Frequency of laboratory test utilization in the intensive care unit and its implications for large-scale data collection efforts

Case Report ■

Frequency of Laboratory Test Utilization in the Intensive Care Unit and Its Implications for Large-Scale Data Collection Efforts

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Abstract **Objective:** Mapping local use names to standardized nomenclatures such as LOINC (Logical Observation Identifiers Names and Codes) is a time-consuming task when done retrospectively or during the configuration of new information systems. The author sought to identify a subset of intensive care unit (ICU) laboratory tests, which, because of their frequency of use, should be the focus of efforts to standardize test names in ICU information systems.

Design: The author reviewed the ordering practices in medical, surgical, and pediatric ICUs within a large university teaching hospital to identify the subset of laboratory tests that represented the majority of tests performed in these settings. The author compared the results of his findings with the laboratory tests required to complete several of the most frequently used ICU acuity scoring systems.

Results: It was found that between 104 and 202 tests and profiles represented 99% of all testing in the three ICUs. All the laboratory studies needed for six commonly used ICU scoring systems fell into the top 21 laboratory studies and profiles performed in each ICU.

Conclusion: The author identified a small subset of the LOINC database that should be the focus of efforts to standardize test names in ICU information systems. Mapping this subset of laboratory tests and profiles to LOINC vocabulary will simplify the process of collecting data for large-scale databases such as ICU scoring systems and the configuration of new ICU information systems.

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Background

One of the major impediments to automated data collection and pooling from multiple institutions for benchmarking and the development of outcome prediction models has been the use of nonstandard terminology within individual hospital information systems. Most hospital and laboratory information systems catalog very similar data under very diverse naming schemas. Problems caused by this diversity in naming led to national and international efforts to create standardized nomenclatures for coding of electronic data elements in the health care setting. One such nomenclature is LOINC (Logical Observation Identifiers Names and Codes). The LOINC database provides "universal" identifiers for diagnostic laboratory tests. The LOINC database strives to contain a universal identifier for at least 98% of the laboratory tests generated by an average clinical laboratory. This database now contains codes and test names along with alternate test names for more than 25,000 laboratory tests.[1]

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Retrospective mapping of current laboratory information system test names to standard identifiers and naming systems such as LOINC is a labor-intensive process. Even with automated mechanisms,[2,3] the costs of retrospective mapping are considerable for individual health care systems. In addition, the costs and complexity of implementing new clinical information systems such as those used in the intensive care unit (ICU) are increased by the need for careful mapping of local-use names to universal nomenclature codes.

One common ICU task requiring the aggregation of data across institutions is the calculation and reporting of ICU patient acuity scores. These scores form much of the objective basis for a number of ICU benchmarking systems. These systems provide detailed comparison data for ICU managers and clinicians by providing acuity adjusted outcomes data. Collection and aggregation of ICU patient acuity scores would be significantly simplified if laboratory data available from participating institutions could be collected and pooled. As such, ICU acuity scoring systems are an example of large-scale databases that would benefit from the use of standardized identifiers and names in disparate hospital systems.

Objectives

The author sought to identify the group of laboratory tests and profiles most frequently performed for the care of patients in three different ICU settings. The goal was to identify the subset of laboratory tests that, due to their frequency of use, are most important to include in the "mapping" of any new or existing ICU information system to standardized nomenclature.

Focusing on the most commonly used tests in the ICU setting should provide most of the benefits of standardization with less cost and effort.

The author also sought to test the hypothesis that most tests necessary for some important large-scale ICU data collection efforts involve a relatively small proportion of the total tests available in the laboratory.

Methods

Setting

This study was performed at a university teaching hospital.

