CRITICAL LIMITS

By Gerald J. Kost, MD, PhD, MS, FADLM

Critical limits define the quantitative boundaries of life-threatening diagnostic test results. Critical results falling outside high and low critical limits must be reported to clinicians urgently, so the patient can be treated promptly if necessary. Critical value reporting was implemented by George Lundberg, MD, and published in *MLO* in 1972.[1] Analysis of the impact of critical notifications on patient outcomes appeared in *MLO* in 1993 with follow-up articles calling for national harmonization and standards of care for critical notification practices.[2-4]

These tables reflect research published in 2025 by Gerald Kost, MD, PhD, MS, FADLM of the POCT•CTR, School of Medicine, UC Davis, and his UC Honors Program student team. The research entailed a review of 50 critical limits/values lists from university hospitals, Level 1 trauma centers, centers of excellence, and high-performing hospitals across the U.S.[5] with comparison to 1990-93 data compiled through the first three national surveys of critical limits used by 92 responding U.S. medical centers, including 20 trauma centers and 39 children's hospitals.[6-8] Most hospital policies posted on the Web defined what a critical value is and stated that a licensed provider must be informed immediately.[9]

Statistically significant differences in 2024 versus 1990-93 critical limits were observed for glucose, calcium, magnesium, CO_2 content, blood gas parameters, hematology, and coagulation tests. Ranges for critical limits narrowed for several tests, and new measurands were added. Point-of-care testing (POCT) listings were scarce and revealed notable differences from main lab values in the high median critical limit for glucose.[5]

The Joint Commission identifies timely reporting of critical tests results as a National Patient Safety Goal (NPSG.02.03.01) in its accreditation programs.[10] Clinical laboratories can develop notification practices collaboratively with emergency physicians, hospitalists, and point-of-care specialists to achieve timely, effective, and focused patient care. For example, the statistically significant increase in the low critical limit for

Table 1: Clinical chemistry critical limits.[5]

