Contents lists available at Science-Gate

International Journal of Advanced and Applied Sciences

Journal homepage: http://www.science-gate.com/IJAAS.html

Enhancing clinical laboratory reporting: The impact of implementing a critical laboratory value protocol

Vasthy Lozano-Fernández [1, 2, *]

[1]Servicio de Laboratorio Clínico, Hospital Regional de Lambayeque, Chiclayo, Peru
[2]Inmunología, Hospital Regional de Lambayeque, Chiclayo, Peru

ARTICLE INFO

Article history:
Received 14 April 2023
Received in revised form
22 September 2023
Accepted 6 October 2023

Keywords:
Clinical laboratory reporting
Critical value protocol
Diagnostic accuracy
Emergency service
Reporting quality

ABSTRACT

This study examines the influence of a newly implemented protocol for critical laboratory values on the quality and accuracy of laboratory reports in a clinical setting. The necessity of strict adherence to protocols in clinical laboratories is underscored by the potential for a deviation of up to 45% in results, leading to diagnostic errors. The research focused on emergency service critical values, adhering to a designated protocol list. Conducted in two phases, the study initially involved training sessions and a knowledge questionnaire regarding the protocol, followed by a repeated questionnaire and analysis of laboratory test reports. Among 181,507 emergency examinations, critical values constituted 2.75% (4,998 cases). While protocol knowledge did not show significant improvement, reporting accuracy for creatinine, glucose, sodium, leukocytes, platelets, and activated partial thromboplastin time (aPTT) markedly increased. Timely and effective notification rates improved significantly, as did staff reporting consistency across shifts. The study concludes that implementing a critical value protocol significantly enhances the quality of clinical laboratory reporting, although timely critical value quality remains below the requisite standard.

1. Introduction

The reporting of clinical laboratory results is a fundamental tool, as it is estimated that they influence up to 70% of medical diagnoses, which has an impact on the course of treatment and prognosis of patients (Angüiano-Sánchez et al., 2011). However, it is the critical laboratory values that indicate a patient's pathological condition, which can be life-threatening if appropriate and timely medical decisions are not made (Campuzano Maya, 2011).

The critical value reporting protocol is a set of guidelines established by each laboratory for the timely flow of information inside and outside the laboratory, considering that the patient's evolution changes according to several factors, one of which is the detection of a critical value in the laboratory. Likewise, the fluidity of communication by laboratory personnel, as an indicator of the quality of the report, contributes to adequate care and prevents adverse results due to a delay in therapeutics, as it can in some cases increase the speed of the diagnostic process or facilitate rapid changes in the therapeutic approach; thus, the entire healthcare team contributes to patient safety and care (Guzmán et al., 2009; Angüiano-Sánchez et al., 2011; Campuzano Maya, 2011; Kopcinovic et al., 2015; Feitosa et al., 2016; Consolato, 2018).

Guzmán and Lagos (2009) emphasized the necessity of instituting a system for notifying critical values in clinical laboratory reports, tailored to the complexity of healthcare facilities in Chile. Their analysis focused on the notification processes for critical values throughout 2007. They observed that the most frequently reported tests potassium, platelet count, activated partial thromboplastin time (aPTT), and hematocrit- corresponded with those documented in existing literature. The absence of a computerized system posed a significant challenge in timely notifications, as evidenced by the fact that 21% of critical values were reported with delays exceeding 30 minutes. This finding underscores the critical need for efficient and technologically supported notification systems in clinical laboratory settings.

Li et al. (2020), in order to obtain information to improve the quality of clinical laboratories and patient safety in hospitals in China, 862 laboratories

* Corresponding Author.
Email Address: vlozano@hrlamb.gob.pe
https://doi.org/10.21833/ijaas.2023.10.020
Corresponding author's ORCID profile:
https://orcid.org/0009-0006-3468-9995

participated and concluded that after coordination with doctors, most included leukocyte count, platelet count, hemoglobin, etc. in the list of critical values. prothrombin time and activated partial thromboplastin time and despite timely reporting in China (8-9 minutes), some steps should be taken to further improve the timeliness of critical value reporting.

Arbiol-Roca et al. (2019), in Spain, announced that the optimization of a critical value notification system positively influenced patient safety, efficiency, and quality of clinical care, given that 80% of the critical values detected belonged to the emergency area, the highest critical value notification parameters in emergency patients were the pH value, hematocrit, glucose, potassium ions and hemoglobin concentrations.

Kopcinovic et al. (2015), in the Department of Clinical Pathology of the National Hospital Dos de Mayo–Peru, processed an average of 103,394 samples monthly, with the areas of greatest demand being the area of Biochemistry with 66,530 samples (64.52%) and Hematology with 21,658 samples (21.00%); a protocol for reporting critical values for the Emergency service was established.

In the initial four months of 2016, the National Hospital Dos de Mayo's laboratory implemented a system for the notification of critical laboratory values. However, this initiative encountered challenges due to the incomplete training of the laboratory personnel, particularly in the Biochemistry and Hematology departments. This lack of comprehensive training resulted in gaps in the execution of the critical value notification system, encompassing identification, communication, and documentation processes. Consequently, this study was designed to investigate the impact of a fully implemented critical value notification protocol on the quality of reporting by laboratory personnel during the period of January to September 2016.

The primary aim of this research was to assess the effect of executing a comprehensive protocol for critical laboratory values on the report quality in the laboratory. Specific objectives included the standardization of effective reporting of critical values and establishing timely notification as a key quality indicator within the laboratory setting.

The research was necessitated by the limitations identified in the pre-intervention notification processes at Hospital Dos de Mayo. Although critical values were reported, they were not done so effectively, indicating a need for improvement. By enhancing the critical value reporting system, the study aimed to minimize reporting delays and integrate these reports seamlessly into physicians' standard workflows. Such improvements are vital for optimizing laboratory processes, which are integral to overall patient care (López-Pelayo et al., 2012; Schapkaitz and Mafika, 2014; Schifman et al., 2016).

This investigation emphasizes the necessity for laboratory services to develop a system for notifying critical values that align with their specific methodologies, irrespective of the institutional complexity. It advocates for collaborative efforts between laboratory and clinical services. This need arises from the observation that the reporting of critical results varies across different laboratories and countries, as noted by Valenstein et al. (2008) and Sun et al. (2018). All staff members should be well-acquainted with the appropriate follow-up procedures within the notification protocol.

To enhance the foundation of an emerging protocol, the Hospital Nacional Dos de Mayo initiated a critical values notification process specifically for emergency situations, where patients are admitted under conditions posing an immediate danger or risk to life. This notification system serves as a pivotal management tool for the heads of clinical laboratories. It encompasses the development of processes from planning and organizing to training personnel, aiming to deliver diagnostic results that are both timely and of high quality.

It is important to recognize that critical value reporting has evolved to become a requirement for accreditation and a broadly accepted practice. Consequently, many laboratories have adopted a critical values policy as a practice of quality assurance, underlining its significance in contemporary medical diagnostics (Piva et al., 2014).

The outcomes of this study aim to furnish health facilities offering laboratory services with valuable insights, facilitating the establishment of definitive guidelines for managing critical values. In doing so, the patient emerges as the primary beneficiary, with these measures significantly contributing to their care and safety. It is crucial to acknowledge that the realization of all objectives associated with instituting a critical values reporting protocol necessitates ongoing enhancements. These continual improvements are expected to yield positive results in the medium to long term, ensuring their sustainability and enduring impact on healthcare practices (Valenstein et al., 2008; López Pelayo et al., 2011; Schifman et al., 2016).

2. Literature review

Llopis Díaz et al. (2010) in Israel, reported in their study conducted in a medical center in Israel that at the end of four years of implementation there were gradual improvements in the report of a critical value, where it was concluded that the report increased from 55% in 2010 to 95% in 2014. These improvements are summarized in the importance of: a) selecting suitable tests and values for the list of critical values, b) using technology and computerized measures to support the process, and c) developing rapid procedures to monitor and control the process.

Rocha et al. (2016) in an emergency hospital in Chile, included within nine quality indicators in a laboratory the percentage of warning of alert values to the treating physician before 30 minutes with a goal greater than 90% of the alert values detected

and with a periodicity of measurement per quarter, in order to identify problems and possible improvements.

