Computers, Quality, and the Clinical Laboratory: A Look at Critical Value Reporting

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The reporting of critical values is an important function of the clinical laboratory. The success of critical value reporting depends on laboratory personnel recognizing critical values and effectively communicating them to clinicians, and on clinicians correctly interpreting and using the critical values to provide appropriate patient care. At LDS Hospital, we have conducted a study of the critical value reporting process. Results of the study indicate that few critical values are actually reported by the clinical laboratory (only 28 of 294 critical values during November 24-30, 1992). Data on the quality of critical value documentation showed that 19 of 124 (15%) patient charts audited during January-February, 1993 contained no documentation that clinicians were ever aware of the critical value, or that corrective actions were taken. Other data on the quality of critical value reporting were also collected and analyzed. Study results have been used to design and implement a computerized critical value reporting system to improve the quality of critical value reporting at our hospital.

INTRODUCTION

The reporting of critical laboratory test values by the laboratory to clinicians has at least a twenty year history, being first introduced by Lundberg et al at the Los Angeles County/University of Southern California Medical Center in the early 1970's [1]. The idea soon became part of requirements for laboratory accreditation by the College of American Pathologists and the Joint Commission on Accreditation of Healthcare Organizations (JCAHO). Since then, reporting of critical values has been an important function of the clinical laboratory because of a realization that quality within the laboratory must extend beyond ensuring accurate laboratory test results.

In general, a laboratory test begins when a clinician formulates a question (regarding a patient) which can be answered by certain laboratory results. It ends only after the clinician receives the results and acts upon them. In this process, there are many stages which take place outside the clinical laboratory and may not be under the laboratory's direct control. As listed by Bartlett [2], these include: 1) ordering of tests, 2) collecting and transporting of specimens, 3) transmitting of information to clinicians, 4) posting of laboratory test result data in patient charts, and 5) interpretation and use of test results by clinicians.

Lundberg [3] has defined a critical value as one which "represents a pathophysiological state at such variance with normal as to be life threatening unless something is done promptly and for which some corrective action could be taken." Because critical values indicate life threatening conditions in patients, it is crucial that the "transmission of information" and "interpretation and use of test results" be performed effectively and in a timely fashion so that patients can receive "quality" care. As noted above, both the transmission of information and the interpretation and use of test results may rely on factors which are not under laboratory control. Thus the success of the critical value reporting process depends on how well it can cross over departmental boundaries to communicate with clinicians, and on whether clinicians and laboratory personnel recognize the critical nature of the test result and act upon it.

At LDS Hospital, we have completed a study of the critical value reporting process in the clinical laboratory. Study results have been used to design a computer system to improve the quality of critical value reporting at our hospital.

METHODS

Background

LDS Hospital is a private 520-bed tertiary care facility which is part of the Intermountain Health Care (IHC) hospital system. It is a teaching hospital associated with the University of Utah College of Medicine and has more than 500 private physicians on staff. The computer facilities at the hospital include a Tandem Risc R mainframe, twelve Charles Rivers minicomputers, over 1200

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"smart" terminals, and several Novell networks. Each nursing division within the hospital has at least four terminals and two printers located at the central nursing station and a terminal at each patient bedside. The clinical laboratory information system is interfaced with the Tandem Risc R mainframe which supports the HELP medical information system [4]. The HELP medical information system integrates and manages patient data from throughout the hospital.

All laboratory test results for hospital patients are entered into the laboratory computer, verified, and transmitted to the HELP system. Laboratory test results are then stored in the HELP computerized patient data base and are available for review on any terminal within the hospital. When laboratory test results are displayed on a computer terminal, critical values are highlighted and an "H" or "L" is placed next to the values to indicate high or low. Criteria for critical values are established by the laboratory in consultation with the medical staff.

The established practice for critical value reporting has been as follows: laboratory personnel, having identified a critical laboratory test result, telephone the appropriate nursing unit and report the critical value to the nurse caring for the "critical" patient. The time of the telephone call and the identity of the person receiving the call are then recorded in the laboratory computer. It is the responsibility of the person receiving the critical value telephone call to ensure that appropriate action is taken.

