Computer-generated Automatic Alerts of Respiratory Distress after Blood Transfusion

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Abstract

Transfusion-related acute lung injury (TRALI), the leading cause of transfusion-related death, is underreported by clinicians. For TRALI research, a clinician-independent, computerized system has been developed to detect patients with acute respiratory distress posttransfusion. A computer system generates an alert when a blood gas result indicated a PaO₂:FiO₂ ratio below 300, within twelve hours of blood issued from the blood bank for a patient. The system was prospectively compared to conventional daily rounds in intensive care units (ICUs). We found that ICU rounds detected 9 of 14 patients (64%), while the computer system detected 13 of 14 patients (93%), p = 0.125. ICU rounds took two to three hours per day, while the computer system took one to one and one-half hours per day of investigator time. In conclusion, an automatic computer alert system was more efficient, and was as effective as conventional daily ICU rounds, in detecting patients with posttransfusion acute respiratory distress.


Introduction

Investigators of acute lung injury (ALI) traditionally use daily intensive care unit (ICU) rounds to identify study patients, as most ALI patients need to be in the ICU. One type of ALI, transfusion-related acute lung injury (TRALI), was the focus of our research. Although uncommon (1:5,000 units transfused), TRALI is the leading cause of transfusion-associated mortality and is often underrecognized by clinicians. For TRALI research, quick identification of the patient is useful, so that the blood product that caused the reaction can be saved and tested. We developed a clinician-independent novel real-time computer-based screening system that has been validated on retrospective data. This article describes the implementation and use of the system and validation by comparison with traditional screening with daily ICU rounds.

Methods

Setting

The study was performed at Moffitt-Long Hospital, the tertiary care hospital of the University of California San Francisco. The institutional Committee on Human Research approved the implementation and validation of the system as a research study, and waived requirement of informed consent for use of the screening systems and review of identified cases.

Patients

All patients in the ICUs were screened by daily weekday rounds by an investigator. Concurrently, all blood gases on patients over the age of two years were screened continuously 24 hours per day, 7 days per week by the computer system described below. As clinically indicated, the patients’ physicians ordered blood gas determinations and provided immediate care as needed. As the study was an observational one; the study did not select patients for arterial blood gas monitoring and care for the patient did not depend on the study.

Design

The validation was performed over a six-week prospective observational study. Two investigators using two methods (ICU rounds versus computer alerts) screened a single patient population. Each investigator was randomly assigned to one of the two screening methods, and then the investigators crossed-over screening methods every two weeks.

ICU Rounds Method

Institutional investigators experienced in ALI research trained the study investigators to identify patients with pulmonary edema. Every weekday morning, the investigator visited all current adult ICU patients who had undergone transfusion the previous day (midnight to midnight) or weekend.
Computer Alert Method
The computer was programmed by Oztech Systems (Burlingame, CA) to detect posttransfusion hypoxemia as previously described. In brief, a server captured the real-time data feed of the hospital clinical laboratory, and the software screened all arterial blood gas results and information on blood products issued to all patients except those under two years of age. The computer was programmed to calculate a P/F ratio, from the blood gas test result, i.e., partial pressure of arterial oxygen (PaO₂) divided by fraction of inspired oxygen (FiO₂). If the P/F was under 300 and if that same patient was issued blood from the blood bank in the previous 12 hours, an electronic alert was issued to blood bank researchers. The alert was a text-message page and an e-mail, indicating the blood gas results and a coded patient identifier. These were sent 24 hours a day, required no human involvement, and were independent of clinician reporting. Alerts that were sent on Monday through Friday between 9 AM and 6 PM were immediately investigated. Alerts during the night and on the weekends were investigated the next weekday morning. If an alert was issued on a patient, no new alerts on that patient occurred until after a four-hour waiting period. It is important to note that the alerts were for notification of a potential temporal relationship between potential ALI and transfusion. An alert itself did not mean that that criteria for either ALI or TRALI had been satisfied. Also, clinical care of the patient was immediately and completely independent of the alert system. The alert system merely added a research component, notification of the blood bank researchers of a temporal link of hypoxemia after transfusion.

Evaluation of Cases
Study investigators consulted with critical care physicians with expertise in ALI about study cases of posttransfusion pulmonary edema. Cases were not reviewed by an expert panel. The diagnosis requires review of a chest radiograph and a thorough evaluation of left atrial pressure. The diagnosis is a clinical one, and the collection of clinical data takes time. The patients were then classified as transfusion-associated circulatory overload (TACO), ALI, or TRALI.

Statistical Method
The proportions of cases of posttransfusion pulmonary edema detected by each method was compared using the McNemar Test with the binomial/sign correction for a continuity correction because of the small numbers (4 and 0) in the diagonal cells. The program SPSS for Windows (SPSS Inc., Chicago, IL) was used for the analyses.