In their study, López Pelayo et al. (2011) conducted a comprehensive analysis at a Spanish hospital regarding the implementation and evaluation of a procedure for the communication of critical values. The process commenced with a consensual determination of critical values in collaboration with the hospital's physicians. Subsequently, a laboratory computer system was developed, integrating automatic rules within automated equipment to trigger alerts for critical tests. Upon detection of a critical value, the laboratory technician was tasked with notifying the physician for validation and subsequent communication. In scenarios where the physician was unavailable, the laboratory technician assumed the responsibility for notification. The researchers noted that although this procedure increased the workload in the laboratory, it significantly enhanced clinical diligence by facilitating immediate medical actions. The most frequently reported critical values were hyperkalemia, followed by hyperglycemia, hyperamylasemia, and anemia.

Li et al. (2020) presented a five-year retrospective observational report on the reporting of critical laboratory values subsequent to the introduction of an electronic reporting system in a Chinese hospital. The study concluded that the implementation of this electronic system for reporting critical laboratory values, encompassing the closed-loop process of detection, notification, and acknowledgment, coupled with short message services (SMS) to mobile phones and telephone calls, constituted effective intervention strategies. These strategies markedly augmented the efficiency of notification, as evidenced by the establishment and application of various quality indicators: the notification index, the rate of timely notification, the rate of receipt of notifications, the rate of receipt of timely notifications, and the physician response rate. Over a five-year period, these indicators yielded impressive results: 100%, 94%, 97%, 92%, and 99%, respectively

In their study conducted in the United States, Sarwar et al. (2022) introduced a novel approach to critical value notification reporting by employing a secure text messaging application. This application facilitated the direct transmission of critical values to physicians on their smartphone devices, diverging from the traditional laboratory practice of telephone-based notifications. The findings revealed a substantial decrease in response times following the implementation of this system: the average response time was reduced from 11.3 minutes (median: 7 minutes, range: 0-210 minutes) pre-implementation to 3.03 minutes (median: 0.89 minutes, range: less than 1 - 95 minutes) post-implementation, indicating a statistically significant enhancement in efficiency ($p<0.001$). Furthermore, survey evaluations at the conclusion of the study indicated a high level of approval among users, with 85% acknowledging an increase in efficiency due to the secure text messaging system, and 95% deeming it more effective than the traditional phone call-based method, primarily due to its significant impact in expediting notification times.

3. Theoretical basis

3.1. Critical value in the laboratory

A critical laboratory value is the laboratory result that reflects pathological states that can endanger the patient's life unless appropriate treatment is promptly initiated. That is why in 2008 the World Health Organization (WHO) published a document of communication or notification of critical values and entered the notification as a strategy for patient safety (Piva et al., 2014; Schifman et al., 2016). The reporting of critical values is an activity described more than three decades ago (Ibrahim et al., 2009), it is one of the functions of the laboratory that has the greatest impact on patient safety (Kost and Hale, 2011; Li et al., 2020), and is a responsibility of the laboratory regardless of the area where the patient is hospitalized or in outpatient consultation (Guzmán and Lagos, 2009; Ibrahim et al., 2009). However, not all laboratories have this activity regulated, so there is a deficient harmonization of the management of critical results present in several laboratories and countries. The key procedures in a critical results management system that require harmonization are: a) definition of the term critical outcome, b) compilation of a list of critical limits, c) definition of critical performance reporting procedures, with special emphasis on the timeliness of reports, communicating procedures on who reports, to whom the critical result is reported and how the reception of the result is confirmed, d) definition of the data to be recorded, e) establishment of procedures to monitor and evaluate the performance of critical results management procedures. The absence of these procedures reflects the lack of specific national recommendations (Lynn and Olson, 2020).

Health institutions should have a list of critical values, considering only values that imply a vital risk. This list should be drawn up from publications available in the literature, but they must necessarily be adjusted to the complexity of the center in question, considering the medical specialties present and ideally agreed with the various clinical services (Campuzano Maya, 2011).

Since accreditation standards only provide general guidance and no specific or universal procedures for the management of critical outcomes are proposed, practices related to critical results reporting are heterogeneous between laboratories and countries; and in the absence of a standardized universal list of critical values for laboratories, most are based on the terms of the American College of Pathologists (CAP) (Arbiol-Roca et al., 2019).

The elaboration of a list is not immediate, it is continuously developed and refined in coordination

with clinical laboratory physicians and physicians of other specialties (Guzmán et al., 2009; Guzmán and Lagos, 2009; Campuzano Maya, 2011; Kopcinovic et al., 2015; Consolato, 2018).

In certain institutions, there is a periodic review and modification of the list of critical values by the laboratory in collaboration with clinicians. This review process occurs annually in 50% of these institutions, biennially in 9%, triennially in 23%, and at various other intervals in 18% of the cases (Cantero Sánchez et al., 2015).

Also, once the list of critical values has been approved, it must be available to the set of professionals who issue and receive the results of the laboratory. This can be achieved by including it in the laboratory quality manual, the center's procedures manual, and the computer system. (López-Pelayo et al., 2012)

Feitosa et al. (2016) meticulously developed over a two-year span with biannual reviews, a tailored list of critical values for a cardiological hospital in Brazil. This list was distinctively modified and adapted to suit the specific pathologies prevalent in the hospital, drawing upon relevant scientific literature. The primary objective of this initiative was to ensure the provision of pertinent information while simultaneously preventing an overload in laboratory operations.

In their research, Cantero Sánchez et al. (2015) conducted an extensive study between July 2012 and November 2013 in the neonatal unit of the Costa del Sol Health Agency (ASCS) in Marbella, Málaga. This study was marked by a series of collaborative clinical sessions between the laboratory and neonatology departments, culminating in the consensus of a critical values list specifically for the neonatal unit. Additionally, an action protocol was established to guide the response once a critical value was identified. This approach underscored the importance of interdisciplinary collaboration in optimizing patient care in neonatal settings.

3.2. Critical value protocol

The establishment of a protocol for the reporting of critical values, as an integral component of a quality indicator within laboratory reports, hinges on its effective execution. This entails ensuring that the reporting is timely, accurate, comprehensive, unambiguous, and comprehensible. A critical element of this process is the implementation of a 'read-back' procedure, wherein the health professionals who have ordered the tests repeat back the information received. Such a protocol significantly mitigates the risk of error, aiming to achieve this within a maximum timeframe of 30 minutes (Ibrahim et al., 2009; Kost and Hale, 2011; Lippi et al., 2017).

The time elapsed between detection and notification of critical values must continue to be monitored continuously, which is why this parameter has been incorporated into the quality indicators, establishing a warning goal of less than 30 minutes for more than 90% of the critical values detected (Schifman et al., 2016).

The process begins with the recognition that a result and the processed sample must be in satisfactory condition and does not present possible analytical interference for that laboratory analysis (e.g., obvious jaundice, turbidity, or hemolysis) or other sources of error (López Pelayo et al., 2011; Lynn and Olson, 2020).

There are laboratories with software integrated into the automated system that automatically verifies the result based on the patient's history and reference values; An alarm signal is then emitted on the equipment that ensures a notification of a critical value (Cantero Sánchez et al., 2015; Feitosa et al., 2016).

Arbiol-Roca et al. (2019) elaborated an analysis of critical laboratory values in a university hospital of reference in Spain, and in the laboratory, the analysis team was configured so that a red warning flag is automatically displayed in the laboratory system when a critical value is detected; Then, analytical reliability is checked, and once the potential margin of error has been eliminated and the result is validated, the person responsible for the patient's care is notified. They also indicated that any notification should be recorded (the critical value, the technician who communicated the information, and the person who received the information), as well as confirmation that the caregiver has accepted responsibility for follow-up and this activity should be carefully considered, as it affects patient safety, efficiency and quality of clinical care.

GebreEyesus et al. (2021) highlighted in their analysis of laboratory performance in procuring critical values the criteria set forth by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) for proper notification of critical values. In JCAHO's "National Patient Safety Goal" (NPSG.02.03.01: "Improve the effectiveness of Communication among caregivers"), recommendations were made detailing which personnel should be informed about a critical value and who is responsible for receiving this information. Ideally, the person verifying the test result should inform the laboratory physician, who then directly notifies the doctor responsible for the patient. However, recognizing that this direct communication may not always be feasible, the guidelines permit other designated individuals to receive and promptly relay the information from the laboratory. Typically, this responsibility extends to various health professionals, including residents and nurses, who are expected to communicate the critical values to the clinician at the earliest opportunity.

