This document provides a general framework that will allow each laboratory to easily design, implement, validate, and customize rules for autoverification (automated verification) based on the needs of its own patient population.

A guideline for global application developed through the Clinical and Laboratory Standards Institute consensus process.
Clinical and Laboratory Standards Institute
Setting the standard for quality in clinical laboratory testing around the world.

The Clinical and Laboratory Standards Institute (CLSI) is a not-for-profit membership organization that brings together the varied perspectives and expertise of the worldwide laboratory community for the advancement of a common cause: to foster excellence in laboratory medicine by developing and implementing clinical laboratory standards and guidelines that help laboratories fulfill their responsibilities with efficiency, effectiveness, and global applicability.

Consensus Process

Consensus—the substantial agreement by materially affected, competent, and interested parties—is core to the development of all CLSI documents. It does not always connote unanimous agreement, but does mean that the participants in the development of a consensus document have considered and resolved all relevant objections and accept the resulting agreement.

Commenting on Documents

CLSI documents undergo periodic evaluation and modification to keep pace with advancements in technologies, procedures, methods, and protocols affecting the laboratory or health care.

CLSI’s consensus process depends on experts who volunteer to serve as contributing authors and/or as participants in the reviewing and commenting process. At the end of each comment period, the committee that developed the document is obligated to review all comments, respond in writing to all substantive comments, and revise the draft document as appropriate.

Comments on published CLSI documents are equally essential, and may be submitted by anyone, at any time, on any document. All comments are addressed according to the consensus process by a committee of experts.

Appeals Process

If it is believed that an objection has not been adequately addressed, the process for appeals is documented in the CLSI Standards Development Policies and Process document.

All comments and responses submitted on draft and published documents are retained on file at CLSI and are available upon request.

Get Involved—Volunteer!

Do you use CLSI documents in your workplace? Do you see room for improvement? Would you like to get involved in the revision process? Or maybe you see a need to develop a new document for an emerging technology? CLSI wants to hear from you. We are always looking for volunteers. By donating your time and talents to improve the standards that affect your own work, you will play an active role in improving public health across the globe.

For further information on committee participation or to submit comments, contact CLSI.

Clinical and Laboratory Standards Institute
950 West Valley Road, Suite 2500
Wayne, PA 19087 USA
P: 610.688.0100
F: 610.688.0700
www.clsi.org
standard@clsi.org
Autoverification of Clinical Laboratory Test Results; Approved Guideline

Volume 26  Number 32

William Neeley, MD, FACP, DABCC
Gerald Davis, MT(ASCP), MPH
Randy R. Davis
Bill Marquardt, C(ASCP), MBA
Karen L. Nickel, PhD, DABCC, FACB

Curtis A. Parvin, PhD
William L. Roberts, MD, PhD
Richard S. Seaberg, MT(ASCP)
David R. Velasquez, MT(ASCP)

Abstract

Clinical and Laboratory Standards Institute document AUTO10-A—Autoverification of Clinical Laboratory Test Results; Approved Guideline provides a general framework that will allow each laboratory to easily design, implement, validate, and customize rules for autoverification (automated verification) based on the needs of its own patient population. The goal is to provide a new set of guidelines that will take us beyond traditional autoverification to the next generation that allows the use of more sophisticated algorithms to meet laboratory needs, as well as accurately reflect the medical philosophy of the laboratory.

In addition, important supporting sections are provided that deal with the different aspects of regulatory compliance and validation of algorithms that are essential to establishing and maintaining a modern autoverification program. Through utilization of this structured approach, the end users will be able to ensure compliance with regulatory agencies (where acceptable by law), yet effectively develop and establish monitors to ensure that all aspects related to quality are maintained. Guidelines are provided for the automated delivery of high priority results that can be customized to meet a provider’s specific needs, along with a confirmation process that results have been received.