Design

With the approval of the institutional review board, the laboratory information system in a university teaching hospital was queried to obtain data on the incidence of individual laboratory tests and profiles completed over the course of 390 days. For the purposes of this study, a test or study was defined as a single laboratory value determination and a profile was defined as a group of laboratory tests that are ordered and reported together. Data were obtained for tests and profiles completed for patients receiving care in three ICUs within the hospital: a surgical ICU, a pediatric ICU, and a medical ICU. The surgical ICU studied has seven beds and serves as the primary adult trauma ICU for a busy urban trauma service as well as the primary postsurgical ICU for general surgical patients. The pediatric ICU studied is an 11-bed multidisciplinary ICU. This unit serves both medical and surgical patients with a wide variety of intensive care needs including a large number of pediatric trauma and respiratory failure patients. The medical ICU studied has 16 beds and is the major medical ICU for the institution, serving patients with nonsurgical life-threatening illness.

Data from the study ICUs were analyzed to determine the laboratory tests and profiles that represent 80%, 90%, 95%, and 99% of the laboratory tests and profiles completed for each type of ICU. Because each of the ICUs studied serves a distinctly different population, the author subsequently sought to identify the tests and profiles that were unique to each of the studied ICUs and to quantify the proportion of the total laboratory testing that these ICU-specific studies represent.

The laboratory tests necessary to complete six commonly used ICU severity scoring systems were determined. The severity scoring systems examined were SAPS II (Simplified Acute Physiology Score II), APACHE III (Acute Physiology, Age, and Chronic Health Evaluation III), PRISM III (Pediatric Risk of Mortality III), PIM (Pediatric Index of Mortality), Project Impact, and MPM II (Mortality Probability Model II). The laboratory test requirements of these severity scoring systems were then compared with the tests performed most commonly in the ICUs studied.

Results

Most Frequent Laboratory Tests and Profiles

A total of 85,257 laboratory tests and profiles were included in this study sample. During the period studied, 45,188 tests and profiles were completed for patients in the medical ICU, 12,989 tests and profiles were completed for patients in the pediatric ICU, and 27,080 tests and profiles were completed for patients in the surgical ICU.

Table 1 ■ Number of Tests and Profiles That Represent Percentage Completed

% of Completed Tests and Profiles	Medical ICU	Pediatric ICU	Surgical ICU
80	17	24	24
90	31	46	34
95	58	82	52
99	152	202	104

ICU = intensive care unit.

Table 2 ■ Medical Intensive Care Unit: Tests and Profiles Representing 80% of Tests and Profiles Completed

Laboratory Test or Profile Name	Local Mnemonic	No. Completed	% of Total
Basic metabolic panel	LY3	7,110	15.73
Arterial blood gas profile	ART BLD GAS	5,703	12.62
Complete blood count	CBC	5,341	11.82
Partial thromboplastin time	APTT	2,803	6.20
Magnesium	MAG	2,106	4.66
Prothrombin time	PT	2,074	4.59
Phosphorus	PHOS	1,680	3.72
Calcium	CA	1,591	3.52
Complete blood count profile	CBC2	1,425	3.15
Creatine phosphokinase-MB fraction	CK-MB	902	2.00
Lactate dehydrogenase	LDH	890	1.97
Aspartate aminotransferase	AST	816	1.81
Alanine aminotransferase	ALT	813	1.80
Alkaline phosphatase	ALK	801	1.77
Total bilirubin	TOT BIL	800	1.77
Hematocrit	HCT	780	1.73
Potassium	K	711	1.57

Total number of tests and profiles completed in the medical intensive care unit was 45,188.

Table 1 indicates the number of tests and profiles that accounted for 80%, 90%, 95%, and 99% of all tests performed for patients in each ICU. Fewer than 25 tests and profiles accounted for 80% of the tests in each of the three ICUs. The number of tests and profiles accounting for 99% of all testing was 152 in the medical ICU, 202 in the pediatric ICU, and 104 in the surgical ICU. Tables 2 to 4 list the tests accounting for 80% of the tests in each ICU.

Unique Tests

Each ICU had a group of tests and profiles that were only ordered in that ICU. Of the total number of laboratory samples analyzed in the study period, these ICU-unique tests and profiles accounted for 0.64% of the total samples analyzed. The medical ICU had the largest volume of ICU-unique samples (287 or 0.64% of its samples), the pediatric ICU had 240 unique samples (1.85% of its samples), and the surgical ICU only 19 (0.07% of its samples.)