There is controversy about who is responsible for receiving the information about the critical value since it will not always be received by the doctor. Llopis Díaz et al. (2010) in the results of a survey on the communication of critical values carried out by the extra analytical quality commission of the SEQC (Quality Assurance and Accreditation Committee,

Spanish Society of Clinical Biochemistry and Molecular Pathology) concluded that the information of the notification of a critical value can be received by a doctor or can be performed by another health professional.

In their study conducted in Italy, Piva et al. (2014) explored the impact of automatically notifying physicians of critical laboratory values via the hospital system to their mobile phones, facilitating effective clinical decision-making. Their findings revealed that in 65% of the cases (13 patients), outpatient clinicians encountered unexpectedly high potassium levels, as reported by the physician. All these patients received treatment within four hours of the report, with 45% (nine patients) subsequently admitted for further hospital care.

The study emphasized that the quality of laboratory tests encompasses the entire 'brain-to-brain circuitry', which includes three critical phases: the pre-analytical phase (selection of the appropriate test at the correct time for the right patient), the analytical phase (accurate results on the appropriate forms), and the post-analytical phase (timely and correct interpretation of the results, along with a clear understanding of subsequent actions).

Furthermore, the study highlighted the importance of clear identification of the interlocutor during the notification process. This process always includes specifying the patient's name, the critical data, and its result. To conclude the communication, the recipient is asked to repeat the patient's name and the communicated value. Only after this correct repetition is the value considered to have been effectively communicated. In all instances of oral communication, it is crucial to confirm the accurate reception of the information (Guzmán and Lagos, 2009; Kost and Hale, 2011; Li et al., 2020).

3.3. Quality in clinical laboratory reporting

In medicine, quality during the reporting of results in the clinical laboratory is associated with excellence in knowledge, perfection of a process, and obtaining good results. On the other hand, ISO (International Standard Organization) 15189 requires the immediate notification of a critical value as a special requirement, as well as the implementation of quality indicators such as the notification time of less than 30 minutes to evaluate and monitor the contribution of the laboratory to patient safety (López-Pelayo et al., 2012; Schapkaitz and Mafika, 2014; Piva et al., 2014; Lynn and Olson, 2020).

Ibrahim et al. (2009) conducted an evaluation in a laboratory at the Apollo Dahka Hospital in South Asia. They identified that one of the primary impediments to the efficient execution of the critical values protocol was the extensive list of tests requiring reporting. Additionally, the lack of a bidirectional interface system, connecting the laboratory's computer system with the physician who requested the test, was noted as a significant factor contributing to delays in the protocol's execution.

Guzmán et al. (2009), in their research on warning of alert values by the clinical laboratory in a university health network, established that alert values represent only 0.3% of the total number of tests, mainly in the area of Clinical Chemistry and Hematology, and that to obtain a real impact on the patient it is essential to shorten the notification period to a time of less than 30 minutes, with appropriate computerized systems and extend the procedure to all personnel involved in patient care.

López-Pelayo et al. (2012) undertook an analysis to assess the clinical impact on patient safety resulting from the communication of critical laboratory values. Their findings indicated that out of 417 critical value alerts, these constituted 0.6% of the total number of requests processed by the laboratory. Furthermore, the average time taken to communicate these values was 12 minutes for emergency situations and 31 minutes for routine cases. Notably, in over 65% of these instances, there was a resultant change in patient treatment, primarily due to conditions like hyperamylasemia, hyperkalemia, and hyperglycemia. Among the critical alerts reported for 92 outpatient patients (22.1%), 30 patients (7.2%) were subsequently referred to the emergency room. This referral for immediate clinical intervention was directly attributable to the timely notification provided by the laboratory.

Guzmán et al. (2009) in the use of the Digital Health History and the application of SMS messages by WebMovil, demonstrated that the notification time for the new protocol was 13 minutes compared to 30 of the traditional system. The success rate of notifications was 97.7%. 0% dropouts were obtained, and the error rate decreased to 3.5% when notification was made through telephone calls.

4. Material and methods

The methodological approach of this research is quantitative and the study types and design are as follows:

- According to the intervention of the researcher: experimental.
- According to scope: analytical
- According to the number of occasions of the measurements of the study variable: longitudinal
- According to the time of data collection: retrospective and prospective

The analytical design of this research focuses on the analysis of data and information regarding the results generated from the application of processes developed by the researcher. Information (test) and the report record of results of critical laboratory values from January - April 2016 prior to the training intervention of laboratory personnel were used and the association with the improvement in the quality of the report of the same group was assessed

considering the information (test) and the report record of results of critical laboratory values during the period from May to September 2016.

For the purpose of sample design, the study encompassed all critical values pertaining to patients at the National Hospital Dos de Mayo, constituting the universe population for this research.

The study population was defined by all critical values originating from the emergency service, in accordance with the standardized list from the protocol of the Biochemistry and Hematology laboratory at the National Hospital Dos de Mayo. This encompassed two distinct periods: January to April 2016 and May to September 2016. The sample size was the entire study population.

4.1. Sampling

All critical values were derived from the processing of laboratory samples from the Emergency Service, adhering to the standardized protocol list of the Biochemistry and Hematology laboratory at the Dos de Mayo National Hospital.

4.2. Selection criteria

The selection criteria for the study were categorized into inclusion and exclusion criteria as follows:

Inclusion criteria:

1. Critical values pertaining to patients of the Emergency Service at the National Hospital Dos de Mayo.
2. Critical values of samples processed in the Biochemistry and Hematology laboratory.

Exclusion criteria:

1. Critical values from patients in the neonatal unit and pediatrics (up to 14 years and 11 months).
2. Critical values from samples exhibiting pre-analytical errors or issues related to sample quality, such as hemolysis, insufficient volume, incorrect sample type, and coagulated samples.
3. Samples processed in the Microbiology laboratory.

4.3. Data collection techniques and procedures

The research team comprised the principal investigator, a medical assistant specializing in Biochemistry and Hematology, and additional collaborators including seven resident doctors, seventeen graduates in Medical Technology, twelve laboratory technicians, and fifteen Medical Technology practitioners. This study was executed in two distinct phases. In the first phase, following a four-month period of critical value notifications by laboratory staff (January-April 2016), three sessions were conducted. The initial session involved a meeting with attending physicians and resident doctors from the Clinical Pathology specialty. The agenda included administering a questionnaire to assess knowledge of the critical values protocol, discussing the updated critical values list (previously reviewed by medical personnel from the emergency service), coordinating corrective measures, instructing on proper information recording (Table 1), and distributing laminated cards listing critical values, with the hospital's main telephone annexes on the reverse side. The second session entailed a series of meetings with Hematology and Biochemistry service technicians and Medical Technology graduates, organized according to their day or night on-call schedule. Each meeting involved administering the questionnaire, training in the notification protocol, reinforcing concepts of effective and timely notification of critical values, instructing on the use of the notification record in the computer's Excel file located in the Biochemistry area, and distributing the aforementioned cards (Tables 1- 3). The third session was dedicated to training and distributing the cards to Medical Technology practitioners.

In the second phase of the study, spanning May to September 2016, the staff was re-evaluated using the same structured questionnaire. Data from the Excel record sheet were collected for a comparative analysis of the period before and after the intervention.

4.3.1. Critical value reporting procedure

Considering the list of critical values that was made known to laboratory personnel (clinical pathologist, clinical pathology resident, technician, or medical technologist), a technical check was first carried out. For example, if the result may be altered by the presence of any condition that may cause interference such as fibrin, hemolysis, jaundice, or lipemia, and then the pathologist or resident of Clinical Pathology is notified for the validation of the result, because in case of detecting any interference or other possible preanalytical error, this result is not communicated and a new sample is requested (Howanitz et al., 2002; Guzmán and Lagos, 2009; Ibrahim et al., 2009; Kost and Hale, 2011; Consolato, 2018; Li et al., 2020).

If it is proven that there was no preanalytical error, it was not necessary to repeat the collection and processing of the sample, since this causes a delay in the notification from 15 to 28 minutes and the same results are obtained, except at the request of the attending physician (Schapkaitz and Mafika, 2014; Lynn and Olson, 2020). As a general rule, the result is checked and checked if there are previous results; If the patient has similar previous results and the doctor is already notified in previous days, the communication is not made (Valenstein et al., 2008; Sun et al., 2018), however, since the diagnosis does not always appear in the medical order in the hospital and there was no way to know if the treating personnel already had knowledge of the presence of these values in the patient, The critical value was communicated, and it was left to the

consideration of the treating physician to act on this information (Schifman et al., 2016).