Pilot Study Data on Critical Value Reporting

From June to October 1985, we conducted a pilot study to determine the potential usefulness of a computerized laboratory alerting system (CLAS) in our hospital. CLAS was designed to alert for life threatening conditions in hospital patients, but alerts were not limited to high and low values, nor did they, in general, correspond to laboratory critical value criteria. The criteria used for CLAS, and the process by which they were developed, are described more fully elsewhere [5].

As part of the 1985 pilot study, we evaluated whether laboratory test results identified by CLAS as life threatening were also identified by the clinical laboratory as critical values and reported to clinicians as such. This was complicated by the fact that many of CLAS' criteria for life threatening conditions differed from the clinical laboratory's criteria for critical values. However, in at least two cases, those of hypokalemia (low potassium) and hyperkalemia (high potassium), the criteria used by CLAS and the clinical laboratory were close enough for comparison. For hypokalemia, the criterion used by CLAS ($K < 2.7$ meq/l) was actually more stringent than that used by the clinical laboratory ($K < 3.2$ meq/l). For hyperkalemia, the criteria were the same ($K > 6.0$ meq/l). Thirty-four charts were reviewed for patients with hypokalemia, and twenty-seven charts were reviewed for patients with hyperkalemia. The charts reviewed were not a random sample.

Critical Value Reporting--November 1992

For a one-week period, from November 24-30, 1992 data were collected on all laboratory test results for which the clinical laboratory had stated it would communicate critical results (by telephone) to the nursing staff. The critical value criteria were taken from the clinical laboratory's policy handbook. Data were collected from the HELP patient data base and checked against data from the clinical laboratory computer data base using a computer program which searched the patient's electronic record (on the HELP system) for critical values and noted whether such values had been telephoned to the nursing floor. After collection, data were downloaded to a personal computer and analyzed using Lotus 1-2-3.

Patient Chart Audit--January-February 1993

During January-February 1993, a patient chart audit was conducted to 1) determine whether clinicians were aware of critical values regardless of laboratory notification, 2) determine the average time interval between specimen collection and result availability (on a computer terminal), 3) determine the average time interval between result availability and critical value reporting, 4) determine the average time interval between result availability and corrective actions taken by clinicians, 5) determine the quality of critical value documentation by clinicians, and 6) collect data on the frequency of critical value reporting by the clinical laboratory.

Data from the chart audit were collected by two nurses recruited from the hospital's general nursing staff. After a three-week period in which the nurses gained experience and the reproducibility of data collection was tested, chart audits were performed on 124 patients. A computer program was used to search the HELP patient data base and identify patients who, during their hospital stay

had had critical laboratory test results. Patients included in the audit were all patients with critical test results who were hospital inpatients on the day of the chart audit. No chart audits were conducted on the weekend, nor for patients who were in the ICU or whose chart was not available to the audit nurses. Data gathered during the chart audit were entered into a Lotus 1-2-3 file on a personal computer for analysis.

CLAS II--A Computerized Critical Value Reporting System

From the results of our studies of critical value reporting, it appeared that there were several weaknesses in the process. To correct these, we have designed a computerized critical value reporting system dubbed CLAS II. The system is modeled on CLAS, a computerized laboratory alerting system implemented at LDS Hospital in the late 1980's [6]. The basic architecture of CLAS has been retained in CLAS II. Differences between the systems will exist in the underlying software, the contents of the medical knowledge base, the methods of alert feedback (to clinicians), and the design of the user interface. The original CLAS was disabled in the early 1990's because of major changes within HELP.

CLAS II is designed to function as follows: when laboratory test results have been verified, they are transmitted from the laboratory computer to the HELP system. At this point, test results are stored in the computerized patient data base, and are available to clinicians on any hospital terminal. Also at this point, decision frames will be activated by HELP to evaluate whether laboratory test results represent critical values. When a critical value is identified, an alert will be transmitted to the bedside terminal of the "critical" patient, to all communal terminals on the appropriate nursing unit, and to the nurse(s) caring for the "critical" patient (via patient-specific digital pagers).