There were 211 named tests and profiles that were unique to a single ICU in the study: 110 in the medical ICU, 86 in the pediatric ICU, and 15 in the surgical ICU (Table 5).

Conversely, from among the tests and profiles that represent 80% of those completed in each of the ICUs studied, 15 tests and profiles were identified that were common to all the ICUs studied (Table 6).

Table 3 ■ Pediatric Intensive Care Unit: Tests and Profiles Representing 80% of Tests and Profiles Completed

Laboratory Test or Profile Name	Local Mnemonic	No. Completed	% of Total
Basic metabolic panel	LY3	2,318	17.83
Arterial blood gas profile	ART BLD GAS	1,260	9.69
Complete blood count profile	CBC2	821	6.31
Complete blood count	CBC	758	5.83
Serum osmolarity	OSMOL, SER	565	4.35
Phosphorus	PHOS	550	4.23
Calcium	CA	518	3.98
Magnesium	MAG	469	3.61
Prothrombin time	PT	348	2.67
Partial thromboplastin time	APTT	343	2.64
Venous blood gas profile	VEN BLD GAS	278	2.14
Albumin	ALB	213	1.64
Alanine aminotransferase	ALT	212	1.63
Urinalysis	UA	209	1.61
Aspartate aminotransferase	AST	207	1.59
Alkaline phosphatase	ALK	203	1.56
Lactate dehydrogenase	LDH	197	1.52
Differential manual	DIFF MANUAL	190	1.46
Total bilirubin	TOT BIL	189	1.45
Hematocrit	HCT	172	1.32
Manual differential after abnormal automated differential	DIFF SCAN/REV	110	0.85
Red blood cell morphology	RBC MORPH	108	0.83
White blood cell morphology	WBC MORPH	108	0.83
Platelet morphology	PLATELET MORPH	108	0.83

Total number of tests and profiles completed in the pediatric intensive care unit was 12,989.

Table 4 ■ Surgical Intensive Care Unit: Tests and Profiles Representing 80% of Tests and Profiles Completed

Laboratory Test or Profile Name	Local Mnemonic	No. Completed	% of Total
Arterial blood gas profile	ART BLD GAS	3,470	12.81
Basic metabolic panel	LY3	3,026	11.17
Complete blood count	CBC	2,873	10.61
Prothrombin time	PT	1,291	4.77
Partial thromboplastin time	APTT	1,216	4.49
Magnesium	MAG	978	3.61
Phosphorus	PHOS	780	2.88
Calcium	CA	668	2.47
Alanine aminotransferase	ALT	647	2.39
Aspartate aminotransferase	AST	644	2.38
Alkaline phosphatase	ALK	643	2.37
Hematocrit	HCT	559	2.06
Lactate	LAC	541	2.00
Potassium	K	504	1.86
Creatine phosphokinase-MB fraction	CK-MB	484	1.78
Osmolarity serum	OSMOL, SER	438	1.62
Amylase	AMY	434	1.60
Albumin	ALB	388	1.43
Complete blood count profile	CBC2	386	1.43
Ammonia	AMM	374	1.38
Total bilirubin	TOT BIL	359	1.33
Glucose	GLU	357	1.32
Lactate dehydrogenase	LDH	351	1.30
Lipase	LIPASE	340	1.26

Total number of tests and profiles completed in the surgical intensive care unit was 27,080.

Table 5 ■ ICU-Unique Laboratory Studies

Unit	Total Laboratory Samples Analyzed	ICU-Unique Laboratory Samples Analyzed	Unique % of Total Laboratory Samples Analyzed	No. of ICU-Unique Named Tests and Profiles
Medical ICU	45,188	287	0.64	110
Pediatric ICU	12,989	240	1.85	86
Surgical ICU	27,080	19	0.07	15
Overall	85,257	546	0.64	211

ICU = intensive care unit.