In the protocol, the ideal is that the notification is given by the specialist in clinical pathology or resident doctor of clinical pathology (laboratory physician) because there will be a more rational opportunity to analyze, discuss the case and help in making a clinical decision [35,36], however, the person responsible for notifying is defined by each hospital (López-Pelayo et al., 2012), and in the protocol of the hospital given to the great demand that attends it was established that in the absence of the specialist doctor in the shift the person responsible for notifying is the medical technologist followed by the technical staff because it is the one who performs and detects the altered result, but the verification steps of the same must be followed to avoid giving an incorrect result (Llopis Díaz et al., 2010). Likewise, although it is ideal that the information be received by the attending physician (Guzmán et al., 2009) and given that in the emergency area, this is not always possible, the protocol established that in order to expedite the notification this information could be received by the resident physician, the medical intern, technician or nursing staff since studies support that health professionals (residents, nurses, etc.) are allowed to be part of the notification process (Kopcinovic et al., 2015; Lippi et al., 2017).

The role of telephonic communication is pivotal in discussing and accurately interpreting critical values, as highlighted by Howanitz et al. (2002). Consequently, upon identification of a critical value, the staff member engaging in the communication will clearly identify themselves and explicitly convey the patient's name along with the value of the critical result.

To conclude the communication, the question is asked: Can you repeat the patient's name and the value communicated? Only after confirming the correct request, the value is considered to have been communicated. In all cases of oral communication, it is necessary to confirm the correct reception of the information, through what is called in the literature the read-back, that is, to ask the person who receives the call to write down the dictated value and to repeat it to the person who informs him, in order to avoid adverse effects capable of causing harm to patients (Guzmán et al., 2009; Guzmán and Lagos, 2009; Llopis Díaz et al., 2010; Kost and Hale, 2011; López Pelayo et al., 2011; Piva et al., 2014; Schifman et al., 2016). Table 1 shows the list of critical values that are taken into account in the clinical laboratory.

4.3.2. Critical value notification documentation

In accordance with ISO 15189:2012, the laboratory must keep records of actions taken documenting the date, time, responsible laboratory personnel member, notified person and transmitted test results, and any difficulties encountered in notifications. This data logging allows laboratories to monitor and measure their performance by reporting critical results and identifying potential improvements (Genzen and Tormey, 2011).

The laboratory personnel meticulously documented all notifications, including unsuccessful attempts, in an electronic Excel format. This documentation encompassed various data points, such as the patient's identification, the specific test conducted and its result, the date and time of the notification, and the identities of both the communicator and the recipient verified through the read-back process. Additionally, within the observation column, a system of numerical registration was utilized: the designation of (1) was used to indicate instances where there was no response to the call yet the result was recorded, and (2) was employed to signify cases where the critical value had not been previously communicated to the laboratory physician (Angüiano-Sánchez et al., 2011).

Table 1: List of critical values of the clinical laboratory of the National Hospital Dos de Mayo

Analytes	Critical values		Units
	Low	High	
Glucose	<50	>600	mg/dL
Sodium	<120	>160	mmol/L
Potassium	<2.5	>6.5	mmol/L
Chlorine	<80	>120	mmol/L
Phosphorus	<1	>8	mg/dL
Magnesium	<1	>5	mg/dL
Calcium	<6.5	>13	mg/dL
Creatinine		>10	mg/dL
Troponin		>0.5	ng/mL
Leukocytes	<2,000	<50,000	/mm3
Hemoglobin	<6	>20	gr/dL
Platelets	<20,000	>1 000, 000	/mm3
INR		>5	
APTT		>100	seg
Fibrinogen	<60		mg/dL

Presence of blasts in peripheral blood; Presence of *Plasmodium* in peripheral blood; Rapid HIV test: reactive

In the field of clinical laboratory communication, it is recognized that certain attempts at contact will inevitably fail. It is considered acceptable to delay the dissemination of information until all avenues of communication have been thoroughly exhausted. This approach is based on the understanding that the ongoing operations of the laboratory should not be disrupted by persistent attempts to reach an individual.

In addition, documentation of critical values that have not been reported serves as an important basis for developing future strategies to improve communication effectiveness. This aspect of laboratory practice is important because unreported critical values are known to contribute to adverse effects in clinical settings (Arbiol-Roca et al., 2019).

4.3.3. Data collection instruments

The instruments employed for data collection in this study were as follows:

1. A structured questionnaire was administered to medical personnel, technicians, and graduates in Medical Technology both before and after the

training intervention. The development of the questionnaire was informed by prior research in this field, which referenced the use of surveys among laboratories. However, due to a lack of detailed survey content in these references, the questionnaire for this study was crafted by the researcher and subsequently reviewed and refined by the advisor, utilizing a previous questionnaire with medical personnel to gather suggestions for enhancing its structure and comprehensibility. The instrument was validated for use in this study as it demonstrated degrees of agreement exceeding 90%, and its relevance, pertinence, and clarity were statistically significant ($p<0.05$). The total reliability of the instrument, as measured by the Kuder-Richardson coefficient, was 0.824, indicating high reliability (exceeding the 0.80 threshold) and internal homogeneity.

2. The hospital's laboratory results database was utilized to extract information on all the results from the emergency service. This included the totality of critical values that were required to be notified by the staff.
3. A data collection form was used to gather information on the critical values that were notified by the laboratory staff.

4.3.4. Data processing and analysis

The comparative analysis presented in the tables constitutes temporal measurements. Consequently, the terms 'before' and 'after' were employed to facilitate a comparison of notification percentages across different time periods. The processing and statistical analysis of the collected data were conducted using SPSS (Statistical Package for Social Sciences) version 25.0 for Windows.

5. Results

In Table 2, of all the examinations performed at the Dos de Mayo National Hospital for outpatient consultation, hospitalization, and emergency during the study period, the critical values in the Emergency area represented 0.96% at the general level. The critical value stands out in the months of January to April with a percentage of 1.03%.

In Table 3, of the total number of examinations performed at the Dos de Mayo National Hospital in the Emergency area during the study period, the critical values in the Emergency area represent 2.75%. The critical value stands out in the months of January to April with a percentage of 3.17%.

In Table 4, the main clinical laboratory area of the Hospital Nacional Dos de Mayo that concentrates the report of critical values is the Hematology area, where the percentage of critical values is equal to 3.08%.

In Table 5, regarding the definition of critical value, it is observed that in the different occupational groups, there was an improvement in the Before and After knowledge of the intervention, but it was not statistically significant ($p>0.05$).

Table 2: Number of critical values in emergency and their percentage in relation to the total laboratory tests performed during the study period

Month	Laboratory exams	Critical values in emergency	Percentage
January-April	254.107	2622	1.03
May-September	268.108	2376	0.89
Total	522.215	4998	0.96

Table 3: Number of critical values in emergency and their percentage in relation to the total number of examinations performed in emergency during the study period

Month	Exams emergency patients	Critical values in emergency	Percentage
January-April	82.640	2622	3.17
May-September	98.867	2376	2.4
Total	181.507	4998	2.75

Table 4: Number of critical values in an emergency and their percentage in relation to the total number of examinations performed in an emergency by area of analysis

Analysis area	Exams emergency patients	Critical values in emergency	Percentage
Biochemistry	127.976	3.350	2.62
Hematology	53.531	1.648	3.08
Total	181.507	4.998	2.75

Table 5: Adequate definition of critical value by professional group

Group	No.	Before %	After %	P-value
Technologist	17	64.7	76.5	0.73
Technician	12	50.0	58.3	1.00
Doctor	7	100.0	100.0	1.00

P-values obtained by the Chi-square proportions comparison test

In Table 6, regarding the concept of the critical value of origin corresponding only to that of the hospital or ambulatory area, by the professional group, there were no substantial improvements before and after the measurement, it did not become statistically significant ($p>0.05$).

Table 6: Appropriate concept if the critical value of origin corresponds only to that of the hospital or ambulatory area per professional group

Group	No.	Before %	After %	P-value
Technologist	17	70.6	52.9	0.45
Technician	12	75.0	66.7	1.00
Doctor	7	85.7	85.7	1.00

P-values obtained by the Chi-square test of comparison of proportions

In Table 7, in the case of laboratory personnel who had the opportunity to report a critical value, only the increase was presented in the Group of technologists and a statistically significant result was not obtained (p>0.05).

