Adult

CLINICAL CHEMISTRY		LOW LIMIT		HIGH LIMIT	
Test	Units	Mean (SD)	Range	Mean (SD)	Range
Glucose	mmol/L mg/dL	2.6 (0.4) 46 (7)	1.7-3.9 30-70	26.9 (8.0) 484 (144)	6.1-55.5 110-1000
Potassium	mmol/L	2.8 (0.3)	2.5-3.6	6.2 (0.4) 8.0 (hemolyzed)	5.0-8.0
Calcium	mmol/L mg/dL	1.65 (0.17) 6.6 (0.7)	1.25-2.15 5.0-8.6	3.22 (0.22) 12.9 (0.9)	2.62-3.49 10.5-14.0
Sodium	mmol/L	120 (5)	110-137	158 (6)	145-170
CO_2 content	mmol/L	11 (2)	5-20	40 (3)	35-50
Magnesium	mmol/L mg/dL	0.41 (0.16) 1.0 (0.4)	0.21-0.74 0.5-1.8	2.02 (0.82) 4.9 (2.0)	1.03-5.02 2.5-12.2
Phosphorus	mmol/L mg/dL	0.39 (0.10) 1.2 (0.3)	0.26-0.65 0.8-2.0	2.87 (0.48) 8.9 (1.5)	2.26-3.23 7.0-10.0
Bilirubin	µmol/L mg/dL	— —	— —	257 (86) 15 (5)	86-513 5-30
Chloride	mmol/L	75 (8)	60-90	126 (12)	115-156
Osmolality	mmol/kg	250 (13)	230-280	326 (18)	295-375
Urea nitrogen	mmol/L mg/dL	— —	— —	37.1 (21.1) 104 (59)	14.3-107.1 40-300
Uric acid	µmol/L mg/dL	— —	— —	773 (119) 13 (2)	595-892 10-15
CSF glucose	mmol/L mg/dL	2.1 (0.6) 37 (10)	1.1-2.8 20-50	24.3 (11.4) 438 (206)	13.9-38.9 250-700
Creatinine	µmol/L mg/dL	— —	— —	654 (380) 7.4 (4.3)	177-1326 2.0-15.0
Ionized calcium[4]	mmol/L mg/dL	0.82 (0.14) 3.29 (0.56)	0.50-1.07 2.00-4.29	1.55 (0.19) 6.21 (0.76)	1.30-2.00 5.21-8.02
Lactate	mmol/L mg/dL	— —	— —	3.4 (1.3) 30.6 (11.7)	2.3-5.0 20.7-45.0
HEMATOLOGY					
Hematocrit	L/L	0.18 (0.05)	0.12-0.30	0.61 (0.06)	0.54-0.80
Hemoglobin	g/L	66 (17)	40-120	199 (27)	170-300
Platelets	$\times 10^9$/L	37 (18)	10-100	910 (147)	555-1000
WBC count	$\times 10^9$/L	2.0 (0.7)	1.0-4.0	37.0 (20.7)	10.0-100.0
PT	s	—	—	27 (9)	14-40
PTT	s	—	—	68 (33)	32-150
Fibrinogen	g/L	0.88 (0.17)	0.50-1.00	7.75 (2.63)	5.00-10.00
BLOOD GASES AND PH					
pCO_2	mm Hg	19 (3)	9-25	67 (6)	50-80
pH		7.21 (0.06)	7.00-7.35	7.59 (0.03)	7.50-7.65
pO_2	mm Hg kPa	43 (6) 5.7 (0.8)	30-55 4.0-7.3	— —	— —