Test	Listing Freq., %		Units	Low Mean (SD)		Low Median (Range)		High Mean (SD)		High Median (Range)	
	2024	1990		1990	2024	1990	2024	1990	2024	1990	2024
Glucose	100	100	mmol/L	2.6 (0.4)	2.7 (0.3)	**2.5 (1.7-3.9)**	**2.8** (2.2-3.3)**	26.9 (8.0)	26.4 (2.8)	27.8 (6.1-55.5)	27.8 (22.1-33.3)
			mg/dL	46 (7)	49 (5)	**45 (30-70)**	**50** (39-60)**	484 (144)	476 (51)	501 (110-1000)	500 (399-1000)
Calcium	98	100	mmol/L	1.65 (0.17)	1.55 (0.10)	**1.62 (1.2-2.2)**	**1.50** (1.2-1.7)**	3.22 (0.22)	3.24 (0.15)	**3.24 (2.62-3.49)**	**3.24** (2.87-3.49)**
			mg/dL	6.6 (0.7)	6.2 (0.4)	**6.5 (5.0-8.6)**	**6.0** (5.0-7.0)**	12.9 (0.9)	13.0 (0.6)	**13.0 (10.5-14.0)**	**13.0** (11.5-14.0)**
Sodium	98	100	mmol/L	120 (5)	121 (2)	120 (110-137)	120 (119-125)	158 (6)	159 (2)	160 (145-170)	160 (153-165)
Potassium	96	100	mmol/L	2.8 (0.3)	2.8 (0.2)	2.7 (2.5-3.6)	2.8 (2.5-3.0)	6.2 (0.4)	6.1 (0.2)	6.0 (5.0-8.0)	6.0 (5.9-7.0)
Magnesium	88	33	mmol/L	0.41 (0.16)	0.41 (0.04)	0.41 (0.21-0.74)	0.41 (0.25-0.49)	2.02 (0.82)	2.3 (0.66)	**1.75 (1.03-5.02)**	**2.02** (1.44-4.53)**
Ionized Calcium	82	57	mmol/L	0.82 (0.14)	0.78 (0.06)	0.80 (0.50-1.07)	0.80 (0.50-0.90)	1.55 (0.19)	1.59 (0.17)	1.50 (1.30-2.00)	1.58 (1.40-2.50)
Phosohorous	78	33	mmol/L	0.39 (0.10)	0.36 (0.06)	0.32 (0.26-0.65)	0.32 (0.29-0.48)	2.87 (0.48)	3.13 (0.48)	3.22 (2.26-3.23)	2.91 (2.58-4.04)
			mg/dL	1.2 (0.3)	1.1 (0.2)	1.0 (0.8-2.0)	1.0 (0.9-1.5)	8.9 (1.5)	9.7 (1.5)	10.0 (7.0-10.0)	9.0 (8.0-12.5)
CO_2 content	74	75	mmol/L	11 (2)	11 (2)	10 (5-20)	10 (8-15)	40 (3)	42 (3)	**40 (35-50)**	**40* (39-50)**
Lactate	62	5	mmol/L	—	—	—	—	3.4 (1.3)	3.9 (1.1)	3.0 (2.3-5.0)	4.0 (2.0-8.0)
Osmolality	40	20	mmol/kg	250 (13)	245 (14)	250 (230-280)	250 (190-260)	326 (18)	332 (18)	320 (295-375)	330 (308-390)
Cerebro-spinal Fluid Glucose	40	16	mmol/L	2.1 (0.6)	1.9 (0.4)	2.2 (1.1-2.8)	2.2 (1.1-2.5)	24.3 (11.4)	17.4 (3.5)	16.7 (13.9-38.9)	16.7 (13.9-25.0)
			mq/dL	37 (10)	34 (8)	40 (20-50)	39 (20-50)	438 (206)	314 (63)	301 (250-700)	300 (250-450)
Ammonia	32	—	µmol/L	—	—	—	—	—	127 (57)	—	108 (50-250)
Chloride	22	20	mmol/L	75 (8)	77 (3)	80 (60-90)	75 (70-81)	126 (12)	125 (5)	120 (115-156)	125 (119-130)
Urea Nitrogen	12	20	mmol/L	—	—	—	—	37.1 (21.1)	32.5 (10)	33.9 (14.3-107.1)	36.1 (14.3-42.9)
			mg/dL	—	—	—	—	104 (59)	91 (28)	95 (40-300)	101 (40-120)
Creatinine	12	10	µmol/L	—	—	—	—	654 (380)	636 (265)	884 (177-1326)	663 (177-884)
			mg/dL	—	—	—	—	7.4 (4.3)	7.2 (3.0)	10 (2.0-15.0)	7.5 (2.0-10.0)
Uric Acid	8	20	µmol/L	—	—	—	—	773 (119)	714 (59)	892 (595-892)	773 (595-773)
			mg/dL	—	—	—	—	13 (2)	12 (1)	15 (10-15)	13 (10-13)
Bilirubin	0	25	µmol/L	—	—	—	—	257 (86)	ACNL	257 (86-513)	ACNL
			mg/dL	—	—	—	—	15 (5)	ACNL	15 (5-30)	ACNL

ACNL, Adult Critical limits Not Listed. *, Significant difference in medians at $p < 0.05$; **, Significant difference in medians at $p < 0.01$. Bold indicates statistically significant difference.

glucose, which increases the notification frequency, may reflect recognition of the level two threshold [54 mg/dL (3.0 mmol/L)] at which neuroglycopenic symptoms require immediate action.[11]

Hospitals are advised to review their notification practices, quantitative decision thresholds, and qualitative critical value notifications to assure that effective life-saving alerts improve patient outcomes without excessively burdening laboratory, bedside, critical care, or emergency staff.