Table 7: Opportunity to report critical value by professional group

Group	No.	Before %	After %	P-value
Technologist	17	76.5	88.2	1.00
Technician	12	83.3	50.0	0.29
Doctor	7	100.0	100.0	1.00

P-values obtained by the Chi-square test of comparison of proportions

In Table 8, on the professional's concept of reporting time of a critical value, there was a substantial improvement in the Group of technicians, it was not statistically significant (p>0.05).

Table 8: Concept of the time in which a critical value must be reported by a professional group

Group	No.	Before %	After %	P-value
Technologist	17	88.2	82.4	1.00
Technician	12	75.0	83.3	1.00
Doctor	7	100.0	100.0	1.00

P-values obtained by the Chi-square test of comparison of proportions

In Table 9, regarding the personnel responsible for reporting critical value, there was an improvement in the knowledge of the Technologists Group failed to be statistically significant (p>0.05).

Table 9: Concept about the person responsible for reporting a critical value by professional group

Group	No.	Before %	After %	P-value
Technologist	17	52.9	88.2	0.13
Technician	12	58.3	50.0	1.00
Doctor	7	85.7	85.7	1.00

P-values obtained by the Chi-square test of comparison of proportions

In Table 10, in the case of personnel responsible for receiving a critical value, there was substantial improvement in the Groups evaluated, it was not statistically significant (p>0.05).

Table 10: Concept about the person responsible for receiving the notification a critical value per professional group

Group	No.	Before %	After %	P-value
Technologist	17	64.7	88.2	0.22
Technician	12	75.0	83.3	1.00
Doctor	7	85.7	100.0	1.00

P-values obtained by the Chi-square test of comparison of proportions

In Table 11, on the concept of effective notification, only the Group of technologists improved and was not statistically significant (p>0.05).

Table 11: Concept of effective notification of a critical value by professional group

Group	No.	Before %	After %	P-value
Technologist	17	41.2	76.5	0.11
Technician	12	58.3	58.3	1.00
Doctor	7	100.0	100.0	1.00

P-values obtained by the Chi-square test of comparison of proportions

In Table 12, there was a substantial improvement with respect to knowledge of the critical list of values in the technologist and technician Group; this improvement was statistically significant (p<0.05).

Table 12: Knowledge of the list of critical values by professional group

Group	No.	Before %	After %	P-value
Technologist	17	23.5	64.7	0.04
Technician	12	16.7	75.0	0.04
Doctor	7	85.7	100.0	1.00

P-values obtained by the Chi-square test of comparison of proportions

In Table 13, regarding the consideration of whether the list of critical values is adequate or not, there was only an increase in acceptance in the Group of technologists and technicians; this finding was not statistically significant (p>0.05).

Table 13: Assessment of whether the list of critical values is adequate or not by a professional group

Group	No.	Before %	After %	P-value
Technologist	17	76.5	88.2	1.00
Technician	12	91.7	100.0	1.00
Doctor	7	100.0	100.0	1.00

P-values obtained by the Chi-square test of comparison of proportions

In Table 14, on the percentage of notification, the critical values that should have been reported (hospital database) and the critical values that were reported by the laboratory (laboratory data registration database) Before and After the intervention was considered, so there was a significant increase in creatinine values, glucose, sodium, leukocytes, platelets, activated partial thromboplastin time (aPTT). These increases were statistically significant (p<0.05). The P-value = 0.000 is optimal, we can conclude that there were general differences in notifications (p<0.05).

Table 14: List of critical values and percentage of notification according to clinical analysis

Analyte	Before %	After %	P-value
Bilirubin	35.3	0.0	Not applicable
Calcium	1.9	8.1	0.05
Chlorine	2.3	4.5	0.41
Creatinine	9.2	52.1	0.000
Phosphorus	2.7	4.8	0.47
Glucose	41.7	64.1	0.002
Magnesium	0.0	50.0	Not applicable
Urea	3.9	0.0	Not applicable
Potassium	31.9	29.5	0.76
Sodium	8.0	25.9	0.001
Hemoglobin	57.2	21.5	0.000
Leukocytes	5.1	19.1	0.002
Platelets	52.9	78.8	0.000
aPTT	2.9	17.2	0.001
Fibrinogen	12.5	20.0	0.18
INR	0.0	19.4	Not applicable
Rapid HIV test	0.0	42.9	Not applicable
Detection of *Plasmodium*	0.0	50.0	Not applicable
Blasts	13.3	17.6	0.33
Troponin	0.0	7.8	Not applicable
Total	13.4	25.4	0.001

P-value with Chi-square proportions comparison test; In total result was compared with the t-test of related groups

In the findings of Table 15, it is observed that the reporting of critical values improved in the Group of Medical Technologists (p<0.05). In the case of telephone calls received by notification of critical

values to the emergency service in Table 16, there was a statistically significant increase ($p<0.05$) in nursing graduates and nursing technicians. In Table 17, we observed an improvement in timely reporting, which became statistically significant ($p<0.05$).

Table 18 shows that there is a statistical improvement in effective reporting ($p<0.05$).

Table 15: Notification of critical values of the laboratory to the emergency service according to professional group

Group	Before %	After %	P-value
Medical technologist	33.22	47.27	0.02
Doctor resident of clinical pathology	66.78	52.73	0.04
Total	100.00	100.00	

P-value with Chi-square proportions comparison test

Table 16: Reception of telephone call by notification of critical values to the emergency service according to professional group

Staff receiving the call	Before %	After %	P-value
Doctor	35.27	34.55	1.00
Medical intern	2.74	5.45	0.07
Bachelor of nursing	29.11	32.73	0.03
Nursing technician	1.03	6.36	0.04
Not get the call	31.85	20.91	0.01
Total	100.00	100.00	

P-value with Chi-square proportions comparison test

Table 17: Notification of critical values according to notification delay time

	Before %	After %	P-value
Timely notification	60.96	83.64	0.000
Untimely notification	39.04	16.36	0.02
Total	100.00	100.00	

P-value with Chi-square proportions comparison test

Table 18: Effective reporting of critical values in the clinical laboratory service

	Before %	After %	P-value
Effective notification	38.70	61.82	0.001
Ineffective notification	61.30	38.18	0.02
Total	100.00	100.00	

P-value with Chi-square proportions comparison test

In Table 19, there may be several causes of ineffective notification, but among the main ones is that there was an increase in timely notification, and they did not respond to the call, however, Before and After the intervention this difference is significant ($p<0.05$). Likewise, there is a percentage decrease mainly in untimely notifications and staff who do not respond to the call, obtaining a statistically significant finding. In Table 20, there was an improvement in reporting during scheduled shifts, indicating the effectiveness of the interventions. These results are highly significant ($p<0.05$).

Table 19: Main causes of ineffective reporting of critical values in the clinical laboratory service

Main causes of ineffective notification	Before %	After %	P-value
Timely and do not respond to the call	30.73	42.86	0.08
Timely and not reported to the laboratory doctor	1.12	4.76	0.06
Timely, did not respond to the call and did not inform the laboratory doctor	2.23	2.38	0.85
Not timely	45.25	35.71	0.19
Not timely and do not respond to the call	14.53	4.76	0.01
Not timely and did not inform the laboratory doctor	5.03	7.14	0.07
Not timely, do not respond to the call, and do not inform the laboratory doctor	1.12	2.38	0.25
Total	100.00	100.00	

P-value with Chi-square proportions comparison test

Table 20: Percentage of shifts in which critical values were reported in the clinical laboratory service

	Before %	After %	P-value
Shifts in which critical values are reported	64.17	89.54	0.007

P-value with the Chi-square proportions comparison test

6. Discussion

The frequency of critical values varies from one laboratory to another and depends on the portfolio of services and the population served (Arbiol-Roca et al., 2019). According to what has been published, the proportion of critical values detected in relation to the total number of examinations performed varies from 0.05 to 1% (Genzen and Tormey, 2011). Other researchers such as López Pelayo et al. (2011), in their study, assumed this value at 0.6% and even up to 2%, as indicated by López-Pelayo et al. (2012), in their analysis of the recommendations of the Andalusian Society of Clinical Analysis.