Adult table modified with permission by *JAMA*, Vol. 263, pp. 704-707, 1990. This table was updated by Dr. Gerald Kost in 2023. CSF, cerebrospinal fluid; WBC, white blood cell; PT, prothrombin time; PTT, partial thromboplastin time. Qualitative critical results for adults[1] include the following: For *blood bank* and *immunology*—incompatible crossmatch, tests positive for syphilis (RPR or VDRL). For *microbiology* and *parasitology*—positive results from Gram stain or in culture from blood, cerebrospinal fluid, or body cavity fluid; positive India ink preparation; positive rapid antigen detection by agglutination tests for *Cryptococcus*, group B streptococci, *Haemophilius influenzae b, or Neisseria meningitidis*, positive results from acid-fast bacillus stain or culture; *Salmonella, Shigella, or Campylobacter* on stool culture; presence of malarial parasites. For *clinical microscopy and urinalysis*—elevated white blood cell count in CSF; presence of malignant cells, blasts, or microorganisms in CSF or body fluids; combination of strongly positive test results for glucose and for ketones in urine; presence of pathologic crystals (urate, cysteine, leucine, or tyrosine) on urinalysis. For *hematology*—listed frequently are the presence of blasts on blood smear; new diagnosis or findings of leukemia; presence of sickle cells (or aplastic crisis). Listed occasionally are plasma cells, band cells, atypical lymphocytes, and abnormal reticulocyte count.

Critical limits define the boundaries of life-threatening diagnostic test results. Critical results falling outside high and low critical limits must be reported to clinicians without delay, so the patient can be treated promptly if necessary. Critical value reporting was first implemented by George Lundberg, MD, and published in MLO in 1972. These tables are based on three national surveys by Gerald Kost, MD, PhD, MS, of UC Davis Health. Adapted with permission from his articles,[1-3] they summarize critical limits used by 92 responding U.S. medical centers, including 20 trauma centers, and by 39 children's hospitals.

Mean low and mean high figures may be considered critical limits for each test listed. The frequency with which critical limits were listed can be found in the original articles. Dr. Kost conducted an independent national survey to determine ionized calcium critical limits.[3] His overview of critical limits and patient outcomes appeared in MLO[4] followed by calls for national harmonization and standards of care for critical value practices.[5,6]

The Joint Commission identifies critical values and the need to report critical results timely in National Patient Safety Goals.[7] Elements of performance comprise: (a) define critical values and develop written procedures for managing critical results, by whom and to whom they are reported, and acceptable lengths of time between resulting and reporting; (b) implement procedures for managing critical results; and (3) evaluate the timeliness of reporting. Laboratories should carefully monitor failed clinician notifications and strive for none.

Surveys and practice reviews are advancing harmonization[8] of critical values and notification practices in Australia,[9] Canada,[10] China,[11-16] Croatia,[17] Iran,[18-20] Italy,[21,22] Kuwait,[23] Turkey,[24] Spain,[25] South Africa,[26] and the U.S.[27-28] Understanding quantitative critical limits, qualitative critical values, alternate nomenclature (e.g., "critical-risk results, significant-risk results, and alert thresholds"[27]), and national norms will be necessary to enable a global standard. Special considerations for newborn and pediatric critical values are necessary because of rapid adaption to the extrauterine demands for physiological changes.

Studies address critical values for cytology,[29,30] cytogenetics and molecular genetics,[31] point-of-care glucose,[32] virology,[33] and anatomic and surgical pathology.[34] One US study addressed false positive critical value results.[35] If institutions list COVID-19 tests, then both false positive and false negatives should be of concern, the former for triggering unnecessary isolation and the latter, for spreading disease by those unaware of infection.[36] Repeat testing will improve the performance of COVID-19 testing[37] but may not be indicated for other critical results.[19,24,38,39]

Lifesaving diagnostic speed and accurately informed decision-making lead to appropriate therapy in times of human crises.[40] Clinical laboratories and point-of-care specialists can assign critical values and develop notification practices collaboratively with emergency physicians, hospitalists, and other clinical colleagues to achieve optimal outcomes for patients.

