Meeting Regulatory Requirements by the Use of Cell Phone Text Message Notification With Autoescalation and Loop Closure for Reporting of Critical Laboratory Results

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Abstract

Critical laboratory results require timely and accurate transmission to the appropriate caregiver to provide intervention to prevent an adverse outcome. We report the use of text messages to notify critical laboratory results in a large teaching hospital to manage the documentation and audit requirements of critical result reporting by regulatory agencies. The text messaging system (critical reportable result health care messaging system [CRR-HMS]) allows a receiver to acknowledge or reject a critical result by short message service reply. Failure to obtain a confirmatory receipt within 10 minutes produces an automated escalation to an alternative physician according to a roster. The median time required for physician response decreased from 7.3 minutes to 2 minutes after implementation of the CRR-HMS. The CRR-HMS is a clinically useful tool to rapidly communicate critical results to targeted physicians to facilitate rapid and timely intervention. This feature seems to be an important laboratory process mediator, and recent Joint Commission reviews have placed this as a requirement.

The postanalytic phase is a vulnerable stage of laboratory testing in which between 10% and 55% of total laboratory error occurs.[1,2] Failure to communicate the right laboratory result to the right person at the right time in the right context is one of the errors.[2] A critical laboratory result is defined as a value that represents a pathophysiologic state at such variance with normal that prompt medical intervention is required to avert imminent danger for the patient concerned and for which effective action is possible.[3] An unusually high number of critical results has been shown to be an early predictor of adverse patient events.[4] Currently, many regulatory bodies, including the Clinical Laboratory Improvement Amendments of 1988, the Joint Commission, and the College of American Pathologists, require clinical laboratories to have in place a mechanism of disseminating critical laboratory result expediently.[5-7]

Information technology has been extensively explored and exploited to improve various safety aspects of clinical laboratory operations. Several studies have demonstrated the usefulness of various electronic means to improve the delivery of critical results to care providers,[8-15] with a recently reported pager alert system achieving an impressive 89% first-pass communication of critical result to the appropriate care provider.[15] The electronic modalities used in the previous studies included alphanumeric pager, electronic medical records, computer display screens, and short message service (SMS).

Advantages of electronic communication include timeliness, automation, reduced waiting time for result transmission, and a captured audit trail of events.[8-15] However, most clinical laboratories are likely to communicate critical results through the telephone, for which the simple practice of read-back has been suggested as a means to improve communication safety.[16,17]

The cellular (mobile) telephone is a communication tool prevalent in modern society. SMS is an attractive candidate for reporting of critical laboratory results for the following reasons: (1) It is a familiar software application. (2) Communication is almost instantaneous. (3) It allows an expanded word limit. (4) It provides direct 2-way communication. (5) There is an electronically captured audit trail. (6) Its hardware device, the cell phone, is in common use among health care workers, negating the cost and inconvenience of an additional portable device. This was the premise for the development and implementation of a novel, fully automated short message system (critical reportable result [CRR]), which incorporates multiple reply options and autoescalation features to deliver critical laboratory results at the National University Hospital (NUH), Singapore. This study reports and discusses the critical values in this hospital and the performance of the automated reporting system.

Materials and Methods

Clinical Setting

The NUH is a 1,000-bed tertiary teaching hospital with a full suite of clinical services encompassing pediatric and adult medicine, obstetrics and gynecology, various surgical disciplines, adult and pediatric emergency departments and psychiatric services. The CORE laboratory, comprising clinical chemistry and hematology divisions, serves the hospital and an extensive network of primary care clinics and referral tests from other private hospitals, receiving in excess of 4,000 clinical samples daily.