The Department of Clinical Pathology at Dos de Mayo National Hospital processes an average of 103,394 samples monthly. If one considers the totality of laboratory tests (outpatient, hospitalized, and emergency) performed during the study period and the critical values in the Emergency area, the

latter represent 0.96% (Table 2) which is a value close to what is reported in the literature, however, if we only consider the tests requested in the emergency, the critical values in this hospital area represent 2.75% (Table 3).

In the study by Guzmán et al. (2009), a total of 5,366 critical values were detected that represented 0.3% of the total examinations and the main areas where these findings were reported were in the area of biochemistry and hematology with 0.2% and 1.1% respectively being a lower finding than that found in the present study (Table 4), where although it is true that the main areas of finding a critical value is in biochemistry and hematology the critical values represent a total of 2.75% of a total of 181,507 patient examinations in the Emergency area, the percentage difference could be due to the fact that in the study mentioned there is a filter that discriminates between critical value in the patient with chronic renal failure or in the patient with chemotherapy, discrimination that has not been taken into consideration at the time of this study because it is not part of the notification protocol.

The notification process begins when the laboratory staff recognizes a possible critical value and ends with the notification of the same in the appropriate period of time (Valenstein et al., 2008; Arbiol-Roca et al., 2019) and as the clinical laboratory has been developing the notification protocol for four months and since this is a dynamic process it was necessary to make some modifications in the list of values and reinforce with training the personnel so that the protocol is carried out Optimal way, which is why a test was performed before and after the intervention in order to evaluate basic concepts in the professional.

After the training, there was a non-significant improvement with respect to the definition of critical value (Table 5) and the adequate concept of its hospital or office origin (Table 6), concluding that the staff, in general, did master these concepts. It should be noted that according to the test, the medical professional group is the one who best masters these concepts, however, what was sought is that all professional groups handle these basic concepts because at some point they will have the responsibility and opportunity to notify a critical value as stated by the staff in the questionnaire (Table 7) where there was an increase in the opportunity to report a critical value in the group of Technologists and although it was not statistically significant ($p>0.05$), this may increase in the future.

Likewise, it was evaluated whether the concept of the minimum notification time (Table 8), the person responsible for notifying (Table 9) and receiving the information (Table 10) was had, however, despite having an improvement in the knowledge of these concepts mainly in medical technologist professionals, this was not significant.

In the analysis of Schapkaitz and Mafika (2014), on the survey of 36 laboratories, 97.2% responded that the reports of critical values were notified by the medical technologist professional (88.2% in our study, Table 8), however in this survey some laboratories with 19.4% authorized administrative personnel to make the notification (in our study 50% of notifications were made by technical staff, administrative personnel were not included) and that although the attending physician is ideally responsible for receiving the notification according to the literature, most of the laboratories surveyed (83%) responded that if the attending physician was not present, the nurse or other personnel in the patient's care could be notified, and according to the result of the survey applied (Table 10) after the training, 100% of doctors, 88.2% of medical technologists and 83.3% of technicians knew that the notification could be made to any personnel in charge of the patient, whether doctor or nurse, however, it did not become statistically significant. These are concepts that staff must handle optimally, so it is a good point to influence gradually in order to raise awareness among laboratory personnel in order to provide clear, accurate, and fast information.

In this study, in reference to the concept of effective notification (timely, correct, complete, unequivocal, and understandable for the recipient assessed with the read-back (Li et al., 2020), after the intervention (Table 11) there was a non-statistically significant improvement in the group of technologists.

In the absence of consensus on the list of critical values that a laboratory should use, it is based on the portfolio of services and on the list suggested by the American College of Clinical Pathology (Guzmán and Lagos, 2009; Ibrahim et al., 2009), that is why during the intervention of this study a modification of the list of critical values was made adapting it to the needs of the emergency service of the hospital (López Pelayo et al., 2011), thus preventing a misguided list from encouraging a negative attitude among staff due to overload in the reporting of results (Ibrahim et al., 2009).

Schapkaitz and Mafika (2014) surveyed 36 clinical laboratories, and 63.9% were aware that the list was prepared based on a local clinical opinion, and 8.3% based on published literature. In the present study after the intervention, a significant difference can be found in the domain of the list of critical values in personnel (Table 12) considering it adequate in most professional groups of the laboratory (Table 12). López-Pelayo et al. (2012), in a level IV Hospital in Córdoba, Spain, of a total of 417 notifications of critical values (emergency and outpatient consultation), the most frequent were due to hyperkalemia and hyperglycemia (14.9%) followed by hyperamylasemia (13.4%), anemia (10.8%), hyperuremia (7.9%), hypernatremia (5.8%) and hypoglycemia (5.5%). Likewise, Piva et al. (2014), in their study in a hospital in Italy, published that the main critical values reported in hospitalized and outpatient patients were the values of hypokalemia (49%), hyperkalemia (14%), hypomagnesemia (8.5%), Hypernatremia (6%), increased INR (5.5%) and thrombocytopenia (4.5%),

etc. This difference in the frequency of the type of critical value that is most frequently reported will be a constant between hospitals and can be explained because there is variation in the ranges of normality for each analysis as approved by each hospital, and according to the level of complexity, however, they are the areas of hematology and laboratory biochemistry in which greater responsibility falls when reporting an altered value. It is worth mentioning that the type of laboratory alterations that were found in the institution during the study period considering the order of the list was hyperbilirubinemia, hypocalcemia, hyperchloremia, hyperphosphatemia, hypoglycemia, hypermagnesemia, hyperuricemia, hyperkalemia, hypernatremia, anemia, leukocytosis, thrombocytopenia, prolonged APTT, decrease in fibrinogen and prolonged INR.

Regarding the critical values that were reported before and after the intervention (Table 14), there were statistically significant increases in the reporting of critical values by personnel in the creatinine, glucose, sodium, leukocytes, platelets, and activated partial thromboplastin time (aPTT) analyses, despite the fact that the new list that was released during the intervention suppressed only 02 analyses (urea, bilirubin) to be reported and added 05 new tests (magnesium, international standardized ratio (INR), rapid HIV test, plasmodium detection, and troponin), which may reflect that staff was compromised with the reporting objective (Arbiol-Roca et al., 2019). Li et al. (2020), in their retrospective observational report of 5 years of reporting of critical laboratory values improved the reporting rate to a value of 100% and according to Guzmán et al. (2009) at the end of four years improved the reporting of critical values from 55% in 2010 to 95% in 2014. In our study, it increased from 13.4% to 25.4% after the intervention.

Genzen and Tormey (2011) pointed out that laboratories face a dilemma in reporting critical value because the overall volume of laboratory tests is increasing, but a continuing shortage in the number of laboratory professionals means that fewer do more and therefore the medical professional or technologist must be committed to this task. After the intervention, on the commitment of all personnel to notify in the presence of a critical value (Table 15), it is observed that the notification of critical values improved in the group of medical technologists ($p<0.05$) compared to resident physicians, this can be explained because prior to the intervention laboratory personnel, in general, delegated the responsibility of notification only to attending or resident physicians mainly in the night watches, and with the training the responsibility has been assumed by both parties.

The Andalusian Society of Clinical Analysis in its recommendations points out that the best results are obtained when a laboratory doctor notifies and the requesting physician receives that information (Hernández-VaraCadillo et al, 2021), in other countries in order to meet the national objectives of patient safety it is established that the results of critical values must be transmitted to the responsible caregiver with license and according to the CAP must be reported to the doctor treating (or another caregiver) and according to Schifman et al. (2016) refers to notifying the individual who requests the test and if applicable, the individual responsible for using the test results.

Genzen and Tormey (2011) referenced a 2007 survey involving 163 clinical laboratories, which inquired about the eligible recipients of critical value notifications for both inpatient and outpatient scenarios. The survey findings indicated that almost all laboratories permitted any licensed caregiver, the treating physician, the on-call physician, or the resident to receive such notifications. Furthermore, the survey revealed that approximately 18% of the institutions authorized additional staff members, such as unit secretaries, to partake in this process. The study observed that notifications made to such non-licensed providers were initially quicker, but any time gained was offset by the additional time required for these individuals to subsequently contact a licensed caregiver.

Howanitz et al. (2002) also noted that some laboratories allowed administrative staff, including ward employees or receptionists, to receive critical value information for outpatients (48%) and inpatients (27%). However, the vital role of patient care personnel, such as nurses or laboratory technicians responsible for contacting the attending physician, should not be overlooked. Regardless of who receives the notification, the importance of training all relevant personnel for an efficient response to critical values is paramount (Ibrahim et al., 2009; Kopcinovic et al., 2015).