REFERENCES

1. Kost GJ. Critical limits for urgent clinician notification at U.S. medical centers. *JAMA*. 1990;263:704-707.
2. Kost GJ. Critical limits for emergency clinician notification at U.S. children's hospitals. *Pediatrics*. 1991;88:597-603.
3. Kost GJ. The significance of ionized calcium in cardiac and critical care. Availability and critical limits at U.S. medical centers and children's hospitals. *Arch Pathol Lab Med*. 1993;117:890-896.
4. Kost GJ. Using critical limits to improve patient outcomes. *MLO*. 1993;25(3):22-27.
5. Kost GJ. Co-creating critical limits for enhanced acute care: proven need and web knowledge base. Part 1: A call to action! *MLO*. 2015;47(12):34, 36-37.

146999404© Julia Pivovarova|Dreamstime.com

6. Kost GJ. Co-creating critical limits for enhanced acute care: proven need and web knowledge base. Part 2: Standard of care, what it means and how it is applied. *MLO*. 2016;48(1):28-29.

7. The Joint Commission. NPSG.02.03.01 for the Laboratory Program, January 2023. Report critical results of tests and diagnostic procedures on a timely basis. Accessed April 18, 2023. https://www.jointcommission.org/.

8. Kost GJ, Hale KN. Global trends in critical values practices and their harmonization. *Clin Chem Lab Med*. 2011;49(2):167-176.

9. Campbell C, Horvath A. Towards harmonization of critical laboratory result management—review of the literature and survey of Australian practices. *Clin Biochem Rev*. 2012;33(4):149-160.

10. Gong Y, Adeli K. A national survey on pediatric critical values used in clinical laboratories across Canada. *Clin Biochem*. 2009;42(16-17):1610-1615.

11. Zeng R, Wang W, Wang Z. National survey on critical values notification of 599 institutions in China. *Clin Chem Lab Med*. 2013;51(11):2099-2107.

12. Fei Y, Zhao H, Wang W, He F, Zhong K, Yuan S, et al. National survey on current situation of critical value reporting in 973 laboratories in China. *Biochem Med (Zagreb)*. 2017;27(3):030707.

13. Ye YY, Zhao HJ, Fei Y, Wang W, He FL, Zhong K, et al. Critical values in hematology of 862 institutions in China. *Int J Lab Hematol*. 2017;39(5):513-520.

14. Duan M, Ma X, Fan J, Guo Y, Wang W, Zhao H, et al. National surveys on 15 quality indicators for the total testing process in clinical laboratories of China from 2015 to 2017. *Clin Chem Lab Med*. 2018;57(2):195-203.

15. Li R, Wang T, Gong L, Dong J, Xiao N, Yang X, et al. Enhance the effectiveness of clinical laboratory critical values initiative notification by implementing a closed-loop system: A five-year retrospective observational study. *J Clin Lab Anal*. 2020;34(2):e23038.

16. Chen J, Wu Z, Liu Y, Wang L, Li T, Dong Y, et al. Prevalence, association relation, and dynamic evolution analysis of critical values in health checkup in China: A retrospective study. *Front Public Health*. 2021;9(630356):1-13.

17. Kopcinovic LM, Trifunović J, Pavosevic T, Nikolac N. Croatian survey on critical results reporting. *Biochem Med (Zagreb)*. 2015;25(2):193-202.

18. Dorgalaleh A, Shiravand Y, Dabbagh A, Tabibian S, Hosseini MS, Mansouri Tourghabeh H, et al. Hemostasis critical values among Iranian clinical laboratories "National Survey of 157 Clinical Laboratories". *Int J Lab Hematol*. 2019;41(6):778-781.

19. Saffar H, Abdollahi A, Hosseini AS, Torabi Farsani M, Hajinasrollah G, Mohaghegh P. Necessity of routine repeat testing of critical values in various working shifts. *Iran J Pathol*. 2020;15(3):161-166.

20. Jafari E, Zarnegar F, Kalantari M, Dabiri S, Naghibzadeh-Tahami A. Critical values in laboratory tests of Iranian patients referring to laboratories: A Cross-sectional study in Kerman. *Arch Iran Med*. 2021;24(6):473-477.

21. Lippi G, Giavarina D, Montagnana M, Luca Salvagno G, Cappelletti P, Plebani M, et al. National survey on critical values reporting in a cohort of Italian laboratories. *Clin Chem Lab Med*. 2007;45(10):1411-1413.