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Table 2: Blood gas and pH critical limits.[5]

Measurand	Listing Freq., %		Units	Low Mean (SD)		Low Median (Range)		High Mean (SD)		High Median (Range)	
	2024	1990		1990	2024	1990	2024	1990	2024	1990	2024
pH	86	35	pH Units	7.21 (0.06)	7.20 (0.03)	7.20 (7.00-7.35)	7.20 (7.10-7.25)	7.59 (0.03)	7.59 (0.02)	7.60 (7.50-7.65)	7.60 (7.55-7.65)
Arterial pO_2	78	26	mmHg	43 (6)	45 (6)	**40 (30-55)**	**40* (39-60)**	—	—	—	—
			kPa	5.7 (0.8)	6.0 (0.8)	**5.3 (4.0-7.3)**	**5.3* (5.2-8.0)**	—	—	—	—
Arterial pCO_2	74	30	mmHg	19 (3)	21 (6)	**20 (9-25)**	**20* (9-44)**	67 (6)	67 (5)	70 (50-80)	70 (55-80)
			kPa	2.5 (0.4)	2.8 (0.8)	**2.7 (1.2-3.3)**	**2.7* (1.2-5.9)**	8.9 (0.8)	8.9 (0.7)	9.3 (6.7-10.7)	9.3 (7.3-10.7)
Carboxyhemoglobin	48	—	%	—	—	—	—	—	15.3 (5.7)	—	17.0 (5.1-25.0)
Methemoglobin	34	—	%	—	—	—	—	—	11.7 (10.4)	—	5.1 (3.0-30.0)
Venous pH	26	—	pH Units	—	7.20 (0.04)	—	7.20 (7.10-7.25)	—	7.59 (0.03)	—	7.60 (7.52-7.60)
Venous pCO_2	16	—	mmHg	—	20 (6)	—	20 (9-28)	—	69 (6)	—	68 (60-75)
			kPa	—	2.7 (0.8)	—	2.7 (1.2-3.7)	—	9.2 (0.8)	—	9.1 (8.0-10.0)

*, Significant difference in medians at $p < 0.05$. Bold indicates statistically significant difference.

Table 3: Hematology and coagulation critical limits.[5]

Test	Listing Freq., %		Units	Low Mean (SD)		Low Median (Range)		High Mean (SD)		High Median (Range)	
	2024	1990		1990	2024	1990	2024	1990	2024	1990	2024
Platelets	96	45	10^9/L	37 (21)	25 (11)	**30 (10-100)**	**20** (10-50)**	894 (206)	984 (73)	1,000 (100-1,000)	1,000 (600-1,000)
Hemoglobin	96	42	g/dL	7.0 (2.2)	6.3 (0.6)	7.0 (4.0-15.0)	6.0 (5.0-7.0)	19.0 (4.4)	20.2 (0.9)	**20.0 (20.0-30.0)**	**20.0 † (19.0-22.5)**
INR	94	—	INR	—	—	—	—	—	4.9 (0.6)	—	5.0 (4.0-7.0)
Partial Thromboplastin Time	90	33	Sec	50	—	50	—	80 (33)	116 (25)	**80 (40-150)**	**110** (69-200)**
Fibrinogen	88	27	mg/dL	85 (26)	88 (19)	100 (8-10)	100 (50-120)	780 (260)	—	800 (500-1,000)	—
WBC Count	84	42	10^9/L	2.2 (0.9)	1.3 (0.5)	**2.0 (1-5)**	**1.4** (0.5-2.0)**	37 (22)	57 (31)	**30 (9.5-100)**	**50** (25-150)**
Hematocrit	72	29	%	20 (8.1)	19 (2)	18 (41)	20 (15-21)	60 (12.8)	61 (5)	60 (20-80)	60 (54-75)
Absolute Neutrophil Count	34	—	10^9/L	—	0.6 (0.2)	—	0.5 (0.3-1.0)	—	—	—	—
WBC Count in CSF	26	—	WBC/mm^3	—	—	—	—	—	39 (55)	—	20 (5-200)
Prothrombin Time	16	33	Sec	12 (2.4)	—	10 (10-15)	—	**29 (8)**	**48** (5)**	30 (14-40)	47 (40-58)
Band Count	12	—	%	—	—	—	—	—	23 (11)	—	20 (10-40)
Blast Cells	12	—	%	—	—	—	—	—	5.7 (2.2)	—	5 (4-10)

**, significant difference in medians at $p < 0.01$. †, $0.10 < p < 0.05$. Bold indicates statistically significant difference.