In the context of our specific circumstances and following coordination with the emergency area prior to the intervention, it was determined that any professional nursing or medical staff member would be capable of receiving laboratory information prior to the notification of a critical value and subsequently communicating this to the patient's responsible doctor (excluding administrative personnel). Based on this arrangement, there was a significant increase ($p<0.05$) in the reception of telephone calls in the emergency service by nursing graduates and nursing technicians, as detailed in Table 16. Conversely, there was a decrease in direct call reception by medical professionals, attributed to the fact that the responsible doctor occasionally attends to other areas of the emergency department. This trend reflects the heightened engagement of other health professionals in the critical value notification process.

Timely reporting of critical values is defined as reporting in less than 30 minutes and can be performed as long as 6.1 minutes in hospitalized patients and 13.7 minutes in outpatient clinics as demonstrated by PDA studies (Piva et al., 2014). In the present study, there was a significant improvement in terms of timely and effective notification, that is, the responsible personnel not

only notified in time (Table 17), but the personnel who received the information did it correctly when confirming by read-back (Table 18).

Rocha et al. (2016) evaluated the efficacy of the reporting process via telephone calls compared to a computerized alert system. Their findings revealed a notable disparity: approximately 30 minutes were required for the telephone call system, whereas the computerized notification system took about 11 minutes. The rate of failed notifications (defined as those taking more than one hour) was 50.9% for telephone calls and 10.9% for computerized alerts. These results suggest that hospitals should aim to implement a computer system that provides real-time information on laboratory results post-validation by the laboratory physician.

Furthermore, when integrating a parameter for a quality indicator - a notification time of less than 30 minutes for more than or equal to 90% of detected critical values - the study observed a significant increase in this percentage post-intervention, from 60.96% to 83.64%. However, this still falls short of the ideal target of 90%, which necessitates assessment every four months. While any failure or delay in reporting could potentially lead to adverse effects, this study reported a decrease in such occurrences from 39.04% to 16.36%. According to the literature, a failure rate of up to 10% is considered acceptable (Howanitz et al., 2002; López Pelayo et al., 2011).

Li et al. (2020), in their study after five years of assessment reached a timely notification rate of 94% and in the present study 83.64%, also point out that the rate of receipt of notifications, the rate of receipt of timely notifications and the response rate of the physician reached percentages of 97%, 92%, and 99% respectively and in the present study the effective notification ranged from 38% to 61.82% with an assessment after 5 months after the intervention.

Kopcinovic et al. (2015) identified several primary reasons for the failure to report critical values, including lapses in notification by laboratory personnel, communication equipment connectivity issues, and incomplete requisition forms lacking the physician's contact information. However, in the context of this study, it is crucial to highlight the main factors contributing to the ineffectiveness of notifications (Table 19). Notably, despite timely notifications by laboratory personnel, the patient's responsible staff often do not respond to calls. This can be attributed to the diverse responsibilities and engagements of medical, nursing, and technician personnel at the time of the call. An improvement could be achieved if the on-duty doctor were available to respond directly to laboratory reports.

The study also recorded a significant statistical decrease in untimely notifications and non-responses to calls. Furthermore, enhancing the communication system was observed to reduce the time for therapy initiation by 11% and the average time for process resolution by 29% through the use of a computerized system for the attending physician. Therefore, once a notification system is established in a hospital and subjected to periodic evaluations, it is imperative to consider the implementation of a new protocol that leverages information technology to improve efficiency and effectiveness.

The present study elucidates that a clinical laboratory with a complexity level akin to that of the Hospital Dos de Mayo operates on a 24-hour basis. This operational framework translates to a schedule encompassing a number of shifts equivalent to the days in a month. Within each shift, there are staff members (spanning various professional groups) who are either receptive to or resistant to innovations and implementations proposed by laboratory managers. The study revealed an improvement in reporting aligned with the number of scheduled shifts (Table 20), signifying the efficacy of the interventions, as these results are statistically significant ($p<0.05$).

Consequently, to ensure effective notification of critical values, the committed involvement of all laboratory and hospitalization personnel is essential. This necessitates the periodic execution of training activities, socialization interventions, and initiatives to raise awareness about the importance of reporting critical values. Such efforts should be directed not only toward laboratory and hospitalization staff but also, in the future, towards establishing a notification system for outpatient patients. This comprehensive approach is pivotal for the successful implementation and adherence to critical value notification protocols within healthcare settings (Alvarado-Díaz et al., 2017; Meneses-Claudio et al, 2018; Huamaní et al., 2019; Cervera-Flores et al., 2021). However, it is important to note that the achievement of this goal is gradual, with an adequate selection of evidence, a dynamic system of notification of critical values according to the institution and having an optimal computer system that facilitates the procedures of notification, monitoring, and control of the process (Brian et al., 2018).

7. Conclusion

The implementation of a protocol for critical laboratory values was found to be positively correlated with an enhancement in the quality of reporting by clinical laboratory personnel. This was evidenced by a notable increase in the timely notification of critical values, with the majority of the results being statistically significant ($p<0.05$). Additionally, the process of reporting demonstrated a significant improvement in the effective communication of critical values, with most outcomes also achieving statistical significance ($p<0.05$).

Regarding the indicator of quality, timely notification achieved a current rate of 83.64%, which falls short of the established standard of greater than or equal to 90% for the timely notification of detected critical values. This discrepancy can be

attributed to the evaluation period for the standard, which is conducted every four months. Such findings underscore the need for ongoing assessment and potential refinement of the protocol to meet and exceed the required quality benchmarks.

8. Recommendations

This study aims to contribute valuable insights for the ongoing enhancement of the current hospital notification protocol, and it is anticipated that these findings will inform similar research endeavors in other health institutions, ultimately improving the quality of patient care. Given the dynamic nature of the protocol for reporting critical values, it offers the potential for expansion to other laboratory areas and customization according to the specific needs of different hospital units.

To elevate the quality of reporting, each laboratory utilizing the notification protocol should engage in regular procedural reviews and ensure continuous training for both laboratory and hospitalization personnel. Additionally, the implementation of a laboratory computer system, along with other technological advancements, capable of automatically generating notifications for the treating physician, would streamline the communication process, thereby reducing the time required for notifying critical values.

Future studies could focus on assessing the duration between the treating physician receiving critical value information and initiating the appropriate treatment or corrective action. In some existing research, it has been observed that the initiation of treatment takes approximately 2.5 hours from the time of notification (a duration that presents significant opportunities for improvement).

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Alvarado-Díaz W, Meneses-Claudio B, and Roman-Gonzalez A (2017). Implementation of a brain-machine interface for controlling a wheelchair. In the 2017 CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON), IEEE, Pucon, Chile: 1-6. https://doi.org/10.1109/CHILECON.2017.8229668

Angüiano-Sánchez N, Perales-Quintana M, and Díaz-Olachea C (2011). Errors in clinical laboratory: Evaluation of types and frequencies. Medicina Universitaria, 13(52): 133-138.

Arbiol-Roca A, Corral-Comesaña S, Cano-Corres R, Castro-Castro MJ, Dastis-Arias M, and Dot-Bach D (2019). Analysis of laboratory critical values at a referral Spanish tertiary university hospital. Biochemia Medica, 29(1): 77-83. https://doi.org/10.11613/BM.2019.010704 **PMid:30591814 PMCid:PMC6294153**

Brian MC, Witman AD, Luis A, Julio GM, and Avid RG (2018). Advances and uses of ICT in public health of Peru. In the 2018 IEEE Sciences and Humanities International Research Conference (SHIRCON), IEEE, Lima, Peru: 1-5. https://doi.org/10.1109/SHIRCON.2018.8593132

Campuzano Maya G (2011). Critical values in the clinical laboratory: From theory to practice. Medicina and Laboratorio, 17(07-08): 331-350.