Results
Detection by ICU Rounds
Investigators following the ICU rounds method visited an average of 13 patients each day (range 5–22 patients per day). During the six-week study period, rounds were made on 402 ICU patients. Nine cases of posttransfusion pulmonary edema were identified.

Detection by Computer Alert System
An average of 8 alerts per day on 6 patients was received. During the six-week study period, a total of 230 alerts were received on 88 patients. The median time from arterial blood gas sample collection to alert generation was 16 minutes (range 4–60 minutes). Indeed, in one case, clinicians at the bedside questioned the investigator on how she had arrived so fast without being called. Almost all of this 16-minute time was due to collection, labeling, and delivery of the sample to the clinical laboratory. The computer system detected a hypoxic patient less than 1 minute after the arterial blood gas result was entered. Thirteen cases of posttransfusion pulmonary edema were identified.

Comparison of ICU Rounds with Computer Alert System
A total of 14 patients were identified during the six-week study period to have posttransfusion pulmonary edema; the diagnoses were TACO (7), ALI (3), or TRALI (4). Among these 14 patients, ICU rounds detected 9 (64%). The computer alert system also detected the same 9 patients, and in addition, identified 4 additional patients not detected by ICU rounds. Of the 4 patients not detected by ICU rounds, 2 were not in the ICU, 1 was in the pediatric ICU, and 1 died before transfer to ICU. Thus, the computer alert system detected 13 of the 14 patients (93%). In this small study, the 93% detection rate by the alert system was not statistically higher than the 64% rate detected by ICU rounds, p = 0.125.

One of the 14 patients was missed by both methods. This patient had posttransfusion pulmonary edema and was missed by ICU rounds because she was not in the ICU. The patient was missed by the computer alert system because she did not have a FiO₂ value in the laboratory computer. This event was discovered when the investigator reviewed the patient’s chart for a recurrence of pulmonary edema one week after the missed event.

In addition to detecting more cases, the computer alert system also took 50% less investigator time. While ICU rounds took two to three hours per day, investigation of computer alerts took only one to one and one-half hours per day.

Discussion
This study showed that an uncommon acute event can be detected in real time by computerized screening. The automated system accomplished similar results and used less staff time. Also, this system is capable of real-time data analysis and can initiate a rapid response by staff. Finally, the system has high-grade security, is compliant with the Health Insurance Portability and Accountability Act, and was acceptable to the hospital information technology security personnel.

During this investigation, it was found that broad and nonspecific criteria worked better than more refined criteria. Other studies have confirmed our discovery that computer-screening systems work best using inclusion criteria and minimum exclusion criteria.

Comparison to Other Electronic Screening Systems
A true real-time system receives data as it is created, continually runs analyses, and responds so quickly that it seems immediate, e.g., a system that alerts on a continuously measured variable that responds rapidly to a change in clinical status. Our system is not a real-time system because blood gas samples are drawn at discrete time points. There may be a delay between the onset of respiratory distress and the collection of a blood gas sample. The system would be a
true real-time system if it monitored blood transfusion status and pulse oximeter readings.

Our system differs from many other surveillance systems because it works independent of the treating physician. This was critical for underrecognized, uncommon events such as TRALI. This is also useful when studying an event that occurs in a patient population not being directly cared for by the investigator.

Our system performs a simple mathematical calculation to detect a transfusion reaction, \( \text{PaO}_2 / \text{FiO}_2 \). Despite the simple logic, the system is more complex than those that issue alerts for pharmacy drug–drug reactions. Our system integrates two data sources (clinical laboratory and blood bank) and screens a large population. As far as the system screening goes, it is real-time. As soon as the blood gas sample is tested, the result is screened by the system and an alert is issued. Syndromic surveillance systems that also integrate multiple data sources are not always analyzing the data and issuing alerts in real time.

Limitations

The aim of our research was to detect TRALI, not mild lung injury, and thus the alert system was not designed to detect mild hypoxemia after transfusion. We would have missed the unusual patient with TRALI who did not have an arterial blood gas measurement performed. Also, our primary criteria were based on FiO\(_2\) data. When FiO\(_2\) is not entered into the laboratory computer, our system would miss the case, as occurred in one case in this study. To remedy this, when FiO\(_2\) is missing, we now add a screening criterion of oxygen saturation of <97% to our computer screening criteria, which would have detected this case. Of note is that this study was designed to compare methods to detect severe posttransfusion hypoxemia. As it was not the purpose of the study to determine TRALI incidence, cases were not reviewed by an expert panel. Finally, every computer-based system at some point relies on human decision-making. Clearly, the system performs best when the investigator receiving alerts is clinically well trained.

Conclusions

Automatic alerts can alert blood bank researchers of patients with potential TRALI shortly after the time of blood gas measurement, including patients who are not in the ICU. This can enable timely retrieval of implicated blood products for research into the mechanism of TRALI. The system design strategy might be useful for alerts for research on other acute clinical events that are uncommon or underrecognized.

References