The Clinical and Laboratory Standards Institute consensus process, which is the mechanism for moving a document through two or more levels of review by the health care community, is an ongoing process. Users should expect revised editions of any given document. Because rapid changes in technology may affect the procedures, methods, and protocols in a standard or guideline, users should replace outdated editions with the current editions of CLSI documents. Current editions are listed in the CLSI catalog and posted on our website at www.clsi.org. If your organization is not a member and would like to become one, and to request a copy of the catalog, contact us at: Telephone: 610.688.0100; Fax: 610.688.0700; E-Mail: customerservice@clsi.org; Website: www.clsi.org
## Contents

Abstract .................................................................................................................................................... i

Committee Membership ........................................................................................................................ iii

Foreword .............................................................................................................................................. vii

1 Scope .......................................................................................................................................... 1

2 Introduction ................................................................................................................................ 1

3 Definitions ................................................................................................................................. 2

4 Design of Algorithms ................................................................................................................. 3
   4.1 Data Elements ............................................................................................................... 3
   4.2 Algorithm-Based Decisions .......................................................................................... 5
   4.3 Reporting of Results ..................................................................................................... 6
   4.4 Selective Suppression of Autoverification .................................................................... 7

5 Regulatory Compliance ............................................................................................................. 7
   5.1 Statutory Obligation ...................................................................................................... 8

6 Validation of Algorithms ......................................................................................................... 10
   6.1 Logic ........................................................................................................................... 10
   6.2 Independent Data Observations/Collection (monitoring of data in/data out) .......... 11
   6.3 Algorithm Updates ...................................................................................................... 11
   6.4 Software Updates ........................................................................................................ 11
   6.5 Validation Tools ......................................................................................................... 11
   6.6 Periodic Revalidation.................................................................................................. 12

References ..................................................................................................................................... 13

Additional References ................................................................................................................ 14

Summary of Comments and Subcommittee Responses .......................................................... 15

The Quality System Approach ................................................................................................. 20

Related CLSI/NCCLS Publication ............................................................................................. 21
Foreword

The basis of this guideline is to provide laboratorians with a “tool set” consisting of basic and complex Boolean logic, to develop algorithms that can be used to make result verification decisions based upon available medical data. Basic Boolean logic can be defined as a statement using the words “AND” or “OR” in the creation of a logical statement (or rule). Complex Boolean logic consists of several statements combined with “AND” or “OR” that allow for precise analysis of a particular situation.1

Minimum requirements for the software tools to build autoverification algorithms include the following:

- ability to use multiple data elements in an unrestricted fashion;
- ability of the laboratory to define and implement changes to algorithms quickly and easily;
- retrieval of selected information from multiple data sources (e.g., EMR, pharmacy, instrument results, other laboratory data, diagnosis code);
- application of algorithms in real time; and
- flexible user interface that provides laboratory-defined information on the autoverification process in real time.

Traditionally, result verification has depended on mental algorithms that are performed by pathologists/medical technologists/technicians on a single or group of analytical results. The purpose is to identify potential analytical error before results are made available outside the laboratory. Preanalytical, analytical, and postanalytical data can be used in this process.

Autoverification is a process whereby computer-based algorithms automatically perform actions on a defined subset of laboratory results without the need for manual intervention by a laboratorian. The computer-based action could be the immediate verification of a result, repeat analysis, reflexive testing, addition of comments, or suggested manual steps including (but not limited to) manual review of the result. By automatically performing actions on results that meet well-defined criteria, more time is made available for manual processing of those results that require special attention. Autoverification ensures that every result consistently receives the very same review process. Additionally, computer-based autoverification algorithms provide the opportunity to develop more sophisticated algorithms that incorporate more extensive data than would be possible for a laboratorian to perform in a consistent, timely, and accurate manner.

Manufacturers and software developers should institute effective risk management and good software life cycle processes in the development of autoverification applications. Please consult appropriate standards such as:

- ISO 14971:2000, Medical devices – Application of risk management to medical devices
- AAMI/ANSI SW68:2001, Medical device software – Software life cycle processes

Implementation of autoverification will involve use of systems that are subject to electromagnetic interference and may be at additional risk to radio frequencies when linked to wireless systems. Manufacturers and healthcare professionals should be aware of these issues and take necessary mitigation measures. For help, consult appropriate standards such as:

The following flow diagram is an example of a simple algorithm for evaluating the BUN/creatinine ratio in human serum. The diagram is based on the use of an enzymatic BUN method, as well as an enzymatic method for creatinine. The algorithm complexity could be increased depending on the information available, such as checks of QC acceptability, etc.