Cantero Sánchez M, Nieto MLH, Moreno JAR, García CR, and Bautista MR (2015). Protocolo de actuación ante valores críticos en pruebas de laboratorio en el lugar de asistencia al paciente en una unidad neonatal. Revista del Laboratorio Clínico, 8(4): 165-172. https://doi.org/10.1016/j.labcli.2015.07.006

Cervera-Flores W, Choque-Garibay Y, Gonzalez-Cordero N, Meneses-Claudio B, Solis-Matta H, and Matta-Zamudio L (2021). Level of empathy in nursing students attending clinical practices of the universidad de ciencias y humanidades. Advances in Science, Technology and Engineering Systems, 6(1): 178-183. https://doi.org/10.25046/aj060120

Consolato S (2018). Promptly reporting of critical laboratory values in pediatrics: A work in progress. World Journal of Clinical Pediatrics, 7(5): 105-110. https://doi.org/10.5409/wjcp.v7.i5.105 **PMid:30479975 PMCid:PMC6242778**

Feitosa MS, Bücker DH, Santos SME, and Vasconcellos LS (2016). Implementation of criteria for automatic release of clinical chemistry test results in a laboratory at an academic public hospital. Jornal Brasileiro de Patologia e Medicina Laboratorial, 52: 149-156. https://doi.org/10.5935/1676-2444.20160026

GebreEyesus FA, Tarekegn TT, Amlak BT, Shiferaw BZ, Emeria MS, Geleta OT, Terefe TF, Mammo Tadereregew M, Jimma MS, Degu FS, and Abdisa EN (2021). Levels and predictors of anxiety, depression, and stress during COVID-19 pandemic among frontline healthcare providers in Gurage zonal public hospitals, Southwest Ethiopia, 2020: A multicenter cross-sectional study. PLOS ONE, 16(11): e0259906. https://doi.org/10.1371/journal.pone.0259906 **PMid:34843502 PMCid:PMC8629282**

Genzen JR and Tormey CA (2011). Pathology consultation on reporting of critical values. American Journal of Clinical Pathology, 135(4): 505-513. https://doi.org/10.1309/AJCP9IZT7BMBCJRS **PMid:21411773 PMCid:PMC7065418**

Guzmán AM and Lagos M (2009). Valores de alerta en el laboratorio clínico y su aporte al cuidado y seguridad del paciente. Revista Médica de Chile, 137(4): 582-584. https://doi.org/10.4067/S0034-98872009000400019

Guzmán AM, Solari S, Lagos M, Poggi H, Sánchez T, Madrid A, Parada J, Román JC, Rodríguez L, and Quiroga T (2009). Aviso de valores de alerta por parte del laboratorio clínico en una red de salud universitaria. Revista Médica de Chile, 137(9): 1137-1144. https://doi.org/10.4067/S0034-98872009000900001

Hernández-VaraCadillo M, Meneses-Claudio B, and Delgado A (2021). Design of a ventilation control system in underground mines and tunnels. International Journal of Emerging Technology and Advanced Engineering, 11(9): 73-81. https://doi.org/10.46338/ijetae0921_09

Howanitz PJ, Steindel SJ, and Heard NV (2002). Laboratory critical values policies and procedures: A college of American pathologists q-probes study in 623 institutions. Archives of Pathology and Laboratory Medicine, 126(6): 663-669. https://doi.org/10.5858/2002-126-0663-LCVPAP **PMid:12033953**

Huamaní EL, Condori P, Meneses-Claudio B, and Roman-Gonzalez A (2019). Render farm for highly realistic images in a Beowulf cluster using distributed programming techniques. International Journal of Advanced Computer Science and

Applications, 10(11): 407–411. https://doi.org/10.14569/IJACSA.2019.0101156

Ibrahim M, Islam I, Nasir TA, and Saha D (2009). Critical laboratory values-An experience in Apollo Hospitals Dhaka. Pulse, 3(1): 7-11. https://doi.org/10.3329/pulse.v3i1.6544

Kopcinovic ML, Trifunović J, Pavošević T, and Nikolac N (2015). Croatian survey on critical results reporting. Biochemia Medica, 25(2): 193-202. https://doi.org/10.11613/BM.2015.019 **PMid:26110031 PMCid:PMC4470108**

Kost GJ and Hale KN (2011). Global trends in critical values practices and their harmonization. Clinical Chemistry and Laboratory Medicine, 49(2): 167-176. https://doi.org/10.1515/CCLM.2011.033 **PMid:21091233**

Li R, Wang T, Gong L, Dong J, Xiao N, Yang X, Zhu D, and Zhao Z (2020). Enhance the effectiveness of clinical laboratory critical values initiative notification by implementing a closed-loop system: A five-year retrospective observational study. Journal of Clinical Laboratory Analysis, 34(2): e23038. https://doi.org/10.1002/jcla.23038 **PMid:31531906 PMCid:PMC7031628**

Lippi G, Adcock D, Simundic AM, Tripodi A, and Favaloro EJ (2017). Critical laboratory values in hemostasis: Toward consensus. Annals of Medicine, 49(6): 455-461. https://doi.org/10.1080/07853890.2016.1278303 **PMid:28042729**

Llopis Díaz MA, Gómez Rioja R, Álvarez Funes V, Martínez Brú C, Cortés Rius M, Barba Meseguer N, Ventura Alemany M, and Alsina Kirchner MJ (2010). Comunicación de valores críticos: Resultados de una encuesta realizada por la comisión de la calidad extraanalitica de la SEQC. Journal of the Clinical Laboratory, 3(4): 177-182. https://doi.org/10.1016/j.labcli.2010.06.002

López Pelayo I, De Castilla RJR, Suárez AF, Jiménez MÁA, Rubio IG, and Rueda AV (2011). Implantación y evaluación de un procedimiento de comunicación de valores críticos. Revista del Laboratorio Clínico, 4(3): 145-152. https://doi.org/10.1016/j.labcli.2011.05.001

López-Pelayo I, Fernandez-Suarez A, Romero-De-Castilla-y RJ, and Zambrana-García JL (2012). Clinical impact of laboratory critical values notification as a tool for patient safety. Medicina Clinica, 139(5): 221-226. https://doi.org/10.1016/j.medcli.2012.01.026 **PMid:22459577**

Lynn TJ and Olson JE (2020). Improving critical value notification through secure text messaging. Journal of Pathology Informatics, 11(1): 21. https://doi.org/10.4103/jpi.jpi_19_20 **PMid:33042600 PMCid:PMC7518196**

Meneses-Claudio B, Alvarado-Diaz W, and Roman-Gonzalez A (2018). Differentiation of brain waves from the movement of the upper and lower extremities of the human body. International Journal of Advanced Computer Science and Applications, 9(11): 485-488. https://doi.org/10.14569/IJACSA.2018.091167

Piva E, Pelloso M, Penello L, and Plebani M (2014). Laboratory critical values: automated notification supports effective clinical decision making. Clinical Biochemistry, 47(13-14): 1163-1168. https://doi.org/10.1016/j.clinbiochem.2014.05.056 **PMid:24886769**

Rocha BCB, Alves JAR, Pinto FPD, Mendes ME, and Sumita NM (2016). O conceito de valores críticos no laboratório clínico. Jornal Brasileiro de Patologia e Medicina Laboratorial, 52: 17-20. https://doi.org/10.5935/1676-2444.20160008

Sarwar S, Shahzad F, Vajeeha A, Munir R, Yaqoob A, Naeem A, Sattar M, and Gull S (2022). Assessment of biosafety implementation in clinical diagnostic laboratories in Pakistan during the COVID-19 pandemic. Journal of Biosafety and Biosecurity, 4(1): 43-49. https://doi.org/10.1016/j.jobb.2022.01.001 **PMid:35072000 PMCid:PMC8768056**

Schapkaitz E and Mafika Z (2014). Critical value reporting: A survey of 36 clinical laboratories in South Africa. South African Medical Journal, 104(1): 65-67. https://doi.org/10.7196/samj.7057 **PMid:24388093**

Schifman RB, Howanitz PJ, and Souers RJ (2016). Point-of-care glucose critical values: A Q-probes study involving 50 health care facilities and 2349 critical results. Archives of Pathology and Laboratory Medicine, 140(2): 119-124. https://doi.org/10.5858/arpa.2015-0058-CP **PMid:26910215**

Sun SCP, Garcia J, and Hayden JA (2018). Repeating critical hematology and coagulation values wastes resources, lengthens turnaround time, and delays clinical action. American Journal of Clinical Pathology, 149(3): 247-252. https://doi.org/10.1093/ajcp/aqx156 **PMid:29425259**

Valenstein PN, Wagar EA, Stankovic AK, Walsh MK, and Schneider F (2008). Notification of critical results: A college of American pathologists q-probes study of 121 institutions. Archives of Pathology and Laboratory Medicine, 132(12): 1862-1867. https://doi.org/10.5858/132.12.1862 **PMid:19061281**