Each nurse on a nursing unit carries a digital pager. When an alert is generated, an alert message will be transmitted to the digital pager of the nurse caring for the alerting patient. If an alert is not acknowledged on the computer terminal within 2 minutes of its original transmission, the alert message will be again transmitted, this time to the digital pager carried by the charge nurse on the nursing unit where the alerting patient is located. The time of acknowledgement and the identity of the person acknowledging the alert are captured by CLAS II.

RESULTS

Pilot Study on Critical Value Reporting

During the pilot study conducted to evaluate the potential usefulness of the original CLAS (June-October 1985), data were gathered on the number of times the clinical laboratory reported critical potassium values to the nursing floor using their standard critical value reporting procedure. These data are summarized in Table 1.

Table 1. Number of Critical Potassium Values Reported by the Laboratory--Pilot Study

Type	Reviewed	Reported
Hypokalemia	34	25 (73.5%)
Hyperkalemia	27	16 (59.3%)
Total	61	41 (67.2%)

Of the 34 critical hypokalemia values reviewed, 25, or 73.5%, were telephoned to the nursing floor. Of the 27 critical hyperkalemia values reviewed, 16, or 59.3%, were telephoned to the nursing floor. Considering both together, 67.2% (41 of 61 critical values) were telephoned to the nursing floor.

Critical Value Reporting--November 1992

Results of the study of critical value reporting during the week of November 24-30, 1992 are shown in Table 2. For each criterion, Table 2 lists the number of critical values which occurred, the number of times the clinical laboratory reported the critical value (by telephone), and the percentage of critical values which were reported.

Two hundred ninety-four critical values were identified during the one-week period. Of these, only 28 (9.5%) were telephoned to the nursing floor. The percentage of potassium critical values reported by telephone was 60% (24 to 40), which corresponds closely to results of the 1985 pilot study (67.2% of critical potassium values reported by phone). The critical value which occurred with the highest frequency was PTT (partial thrombin time), making up 42.5% (125 of 294 values) of the total. ***None*** of the PTT critical values were telephoned to the nursing floor. Of the 13 critical value criteria for which data were collected, critical values were reported by telephone for only 5: bilirubin (1 of 11 values), glucose (1 of 6 values), potassium (24 of 40 values), carbon dioxide (1 of 8

values), and phosphorus (1 of 8 values).

Table 2. Clinical Laboratory Critical Value Reporting--November 24-30, 1992

Criteria	Number of Values	Values Phoned	Percent Phoned
Bilirubin > 12	11	1	9.1
Glucose < 50 or > 400	6	1	16.7
Potassium < 3.2 or > 6.0	40	24	60.0
CO2 < 12 or > 40	8	1	12.5
Magnesium < 1.0 or > 5.0	9	0	0.0
Sodium < 120 or > 155	3	0	0.0
Phosphorus < 1.2 or > 8.0	8	1	12.5
Hematocrit < 20%	4	0	0.0
Hemoglobin < 6.5	5	0	0.0
Platelets < 50,000	42	0	0.0
Protime > 30	5	0	0.0
WBC < 3000	26	0	0.0
WBC (CSF) > 10	2	0	0.0
PTT > 50	125	0	0.0
TOTAL	294	28	9.5

Chart Audit--January-February 1993

Data collected during the chart audit of patients with critical values are summarized in Tables 3 and 4. Of 124 charts audited, 19 (15%) contained no documentation indicating that either a nurse or a physician was aware of the critical value. Six of the 19 critical values for which there was no documentation in the patient chart were reported by the clinical laboratory. For those charts in which there was documentation of the critical value (105 charts), 16 (15%) contained documentation by both the physician and the nurse and 89 (85%) contained documentation by the physician only. Of the 124 critical values for which charts were audited, the clinical laboratory reported 44 (35%). However, there was ***only one instance*** in which the critical value was reported directly to the nurse caring for the "critical" patient.