![Simple Algorithm Flow Diagram]

**Figure 1. Example of a Simple Algorithm**

The following flow diagram is provided as an example of a complex algorithm that deals with artifactual hyponatremia. If a sodium measurement is done on a patient’s serum or plasma containing either very high levels of lipidemia and/or paraproteinemia, there can be an artifactual lowering of sodium levels if the chemistry analyzer does the assay on a diluted sample.
Sodium ions will be excluded or displaced from the space occupied by large amounts of lipids or paraproteins. Sodium ions are located in the aqueous portions of the sample. Accurate sodium measurements can be made if the ion-selective electrodes for sodium are placed directly in the sample where no sample dilution (nondilution or direct method) is done. If a dilution is done prior to the sodium measurement, the sodium value will be falsely low, regardless of the analytical method used. In the case of highly lipemic samples, a high-speed centrifuge can be used to physically separate the aqueous portion from the lipids and the sodium can be accurately measured. In the case of hyperparaproteinemia, high-speed centrifugation will not separate the high molecular weight molecules and a nondilution method should be used. Based on the algorithm and the methods used in the laboratory, the flowchart can instruct the technologist how to correctly handle the sample.
Figure 2. Example of a Complex Algorithm
Autoverification can be achieved through the use of information technology (IT) tools, but the laboratory is ultimately responsible for defining the criteria that are implemented with the IT tools to make autoverification decisions. This document provides guidelines for developing criteria that may be used in autoverification algorithms.

Figure 3. Autoverification Process

Key Words

algorithms, automated verification, autoverification, Boolean logic
Autoverification of Clinical Laboratory Test Results; Approved Guideline

1 Scope

This guideline specifies recommendations for the design, building, implementation, validation, and compliance of the algorithms used for autoverification of laboratory results.

The intended users of this guideline are information system vendors; hospital, reference, independent, and physician office laboratories; data management vendors; instrument manufacturers; and those involved in point-of-care testing.

This guideline is not intended to provide test parameter rules or limits for practicing medicine or methods for confirmation of result delivery. This guideline does not address hardware specifications, interface specifications, connectivity, or software configuration. Security measures are beyond the scope of this document and are assumed to be covered by country-specific policies. For additional information, refer to the current edition of CLSI document AUTO11—IT Security of In Vitro Diagnostic Instruments and Software Systems.

2 Introduction

The clinical laboratory continues to be pressured to increase productivity in response to external pressures related to reimbursement and allocated human resources. The pressures related to difficult recruitment within the technical ranks have led to a continued movement towards laboratory automation and enhanced computer systems that can help ensure adequate turnaround times (TAT) and enhancements to the quality of the result streams to the clinicians.

A natural response to these external pressures resides in the reexamination of the laboratory procedures (preanalytical, analytical, and postanalytical) related to the production of a reportable result. By the examination of these processes, the laboratory can seek mechanisms whereby enhanced services can be provided at lower costs and with enhanced quality.

The preanalytical and analytical processes continue to experience development and implementation within active laboratory environments. However, the development and implementation of postanalytical algorithms can significantly assist in the process of releasing results to the medical record. This process is known as autoverification. This postanalytical tool enables the user to electronically check analytical results against certain criteria. These criteria—including but not limited to reference ranges, quality control results, moving averages, instrument flagging, delta checks, maintenance checks, lot checks, clinician information/requests, and critical limits—can be used to make up the algorithms. The establishment of such processes can be tailored to each individual facility and is under the supervision of that facility’s laboratory director and laboratory staff. Autoverification also ensures the quality of results, since every result is passed through the same rigorous algorithmic process.

As a result, a carefully planned and systematic mechanism is necessary to develop such postanalytical processes. By adhering to such a structure, the laboratory ensures that the process has been documented and examined, so the clinical and regulatory requirements are fulfilled when incorporating autoverification within the clinical laboratory environment.

Hence, this guideline was developed for the laboratory user. It is to be used strictly as a guideline to help establish, install, implement, and monitor this postanalytical process. By defining such computer-based rules and identifying such processes, the laboratory will make certain that the quality processes are met and documented.
This document provides examples of parameters and rules that can be used to develop an autoverification process. Individual laboratories may lack some of the capabilities described herein or may choose not to implement some rules in use by other laboratories for a variety of reasons. The laboratory director has the responsibility to select and implement autoverification rules and processes that are appropriate for his or her laboratory.

3 Definitions

**accuracy (of measurement)** – closeness of the agreement between the result of a measurement and a true value of the measurand (VIM93).

**algorithm** – a set of rules for solving a problem in a finite number of steps, as for finding the greatest common divisor.