Development and Implementation

In 2008, NUH set out to overhaul its critical reporting system, which until then was carried out by a manual call center system, connecting the laboratory staff to physicians, nurses, or clerical staff based on the ordering location to ensure expedient reporting. Such manual communication was time- and resource-intensive and at risk of communication error when a result was relayed through multiple parties. A steering committee, including representatives from nursing professionals, various clinical divisional leaders, laboratory professionals, hospital administrators, information technology department, the call center, and a local private software development partner (Healthcare Messaging Systems, Singapore), was set up to build an information technology engine that automatically alerts physicians to critical results.

The CRR engine is a developed software application loaded onto the health care messaging system (HMS), an existing platform used by the call center to maintain and retrieve departmental physician rosters. Validated laboratory results flow from an HL7 gateway into the CRR-HMS server, which then filters the results for any critical values **Table 1**. A critical result will trigger the application to pull data and information from various existing in-house applications—the hospital information system, computerized physician order entry, laboratory information system, and the HMS server to automatically assemble a concise short message and send it to the ordering physician or physician on call, according to the roster.

The short message contains the requisite 2 unique patient identifiers, latest patient location, identity of attending physician, the critical laboratory result, reference interval, and relevant laboratory comments (eg, grossly hemolyzed). Built into the application are 3 numeric reply options that obviate the need to type text replies, allowing rapid, standardized responses from busy physicians. Replying 1 indicates "I would act on the result; this is my patient."; 2 indicates "I would act on the result, although this is not my patient."; and 3 indicates "I would not act on the result, as this is not my patient." If option 1 or 2 is used, the critical result is considered acknowledged and the transaction is captured by the CRR-HMS system and closed. Failure to receive a 1 or 2 reply within 10 minutes initiates an autoescalation in which a short message will be sent to a more senior physician from the department roster and/or trigger a manual intervention from the hospital call center. The workflow of the CRR-HMS system is summarized in **Figure 1**. In situations in which the SMS fails to transmit because of CRR-HMS application failure, an alert will be triggered on a dashboard prominently displayed in the CORE laboratory and the critical result is manually reported by the call center. All CRR-HMS transactions are electronically captured, and an audit trail traceable to the sender and receiver is recorded.

The CRR-HMS system was first piloted during June through August 2008. Further enhancements and modifications were made to the initial version based on feedback, and the system was rolled out to all departments within the hospital by January 2009.

Characteristics of critical laboratory results were described for a 12-month period ending in March 2010. Response times for manual and automated reporting 3 months before and after intervention were also computed.

Results

In all, there were a total of 18,525 critical laboratory results reported for the 12-month period ending March 31, 2010, representing 0.44% of reported results. This averaged 51 critical results per day. Of these, 79.9% originated from inpatient locations, 8.5% were from outpatient locations, and 11.3% and 0.3% were from the adult and pediatric emergency departments, respectively. The inpatient clinical service with the highest number of critical alerts was the adult critical care units (26% of total critical laboratory result reported), which included intensive care units and high dependency units. It was followed by hematology/oncology (12.0%), surgical services

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Table 1
Critical Value Thresholds for Various Analytes and the Distribution of Critical Laboratory Results (in Percentages) Within Adult and Pediatric Inpatient Units, Outpatient Clinics, and Emergency Departments*