Laboratory Studies Required by Severity Scoring Systems

Of the laboratory data required in the six systems examined (SAPS II, APACHE III, PRISM III, PIM, Project Impact, and MPM II), all laboratory data needed to complete the scores fell into the top 21 laboratory studies and profiles performed in each of the ICUs.[4–7] Thus, if these large-scale data sets used a universal nomenclature such as LOINC to identify individual laboratory data elements, one would need to map only the top 21 laboratory studies and profiles to the same universal nomenclature to provide the necessary laboratory data to all the severity scoring systems examined (Table 7).

Discussion

The local naming of diagnostic tests within hospital informations systems has been a problematic issue since the introduction of computerized laboratory data systems. Most hospitals today use locally developed naming schemas for assigning names to individual laboratory tests and profiles performed by their hospital laboratories. Utilization of local terminology for individual tests greatly complicates efforts at large-scale data collection across institutions. An example of such large-scale efforts at data collection are ICU severity scoring systems, which attempt to use data gathered from multiple institutions to develop prediction models for ICU outcomes. The process of electronically gathering these data across institutions today requires that the local terminology for each participating institution be translated into a standard nomenclature such as LOINC. The translation of the elements necessary for this data collection so that each institution's data can be aggregated to form a large-scale database is time-consuming and costly. It has been suggested that, during installation of information systems that include laboratory data, local naming schemas be mapped to standard nomenclature systems. Unfortunately, the large number of different tests and profiles performed by any one institution often makes this mapping prohibitively expensive and time-consuming. For instance, the LOINC database contains standardized names for more than 25,000 tests. In this review of laboratory tests and profiles ordered in three ICUs at a university medical center, a small number of different tests and profiles represented the bulk of all the laboratory testing ordered. This finding indicates that there may be a subset of laboratory tests and profiles that are important to map within information systems to a standard vocabulary such as LOINC.

Table 6 ■ Laboratory Tests and Profiles from the Top 80% That Were Common to All Intensive Care Units Studied

Laboratory Test or Profile Name	Local Mnemonic
Alanine aminotransferase	ALT
Alkaline phosphatase	ALK
Arterial blood gas profile	ART BLD GAS
Aspartate aminotransferase	AST
Basic metabolic panel	LY3
Calcium	CA
Complete blood count	CBC
Complete blood count profile	CBC2
Hematocrit	HCT
Lactate dehydrogenase	LDH
Magnesium	MAG
Partial thromboplastin time	APTT
Phosphorus	PHOS
Prothrombin time	PT
Total bilirubin	TOT BIL

Table 7 ■ Laboratory Values Required for Common Intensive Care Unit Acuity Scoring Systems

Laboratory Observation Utilized	SAPS II	APACHE III	Project Impact	PRISM III	PIM	MPM II 24, 48, 72 Hr
Serum Na	X	X	X			
Serum K	X		X	X		
Serum bicarbonate	X		X	X		
Bilirubin	X	X	X			
Blood/urea/nitrogen	X	X	X	X		
Hematocrit		X	X			
White blood cell count	X	X	X	X		
Pa_{O_2}	X	X	X	X	X	X
Pa_{CO_2}		X	X	X		
Creatinine		X	X	X		X
Prothrombin time			X	X		X
Prothrombin time control			X			
Arterial pH		X	X	X		
Base excess					X	
Albumin		X				
Glucose		X		X		
Partial thromboplastin time				X		
Platelets				X		

APACHE III = Acute Physiology, Age, and Chronic Health Evaluation III; MPM II = Mortality Probability Models II; PIM = Pediatric Index of Mortality; PRISM III = Pediatric Risk of Mortality III; SAPS II = Simplified Acute Physiology Score II.