Table 4: Qualitative critical values.[5]

Measurand	Detection Method(s) (If Identified)	Listing Frequency (%)
A. Microbiology		
Positive culture from blood, cerebrospinal fluid, or sterile body fluid	Culture	82
Cryptococcus species (*Cryptococcus neoformans or gattii*)	Culture, Latex agglutination, PCR, RAgT	70
Acid-Fast Bacillus (AFB)	Culture, stain	68
Positive Gram stain from blood, cerebrospinal fluid, or sterile body fluid	Gram stain	60
Pathogenic fungus in a potentially invasive space (CSF, blood, or sterile body fluid)	Culture, PCR, smear, stain	44
Mycobacterium tuberculosis	Culture, PCR, stain	34
Dimorphic fungal pathogens (e.g., *Histoplasma*, *Blastomyces*, or *Coccidioides species*)	Culture, PCR, smear	32
Brucellosis (*Brucella* species)	Culture	26
Tularemia (*Francisella tularensis*)	Culture	26
Anthrax (*Bacillus anthracis*)	Culture	24
Antibiotic resistant bacteria	Culture	24
Eye and ocular cultures positive	Culture, Gram stain	24
Plague (*Yersinia pestis*)	Culture	24
Pneumocystis species	PCR, RAgT	24
Burkholderia mallei or *pseudomallei*	Culture	20
Bordetella pertussis	Culture, PCR	18
Escherichia coli O157:H7 or Shiga-toxin tests	Culture, PCR	18
Legionella	Culture, RAgT	18
Neisseria meningitidis from sterile sites	Culture, RAgT	18
Meningitis/Encephalitis panel	PCR	16
Syphilis	RPR	16
Botulism (*Clostridium botulinum* toxin)	Culture	14
Candida auris	Culture, PCR	14
Cholera (*Vibrio cholerae*)	-	14
Corynebacterium diphtheriae	Culture	14
Group A *Streptococcus*	Culture, RAgT	14
Listeria	Culture	14
Methicillin-resistant *Staphylococcus aureus* (MRSA)	-	14
Neisseria gonorrhea in the eye	Culture, probe	14
Salmonella species	Culture	14
Vancomycin Resistant *Enterococcus* (VRE)	-	14
Pseudomonas eye/ocular positive	Culture, probe	12
Streptococcus pneumoniae	Culture, PCR, RAgT	12
Group B *Streptococci*	Culture, PCR, RAgT	10
Shigella	Culture	10
Vancomycin-resistant *Staphylococcus aureus* (VRSA)	-	10
Chlamydia	Culture, PCR	8
Clostridium difficile	Culture, PCR	8
Nocardia	Culture, PCR	8
Q fever (*Coxiella burnetii*)	-	8
B. Virology		
Herpes simplex virus (HSV) in CSF	PCR	36
Herpes simplex virus (HSV) in newborns or near-term pregnant mothers	Culture, Pap, PCR	34
Human Immunodeficiency Virus (HIV)	Ag/Ab combo, PCR, RAgT, Western blot	32

Table 4: Qualitative critical values.[5]