Analyte (Threshold)	Adults	Children	Clinic	EMD	CE	Overall
Troponin I (>0.01 ng/mL [0.01 μg/L])†	36.2	1.4	2.9	0.18	0.0	26.5
Potassium, serum (<2.5 or >6.0 mEq/L [<2.5 or >6.0 mmol/L])	13.9	18.8	16.4	37.4	13.3	17.2
Platelet count (<20 or >800 × 10^3/μL [<20 or >800 × 10^9/L])	14.1	16.8	31.7	7.7	28.3	15.1
WBC count (<1,000 or >50,000/μL [<1 or >50 × 10^9/L])†	7.5	4.7	20.2	4.6	5.0	8.1
Sodium level, serum (<120 or >160 [120 or >160 mmol/L])	6.5	8.0	2.2	14.7	8.3	7.2
APTT (>100 s)	4.9	11.2	0.30	1.6	1.7	4.6
Corrected calcium level (<7 or >12 mg/dL [<1.75 or >3.00 mmol/L])	4.5	4.8	3.9	0.55	0.0	4.0
Glucose level, serum (45-396 mg/dL [<2.5 or >22.0 mmol/L])	0.96	4.1	4.1	22.8	5.0	4.0
Uncorrected calcium level (<7 or >12 mg/dL [<1.75 or >3.00 mmol/L])	3.5	4.2	1.8	0.50	0.0	3.1
INR (>5.0)	1.6	3.4	4.6	2.3	0.0	2.0
Hemoglobin level (<5 g/dL [50 g/L])	1.2	1.7	2.9	4.8	6.7	1.8
pH (<7.20)	2.2	0.93	0.12	0.05	1.7	1.7
Phenytoin level (>20 mg/L [79 μmol/L])	1.2	1.9	3.1	0.87	1.7	1.4
Ammonia level (140 μg/dL [>100 μmol/L])	0.52	8.02	1.3	0.46	1.7	1.1
Bilirubin level, neonatal (17.5 mg/dL [>300 μmol/L])	0.00	7.0	2.8	0.00	25.0	0.83
Vancomycin level (>80 μg/mL [55 μmol/L])	0.71	0.57	0.85	0.00	0.0	0.62
Malaria parasite (positive)†	0.16	0.07	0.12	0.96	0.0	0.24
Phenobarbital level (>40 μg/mL [172 μmol/L])	0.01	2.1	0.55	0.00	1.7	0.22
Salicylate level (>300 μg/mL [2,172 μmol/L])	0.06	0.14	0.00	0.18	0.0	0.07
Digoxin level (>2.4 μg/L [3.1 nmol/L])	0.06	0.21	0.00	0.14	0.0	0.07
Theophylline level (>20 μg/mL [111 μmol/L])	0.05	0.00	0.00	0.00	0.0	0.04
Lithium level (>2 mEq/L [2 mmol/L])	0.04	0.00	0.00	0.05	0.0	0.04
Valproate level (>200 μg/mL [1,386 μmol/L])	0.02	0.00	0.00	0.05	0.0	0.02
Acetaminophen level (>200 μg/mL [1,324 μmol/L])	0.00	0.00	0.00	0.18	0.0	0.02
Amikacin level (>38 μg/mL [65 μmol/L])	0.03	0.00	0.00	0.00	0.0	0.02
Urine dipstick ketone (>2+)	0.00	0.07	0.12	0.00	0.00	0.02
Rapid plasma reagin (titer >2)	0.00	0.00	0.12	0.00	0.00	0.01
Gentamicin level (>16 μg/mL [33 μmol/L])	0.01	0.00	0.00	0.00	0.0	0.01

APTT, activated partial thromboplastin time; INR, international normalized ratio.
* Adults refers to the adult inpatient units, Children to pediatric inpatient units, clinic to the outpatient clinics, CE to the children's emergency department, and EMD to the emergency medicine department.
† For first presentation only.