22. Piva E, Sciacovelli L, Laposata M, Plebani M. Assessment of critical values policies in Italian institutions: comparison with the US situation. *Clin Chem Lab Med*. 2010;48(4):461-468.

23. Fadhalah T, Mudaf B, Tawalah H, Fouzan WA, Salem G, Alghanim HA, et al. Baseline assessment of staff perception of critical value practices in government hospitals in Kuwait. *BMC Hlth Ser Res*. 2022;22(986):1-17.

24. Orhan B, Budak H, Topkaya BC, Sonmez D, Ozturk-Emre H, Bercik-Inal B. Analysis of prescribed critical values in Istanbul training and research hospital biochemistry laboratory: Should critical values be repeated? *Clin Lab*. 2020;66(9).

25. Arbiol-Roca A, Corral-Comesaña S, Cano-Corres R, Castro-Castro MJ, Dastis-Arias M, Dot-Bach D. Analysis of laboratory critical values at a referral Spanish tertiary university hospital. *Biochem Med (Zagreb)*. 2019;29(1):010704.

26. Schapkaitz E, Mafika Z. Critical value reporting: a survey of 36 clinical laboratories in South Africa. *S Afr Med J*. 2013;104(1):65-67.

27. Young AB, et al. Management of critical- and significant-risk results. Wayne, PA: CLSI GP47. 2015.

28. Gosselin RC, Adcock D, Dorgalaleh A, Favaloro EJ, Lippi G, Pego JM. International Council for Standardization in Haematology recommendations for hemostasis critical values, tests, and reporting. *Semin Thromb Hemost*. 2020;46(4):398-409.

29. Pereira TC, Clayton AC, Tazelaar HD, Liu Y, Leon M, Silverman JF. Critical values in cytology. *Diagnostic Cytopathology*. 2006;34(6):447-451.

30. Onken AM, VanderLaan PA, Rosenbaum MW. Critical values in cytology. *J Am Soc Cytopathol*. 2021;10(4):341-348.

31. Goh ES, Stavropoulos DJ, Adeli K. Defining and reporting on critical values in genetics: A laboratory survey. *J Appl Lab Med*. 2021;6(5):1299-1304.

32. Schifman RB, Howanitz PJ, Souers RJ. Point-of-care glucose critical values: A Q-Probes study involving 50 health care facilities and 2349 critical results. *Arch Pathol Lab Med*. 2016;140(2):119-124.

33. Stanford Healthcare. Critical values: Virology. March 22, 2022. Accessed April 18, 2023. https://stanfordlab.com/test-directory/critical-values.html.

34. Staats PN, Parkash V, Otis CN, Sharma P, Ioffe O, Bracamonte ER. The current state of communication of urgent and significant, unexpected diagnoses in anatomic pathology. *Arch Pathol Lab Med*. 2020;144(9):1067-1074.

35. Dighe AS, Jones JB, Parham S, Lewandrowski KB. Survey of critical value reporting and reduction of false-positive critical value results. *Arch Pathol Lab Med*. 2008;132(10):1666-1671.

36. Kost GJ. The Coronavirus Disease 2019 spatial care path: Home, community, and emergency diagnostic portals. *Diagnostics*. 2022;12(5):1216, 1-16.

37. Kost GJ. Diagnostic strategies for endemic Coronavirus Disease 2019 (COVID-19). *Arch Pathol Lab Med*. 2022;146(1):16-25.

38. Lehman CM, Howanitz PJ, Souers R, Karcher DS. Utility of repeat testing of critical values: a Q-probes analysis of 86 clinical laboratories. *Arch Pathol Lab Med*. 2014;138(6):788-793.

39. Sun SP, Garcia J, Hayden JA. Repeat critical hematology and coagulation values wastes resources, lengthens turnaround time, and delays clinical action. *Am J Clin Path*. 2018;149(3);247-252.

40. Kost GJ. *The Critical Human: A Prospectus*. Davis, California. Knowledge Optimization, 2023.