each of the PLT ordering indications. For example, the mean antecedent PLT count for an order placed using a PLT count less than 10,000/µL in a stable patient was 16,000/µL, and 61% of the orders placed using that indication generated an alert. If the Other indication was selected, then the alert would appear if the antecedent PLT count was more than 50,000/µL. Alerts were not generated for orders placed using the following indications: massive bleeding, patient on anti-PLT medications preprocedure, or bleeding on anti-PLT medications regardless of the antecedent PLT count. **B**, Comparison of cryoprecipitate ordering indications with mean ± SD antecedent fibrinogen level (column) and percent alert rate (dark bar). For example, the mean antecedent fibrinogen concentration for an order placed using a fibrinogen level less than 100 mg/dL preprocedure was 99 mg/dL, and 65% of the orders placed using that indication generated an alert. If the Other indication was selected, then the alert would appear if the antecedent fibrinogen level was more than 100 mg/dL. Alerts were not generated for orders placed using the active bleeding indication regardless of antecedent fibrinogen concentration.



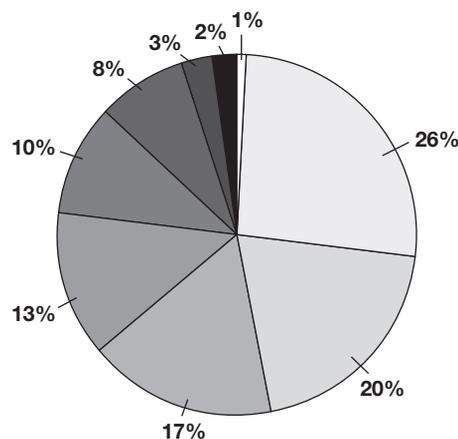
were misplaced and should have been placed using one of the evidence-based ordering criteria. It is unclear why these orders were not correctly categorized at the time of ordering, and further honing of the CPOE interface may be necessary to reduce these occurrences. To decrease the number of orders placed with the Other indication, it is possible to create additional ordering indications in the CPOE system to accommodate the current ordering practices (such as postoperative neurosurgical patients with a PLT count $<100,000/\mu\text{L}$). However, if these practices are not evidence based, an opportunity to refine physicians' ordering practices may be lost. Since only one of the cryo ordering indications triggered alerts based on antecedent fibrinogen levels, it is unclear how much effect the CPOE alerts can have on cryo ordering practice. The alert rate was consistently high for cryo orders, and the alert heed rate was highly variable but low.

There were fewer orders for cryo compared with PLT, and the number of orders per month was highly variable. It is interesting to note that attending physicians generated fewer alerts with cryo, but house staff generated fewer alerts with PLTs. It is unclear why this is so, but it is possible that house staff education focuses more on PLT and red blood cell transfusions, with less instruction on the appropriate use of cryo.

The large variation in alert rate between medical specialties is also of interest and may highlight the differing patient populations encountered by these clinicians. Hematology/oncology physicians had the highest alert rates for both PLT and cryo, which may be due to the significant number of these components that their patients tend to require. One limitation of the current CPOE system is that, in generating an alert, it only checks the patient's most recent PLT or cryo value; it cannot track counts over time to see if a trend toward decreasing values has developed, and it is also unable to capture clinical information other than that provided in the free text at the time of ordering by the clinical team. Without a detailed medical record review, these limitations make it difficult to determine the appropriateness of some of the alerted transfusion orders and may explain the high rate of orders placed using the Other indication seen in both the PLT and cryo orders.

There are several limitations inherent in this study. As mentioned earlier, the CPOE system is unable to capture complete information for canceled orders. It would be very useful to know the characteristics of physicians who heed the alerts. It would also be helpful to know if these canceled orders are subsequently being placed by another trainee or attending physician. In addition, the current system is unable to capture orders placed on patients in the operating rooms since these orders are typically telephoned to the blood bank or submitted on paper order forms.

This study examined the current practice of PLT and cryo ordering in a multihospital health care system. Even with



None	($105 \pm 48 \times 10^3/\mu\text{L}$)
PLT $>50 \times 10^3/\mu\text{L}$ preprocedure	($96 \pm 38 \times 10^3/\mu\text{L}$)
PLT $>50 \times 10^3/\mu\text{L}$ with bleeding	($93 \pm 27 \times 10^3/\mu\text{L}$)
Other	($85 \pm 9 \times 10^3/\mu\text{L}$)
Misplaced	($58 \pm 31 \times 10^3/\mu\text{L}$)
Intracranial hemorrhage	($93 \pm 7 \times 10^3/\mu\text{L}$)
PLT $>10 \times 10^3/\mu\text{L}$ stable	($30 \pm 5 \times 10^3/\mu\text{L}$)
PLT $>20 \times 10^3/\mu\text{L}$ with consumption	($45 \pm 11 \times 10^3/\mu\text{L}$)
Abnormal aspirin response	($176 \pm 0 \times 10^3/\mu\text{L}$)

Figure 4 Post hoc defined categories derived from platelet (PLT) orders placed using the Other indication (mean \pm SD antecedent PLT count for each category).

focused alerts based on a patient's current laboratory values, there has been minimal impact on ordering practice over time. Prescriber feedback on the wording of the alerts and suggestions for additional evidence-based indications is ongoing. It is evident that electronic alerts alone are not sufficient to substantially modify clinician practices, and further focused education may be necessary to reduce non-evidence-based orders.

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