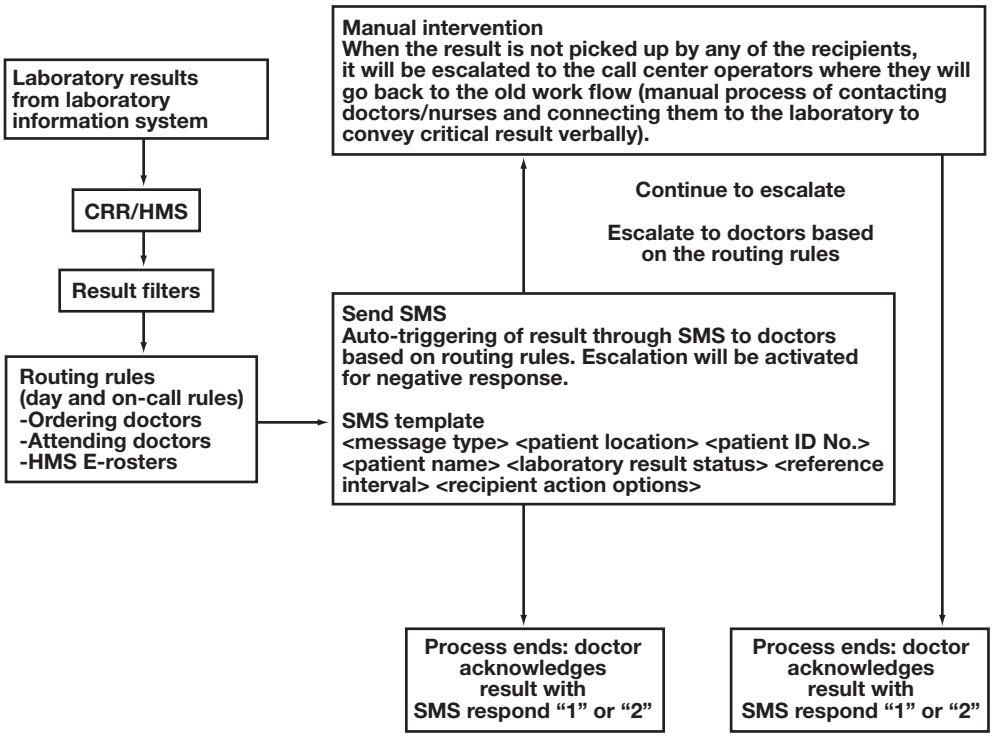

Figure 1 The workflow of the CRR-HMS system. CRR, critical reportable result; HMS, health care messaging system; SMS, short message service.

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(8.9%), general medicine (8.0%), and renal medicine (6.6%). Nearly 70% of the critical results came from clinical chemistry division. Troponin, potassium, platelet, and sodium results, in descending order, were most frequently reported, collectively accounting for two thirds of the total critical values.

The timing of critical results showed a bimodal distribution peaking at 8:00 AM and at 12:00 PM and was lowest from 2:00 to 4:00 AM. The proportion of critical results reported during the trough was 35% of the peaks. The distribution of various critical laboratory results among inpatient, outpatient, and emergency departments is summarized in Table 1.

Before the full implementation CRR-HMS system, the mean and median response times of critical laboratory result reporting were 14.6 and 7.3 minutes, respectively (March-May 2008). These times represent the time when a result was available to the time when the result was acknowledged by a person from the ordering location and the reporting was considered complete. They included the time taken to validate the critical result, which was not separately captured then. At that time, 96.8% of critical results were communicated within 1 hour. More than a year after the automated CRR-HMS system was implemented (March-May 2010), the mean and median response times became 18.3 and 11.0 minutes, respectively. Excluding the time taken by the laboratory to validate critical values, the mean and median times to respond to an SMS alert were 4.7 and 2.0 minutes, respectively. During this period, 92.9% of critical results were acknowledged within 1 hour. At NUH, all critical laboratory results were communicated to a physician eventually, ie, no critical result was abandoned.

Discussion

Reporting of critical laboratory results has gained increasing contemporary interest among laboratory practitioners, promoted by regulatory requirements. This was evident in 2 large College of American Pathologists Q-Probes studies on critical value notification in 2002 and 2008.[18,19] In the initial survey, significant heterogeneity in the practice of critical result reporting was noted among participants, including personnel providing and receiving critical value calls, definition of critical thresholds and tests, policy for handling of repeated critical values, attitude toward critical value list, and time spent to complete or abandon a call for a critical value.[18] A follow-up survey 6 years later found that delay in therapy initiation meant that the interval required for critical result notification may be less important than ensuring no abandoned critical results, delayed therapy, or other communication pitfalls.[19] Similar studies have been conducted in Italy and compared with the Q-Probes surveys with several notable differences.[20,21]