Measurands	Detection Method(s) (If Identified)	Listing Frequency (%)
B. Virology		
Varicella zoster virus (VZV)	PCR	18
Epstein–Barr Virus (EBV)	PCR	14
Cytomegalovirus (CMV)	Culture, PCR	12
Respiratory Syncytial Virus (RSV)	PCR	12
Enterovirus in blood/sterile sites	Culture, PCR	10
Hepatitis B surface antigen	-	8
Viral hemorrhagic fever	-	8
Smallpox (Variola major)	-	6
COVID-19 (SARS-CoV-2) Detected	PCR, RagT	4
C. Parasitology		
Malarial parasites	RAgT, smear	42
Parasites from sterile body sites	RAgT, smear	22
Babesia microti	PCR, smear	14
Plasmodium species	Smear, stain	10
Microfilaria	Smear, stain	8
D. Blood Bank		
Positive Direct Coombs test/Direct antiglobulin test (DAT)	-	28
Hemolytic transfusion reaction	-	22
Positive culture or Gram stain on a blood product associated with a transfusion reaction	Culture, Gram stain	20
New positive antibody screen	-	20
Non-availability of ordered transfusion	-	18
Incompatible crossmatch	-	16
Fetal maternal hemorrhage		8
E. Hematology		
Presence of blasts in blood or CSF	Smear	26
Heparin induced platelet antibodies	-	10
New diagnosis or findings of leukemia	Smear	8
F. Anatomical/Surgical Pathology		
Fat in endometrial curettage	-	14
Significant disagreement between the frozen section and final diagnosis	-	14
Significant discrepancy between outside diagnosis and the review diagnosis	-	14
Unexpected diagnosis of malignancy	-	14
Amended report with a significant change in diagnosis	-	12
Absence of chorionic villi when clinically expected	-	10
Crescents in kidney biopsy specimen	-	8
Significant discrepancy between the fine needle aspiration (FNA) immediate interpretation and the final diagnosis	-	8
Transplant rejection	-	8
Unexpected fat in colonic endoscopic specimens	-	8
G. Urinalysis		
Positive urine glucose	-	18
Positive urine ketones	-	16
RBC casts	Microscope	8

Abbreviations (in addition to those in the table): COVID-19, coronavirus infectious disease-2019; CSF, cerebrospinal fluid; PCR, Polymerase Chain Reaction; RAgT, rapid antigen test; RBC, red blood cells; RPR, rapid plasma reagin; and SARS-CoV-2, severe acute respiratory syndrome-coronavirus-2.

Table 5. Listing frequencies of critical pathogens.[5]

Pathogen	NIH	CDC	WHO	IDSA	Frequency (%)
Cryptococcus species (*C. neoformans* or *gatti*)					70
Herpes simplex virus (HSV)					50
Malarial parasites			■		42
Tuberculosis (*Mycobacterium tuberculosis*)	■			■	34
Human Immunodeficiency Virus (HIV)				■	32
Brucellosis (*Brucella* species)	■				26
Tularemia (*Francisella tularensis*)	■				26
Anthrax (*Bacillus anthracis*)	■	■	■		24
Plague (*Yersinia pestis*)	■		■		24
Pneumocystis species					24
Coccidiodes species	■			■	22
Burkholderia mallei or *psuedomallei*	■	■			20
Bordatellapertussis	■				18
Escherichia coli	■	■			18
Legionella					18
Neisseria meningitidis			■		18
Varicella Zoster Virus (VZV)					18
Syphilis					16
Botulism (*Clostridium botulinum toxin*)	■				14
Cholera (*Vibrio cholerae*)	Consensus	■	■	■	14
Methicillin-resistant *Staphylococcus aureus* (MRSA)	■				14
Salmonella species	■	■			14
Viral hemorrhagic fever			■		8
Influenza viruses	Consensus	■	■	■	6
Smallpox (Variola minor)	■		■		6
COVID-19 (SARS-CoV-2)	Consensus	■	■	■	4

Purple fill-ins indicated that the corresponding pathogen is deemed as demanding rapid detection by that agency.

Table 6. Newborn critical limits.[5]