**autoverification (automated result verification)** – the automated actions performed by a computer system related to the release of test results to the medical record using criteria and logic established, documented, and tested by the medical staff of the laboratory; **NOTE:** The criteria can be simple or complex and involve many different parameters. The system offers the highest levels of consistency and the ability to handle complex algorithms in a very efficient way.

**Boolean logic** – developed by George Boole in the mid-1800s, operates on a set of rules that provides a consistent output based on a predefined set of input parameters; **NOTE:** The rules can be easily defined in a set of logic tables or diagrams. The most common rules are AND, OR, NAND, and NOR logic statements.

**HIS (hospital information system)** – the computer system used for management of data collected and generated by various services, laboratories, and facilities served by a hospital.

**LAS (laboratory automation system)** – a system of information and hardware technology that allows the operation of the clinical laboratory process without significant operator intervention.

**LIS (laboratory information system)** – the information system that is responsible for management of data regarding patient specimen identification, tests requested, results reported, quality control testing, and other aspects of sample analysis.

**medical alert value** – assay values that may require immediate medical attention, due to dangerously abnormal levels of a particular analyte; **NOTE:** Also called “critical values.”

**result verification** – a process that is known by a variety of names, such as verifying, accepting, or releasing of results by the laboratory staff, so the results are made available or accessible to care providers outside the laboratory, such as physicians, nurses, etc.; **NOTE:** The process implies that results have been examined and meet the quality criteria established by the laboratory and can be used in the treatment and management of patients.

**validation** – confirmation, through the provision of objective evidence, that requirements for a specific intended use or application have been fulfilled (ISO 9000).

**validation plan** – a written document that describes the required validation activities and acceptance criteria; **NOTE:** Validation plans are customized for each type of hardware/software that needs to be validated and should be approved by the laboratory director prior to initiation.

**validation summary** – the summarized, documented results of the validation plan.
The Quality System Approach

Clinical and Laboratory Standards Institute (CLSI) subscribes to a quality system approach in the development of standards and guidelines, which facilitates project management; defines a document structure via a template; and provides a process to identify needed documents. The approach is based on the model presented in the most current edition of CLSI/NCCLS document HS1—*A Quality Management System Model for Health Care*. The quality system approach applies a core set of “quality system essentials” (QSEs), basic to any organization, to all operations in any healthcare service’s path of workflow (i.e., operational aspects that define how a particular product or service is provided). The QSEs provide the framework for delivery of any type of product or service, serving as a manager’s guide. The quality system essentials (QSEs) are:

- Documents & Records
- Organization
- Personnel
- Equipment
- Purchasing & Inventory
- Process Control
- Information Management
- Occurrence Management
- Assessment
- Process Improvement
- Service & Satisfaction
- Facilities & Safety

AUTO10-A addresses the quality system essentials (QSEs) indicated by an “X.”

Path of Workflow

A path of workflow is the description of the necessary steps to deliver the particular product or service that the organization or entity provides. For example, CLSI/NCCLS document GP26—*Application of a Quality Management System Model for Laboratory Services* defines a clinical laboratory path of workflow, which consists of three sequential processes: preexamination, examination, and postexamination. All clinical laboratories follow these processes to deliver the laboratory’s services, namely quality laboratory information.

AUTO10-A addresses the clinical laboratory path of workflow steps indicated by an “X.”
Related CLSI/NCCLS Publication

AUTO11-A  IT Security of In Vitro Diagnostic Instruments and Software Systems; Approved Standard (2006). This document provides a framework for communication of IT security issues between the IVD system vendor and the healthcare organization.

* Proposed-level documents are being advanced through the Clinical and Laboratory Standards Institute consensus process; therefore, readers should refer to the most recent editions.
Explore the Latest Offerings from CLSI!

As we continue to set the global standard for quality in laboratory testing, we’re adding initiatives to bring even more value to our members and customers.

The Key to Quality

Power Forward with this Official Interactive Guide
Fundamentals for implementing a quality management system in the clinical laboratory.

Visit the CLSI U Education Center
Where we provide the convenient and cost-effective education resources that laboratories need to put CLSI standards into practice, including webinars, workshops, and more.

Find Membership Opportunities
See the options that make it even easier for your organization to take full advantage of CLSI benefits and our unique membership value.

Shop Our Online Products
Including eCLIPSE Ultimate Access™, CLSI’s cloud-based, online portal that makes it easy to access our standards and guidelines—anytime, anywhere.

For more information, visit www.clsi.org today.