Comprehensive characterization of critical laboratory results from the Asian region is lacking. This study attempts to fill this gap by describing the features of clinical laboratory results in a large tertiary hospital in Singapore during a 12-month period. Despite the use of different critical thresholds and analytes for monitoring, the findings of this study were broadly similar to those previously published from other academic medical centers. Potassium, platelet count, and partial thromboplastin time were commonly among the tests with highest number of critical results.[22] A similar observation was made when comparing the departmental incidence rate of critical results in another study.[13] The number of critical laboratory results in all 3 studies, including the present study, peaked around midday and gradually subsided toward midnight.[21,22] This probably reflects the number of tests performed during the time of day. The distribution of critical results by location (ie, inpatient, outpatient, and emergency department) and by laboratory discipline (eg, hematology, clinical chemistry) was also highly similar.[22]

The use of SMS in reporting critical laboratory results is relatively underused compared with the more widely adopted pager systems. To date, only 3 studies have evaluated the use of SMS as a means to communicate critical laboratory results.[12,13,23] The study by Park et al[12] looked into the use of SMS only for reporting hyperkalemia, while another study from Taiwan reported a 1-way SMS system for reporting clinical laboratory results. [23] The 1-way SMS system is not ideal in clinical practice because it does not allow acknowledgement from the receiver, leaving the communication loop open. In another study, the combined use of SMS notification and desktop computer alert reduced the average response time for critical laboratory results from 30 minutes, using a conventional telephone call system, to 11 minutes. The rate of failed reporting was similarly reduced, from 50% to 10.9%.[13]

The median physician response time of 2.0 minutes achieved after the implementation of the CRR-HMS system is comparable to other clinically implemented automated critical reporting systems, including a pager system (median time, 1.5 minutes)[15] and the SMS system described in an earlier section.[13] Other qualitative benefits, such as reduced stress on laboratory staff for constantly monitoring and reporting critical laboratory results, should not be overlooked.

The CRR-HMS reporting system has loop closure and assurance of receipt built into the application, as well as 2 features not previously reported. The use of multiple reply options allows the receiver to quickly pass on inappropriate critical laboratory results to the next physician on the roster. This discourages the practice of ignoring a text message and waiting for it to expire before the result is escalated to the next physician or a manual intervention is instituted. The other feature is the ability to self-escalate an unanswered short message to ensure that an acknowledgment is obtained with minimal human intervention. Beyond the benefit of automation, this mechanism acts as real-time feedback to senior staff members of the departments to ensure that junior staff members acknowledge and act on critical laboratory results.

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The apparent deterioration in the response time after the implementation of the CRR-HMS system can be explained by 2 factors. First, the response time for the CRR-HMS system included delay of the SMS escalation logic, whereas a call operator could repeatedly contact a person or immediately move on to an alternative person if no response was obtained. Second, the manual reporting response time was underestimated because it stopped after any staff, including nurses and clerical staff who are more readily available, acknowledged the critical result. The additional time required to relay the result to the appropriate physician was unrecorded. The critical result short message is sent directly to physicians.

It is not enough to ensure that critical laboratory results are transmitted to somebody. Evidence suggests that this is only the end of the beginning of an intervention to correct a grossly abnormal pathophysiologic finding to avert an adverse outcome.[19,24] Key challenges in critical laboratory result notification, succinctly summarized here,[24] include defining critical results, improving communication with end users, appropriate routing of results to an alternative receiver, and compliance with standards without losing sight of the objectives. Already, increasing emphasis is made to ensure timely institution of interventions when a critical result arises.[19,25] The electronic audit trail captured by the CRR-HMS system has a central role in our laboratory's audit efforts for targeted intervention for recalcitrant parties who ignore or do not act on critical results.

This study comprehensively described the characteristics of critical laboratory results in a large Asian teaching hospital. It also demonstrated the clinical usefulness of an SMS system for notifying appropriate people of critical laboratory results and complying with regulatory requirements.

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