Table 3. Chart Audit Data--Frequencies

Category	Number	Percent
Numbers of Charts	124	100%
Documentation of Critical Value	105	85%
No Documentation of Critical Value	19	15%
Reported by Lab	44	35%
Reported to Nurse	1	1%

The average time between specimen collection and test result availability (computer terminals) was 73.9 minutes. The average time between availability of results on computer terminals and reporting of critical values by the clinical laboratory was -7.0 minutes. The average time between availability of critical values and documentation of the critical values was computed for 92 of the 124 critical values. Nurses were unable to assign a time to documentation of critical values in 19 cases. For the 92 charts, the average time between result availability and documentation was 137.0 minutes.

Table 4. Chart Audit Data--Times

Category	Minutes	Hours
Laboratory Results Available (Computer)	73.9	1.2
Time between Availability and Reporting	-7.0	-0.1
Time between Availability and Documentation (92 charts)	137.0	2.3

DISCUSSION

Results of our studies of critical value reporting in the clinical laboratory have identified a number of weaknesses in the process. Among these are 1) that critical values are not always reported by the clinical laboratory, 2) when critical values are reported, it is often to someone not directly involved in the "critical" patient's care, 3) documentation of critical value reporting by the laboratory is incomplete, 4) clinicians' awareness of critical values is not always documented, 5) clinicians' decisions to undertake corrective actions (or their decisions not to) are not adequately documented, and 6) the time interval between the availability of critical test results and the institution

of corrective measures is sometimes unacceptably long.

One possible reason for the low rate of critical value reporting is inadequacy of the criteria used to identify critical values. For example, though the clinical laboratory's policy manual states that PTT values over 50 are critical and will be reported to the nursing floor, many patients with elevated PTT's are receiving heparin therapy for which PTT values of up to 90 are considered therapeutic. Knowing this, the clinical laboratory usually only reports extreme PTT values (PTT > 130).

Berwick [7] has emphasized that most errors in a process take place in handoffs between steps rather than within the steps themselves. This is borne out by chart audit data showing that only one of the 44 critical values reported by the clinical laboratory was documented to have been received by the nurse caring for the "critical" patient. Also, of the 19 cases in which there was no documentation of the critical value by clinicians, 6 ***were*** reported as critical values by the laboratory.

It is also interesting that the overall rate of critical value reporting found in November 1992 and in January-February 1993 differed substantially (9.5% in November vs. 35% in January-February). The improvement may be due to the fact that the results of the November study were shared with the director of the clinical laboratory in December 1992, thus triggering a greater effort to report critical values. Even so, there remains much room for improvement in critical value reporting.

We believe that the implementation of CLAS II, a computerized critical value reporting system, will correct many of the weaknesses in the critical value reporting process. (CLAS II was designed with the help of nursing and the clinical laboratory and is presently being tested on one nursing unit within the hospital.) Because of CLAS II's automatic nature, every critical value ***is*** reported. Since critical value alerts are routed directly to the nurse via patient specific digital pagers, there is no delay in getting critical values to those directly responsible for "critical" patient care. Documentation should be improved because CLAS II records when critical alerts are transmitted, when alerts are acknowledged, and by whom they are acknowledged. CLAS II also provides a fail-safe mechanism by keeping track of whether critical value alerts have been acknowledged, and by retransmitting alerts when they are not.

A number of studies have shown the benefit of computer-generated alerting (reminder) systems in the patient care process [8,9]. Among these are systems designed to alert on conditions indicated by laboratory test results in the acute care setting. Besides the original CLAS [5], two such systems, one designed to alert on critical creatine values [10] and one designed to detect critical values and trends in ICU patients [11], have been shown to have a positive impact on patient care. As with these other systems, we believe that CLAS II's rapid and reliable reporting and follow-up of critical values will improve the patient care process by insuring timely and appropriate care for patients with critical laboratory test results.

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