Table 8 ■ Panels and Component Tests

Panel/Component Tests
Arterial blood gas (ABG)
pH-ABG
P_{CO_2}-ABG
P_{O_2}-ABG
HCO_3-ABG
$\%O_2$ SAT-ABG
PUL LAB O_2 Content
Alveolar to arterial P_{O_2}
Alveoloarterial P_{O_2} differential
Oxygen delivery
Arteriovenous O_2 differential
Physiologic shunt fraction
Oxygen consumption
O_2 SAT estimated
Base excess
Venous blood gas (VBG) profile
pH-VBG
P_{CO_2}-VBG
P_{O_2}-VBG
HCO_2-VBG
$\%O_2$ SAT-VBG
PUL LAB O_2 content
O_2 SAT estimated
Complete blood count (CBC)
WBC
RBC
HGB
HCT
MCV
MCH
MCHC
RDW
CBC repeated
Platelet count
Mean platelet volume
Platelet estimate
Complete blood count profile
WBC
Corrected WBC
RBC
HGB
HCT
MCV
MCH
MCHC
RDW
CBC repeated
Platelet count
Mean platelet volume
NE
LY
MO
EO
BA
Absolute NE no.
Absolute LY no.
Absolute MO no.
Absolute EO no.
Absolute BA no.
Comment
Platelet estimate
Basic metabolic panel
Sodium
Potassium
Chloride
Carbon dioxide
Anion gap
Glucose
Blood/urea/nitrogen
Creatinine

BA = basopils; EO = eosinophils; HCT = hematocrit; HGB = hemoglobin; LY = lymphocytes; MCH = mean corpuscular hemoglobin; MCHC = mean corpuscular hemoglobin concentration; MCV = mean corpuscular volume; NE = neutrophils; RBC = red blood cell count; RDW = red cell distribution width; SAT = saturation; WBC = white blood cell count.

This study examined the frequency of both individual tests and profiles (batteries of individual tests that are both ordered and reported together). The LOINC nomenclature is evolving to include standardized naming for common panels and currently includes nomenclature for some of the most commonly used testing batteries such as the basic metabolic panel. The current version of the LOINC database contains LOINC codes for 148 commonly used panels of laboratory tests.[8] Review of the results of this study reveals that many common tests are most frequently ordered as part of testing panels (Table 8). Blood/urea/nitrogen and creatinine are examples of such tests that are most often nested within testing profiles. More work is yet to be done to identify less common panels and to provide standardized naming for them. However, this task is complicated by the fact that beyond the most commonly used panels, there is little agreement as to which tests should be included in an individual test battery.

During this study period, none of the ICUs studied used bedside testing devices that reported to the laboratory information system (LIS). The only bedside device in use in the ICUs studied was the bedside glucometer. The results from this device were not reported to the LIS but were recorded in the patient chart manually. This would likely lead to an underestimate of the frequency of the blood glucose test in the sample in this study given the data collection method used, which reported only tests ordered and reported through the LIS.

Examination of ICU-unique tests reveals that, although ICUs may have widely varied patient populations and missions, the bulk of the tests and profiles ordered are very similar. For instance, although the unique issues surrounding the sampling of arterial blood in very small children makes the venous blood gas profile a commonly used test in that ICU alone in the sample in this study, the vast majority of tests ordered in that ICU were not unique to that environment. A similar observation could be made for the relative frequency of creatine phosphokinase MB fraction (CK-MB) testing in the medical and surgical ICUs studied and the relative paucity of such testing in the pediatric ICU. However, even with these differences in patient population and illnesses treated, the majority of tests and panels ordered in all ICUs studied were remarkably similar.

Study Limitations

Although the ICUs in this study serve widely varied patient populations, the ICUs studied were from a single institution. It is possible that results of a similar review in another institution might vary with local test usage patterns and ICU mission.

Lessons Learned

The data suggest that a small proportion of the total number of tests and profiles available from a clinical laboratory should receive priority in mapping to standard nomenclature during the installation and configuration of new ICU information systems. In addition, it is expected that these findings may help to prioritize the task of retrospective mapping of local use names within existing information systems to standard terminologies such as LOINC.

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