Test	Listing Freq., %		Units	Low Mean (SD)		Low Median (Range)		High Mean (SD)		High Median (Range)	
	2024	1990		1990	2024	1990	2024	1990	2024	1990	2024
Clinical Chemistry											
Bilirubin	94	9	µmol/L	…	…	…	…	239 (34)	257 (34)	257 (171–308)	257 (171–342)
			mg/dL	…	…	…	…	14 (2)	15 (2)	15 (10–18)	15 (10–20)
Glucose	80	42	mmol/L	1.8 (0.4)	2.2 (0.3)	**1.7 (1.1–2.8)**	**2.2 ** (1.7–3.1)**	18.1 (6.0)	14.7 (4.4)	16.7 (11.1–38.9)	13.9 (8.3–27.8)
			mg/dL	32 (7)	40 (6)	**31 (20–50)**	**40 ** (30–55)**	326 (108)	265 (80)	301 (200–700)	250 (150–500)
Potassium	30	32	mmol/L	2.6 (0.2)	2.8 (0.3)	**2.5 (2.5–3.5)**	**2.9 ** (2.0–3.0)**	7.7 (0.7)	6.8 (0.6)	**8.0 (5.5–8.0)**	**6.9 ** (6.0–8.0)**
Sodium	18	…	mmol/L	…	125 (2)	…	125 (124–130)	…	154 (4)	…	155 (150–160)
Hematology											
Hemoglobin	44	7	g/dL	9.5 (3.5)	7.9 (1.8)	8.5 (5.0–15.0)	8.0 (6.0–12.0)	22.3 (2.3)	22.4 (1.5)	21.0 (21.0–25.0)	22.0 (20.0–25.0)
Hematocrit	32	7	%	33 (6)	24 (6)	**30 (24–45)**	**21* (18–35)**	**71 (4)**	**66 * (3)**	70 (65–75)	66 (60–70)
Platelets	28	…	10^9/L	…	44 (22)	…	45 (20–100)	…	950 (84)	…	1000 (800–1000)
Blood Gas and pH											
pH Cord Blood	28	…	pH Units	…	7.05 (0.09)	…	7.00 (7.00–7.25)	…	7.52 (0.03)	…	7.50 (7.50–7.55)
Arterial pO_2	16	8	mm Hg	37 (7)	46 (5)	**35 (30–50)**	**50 * (40–50)**	92 (12)	120 (73)	100 (70–100)	95 (90–300)
			kPa	4.9 (0.9)	6.1 (0.7)	**4.7 (4.0–6.7)**	**6.7 * (5.3–6.7)**	12.3 (1.6)	16.0 (9.7)	13.3 (9.3–13.3)	12.7 (12.0–40.0)
Arterial pCO_2	16	2	mm Hg	35 (7)	30	35 (30–40)	30	55 (7)	66 (11)	55 (50–60)	70 (50–80)
			kPa	4.7 (0.9)	4.0	4.7 (4.0–5.3)	4.0	7.4 (0.9)	8.8 (1.5)	7.4 (6.7–8.0)	9.3 (6.7–10.7)

*, significant difference in medians and one mean at $p < 0.05$; **, significant difference in medians at $p < 0.01$. Bold indicates statistically significant difference.

Table 7: POCT critical limits[5]

Measurands	Listing Frequency (%)	Units	Low Mean (SD)	Low Median (Range)	High Mean (SD)	High Median (Range)
Clinical Chemistry						
Glucose	24.1	mg/dL	49.5 (4.4)	50 (40–55)	415.4 (87.5)	400 (200–500)
Newborn Glucose	9.3	mg/dL	40.8 (7.3)	40 (30–50)	220.0 (73.7)	200 (125-325)
Potassium	16.7	mmol/L	2.6 (0.3)	2.5 (2.0-3.0)	6.2 (0.2)	6.0 (6.0-6.5)
Ionized Calcium	14.8	mmol/L	0.81 (0.10)	0.77 (0.70-1.0)	1.57 (0.13)	1.50 (1.40-1.75)
Sodium	14.8	mmol/L	121.1 (2.1)	120 (120-125)	160.1 (2.4)	160 (156-165)
Blood Gas						
pCO_2	13.0	mm/Hg	20 (3.2)	20 (15-25)	64.3 (7.9)	70 (50–70)
pH	13.0		7.21 (0.04)	7.20 (7.2-7.3)	7.59 (0.019)	7.60 (7.55–7.6)
pO_2	13.0	mm/Hg	45.7 (6.1)	45 (0-55)	na	na
Hematology						
Hematocrit	11.1	%	18.2 (2.1)	18 (15-21)	63.3 (6.1)	60 (60–75)
Hemoglobin	11.1	g/dL	6.4 (0.5)	6.25 (6-7)	20.25 (0.5)	20 (20–21)
INR	9.3				4.9 (0.22)	5 (4.5–5.0)

INR, International normalized ratio.