



Blood Gas and Electrolytes *Reference ranges and critical values*



Reference ranges and critical values

Introduction

Monitoring the changes in blood gases and electrolytes in acutely ill patients is one of the key responsibilities of the perioperative practitioners to assess patient's condition to optimize the therapeutic response and modify the treatment if needed.¹

Blood gas analysis is an important tool in ICUs to monitor the acid base balance of patients and effectiveness of gas exchange.² Available information is critical for timely diagnosis of metabolic and respiratory disorders. In addition to blood gases, the electrolytes are also critically important in the management of acutely ill patients. This is because the majority of metabolic processes are mediated by electrolytes and any changes in electrolyte concentration may be a sign of a variety of disorders which must be addressed without delay.

Reference ranges in diagnostics represents the characteristic of 95 percent of values from a normal population.³ They are generally established by taking either the lowest and highest values (range) of results obtained on a normal population and should be distinguished from clinical decision limits that are derived from known diseased patients.³ The normal range for a particular test result may differ depending on the test method or technology used in the measurement, circadian rhythm of the target analyte, patient's age, smoking status, body mass index, gender, race, ethnicity, eating habits or even season.⁴⁻⁶

Critical value, also known as panic or alert values is laboratory results that indicate a life threatening situation for the patient.³ Because of their critical nature, urgent notification of a healthcare professional is necessary.⁶

Critical value reporting is required by a variety of laws and accreditation programs. Additional local regulations regarding the critical value reporting may also exist and should be implemented accordingly by each laboratory and hospital.⁶ At a global level, the International Organization for Standardization (ISO) describes the requirements for quality and competence in medical laboratories.⁷ At a country level, the College of American Pathologists checklist (component GEN.41330) specifies what information must be documented during critical value notifications and CLIA '88 defines the requirements on critical value reporting.⁶ A laboratory manual is also required and must address critical values along with protocols for reporting the critical value results.⁶ In general, critical value for diagnostic test results should be strictly defined and implemented by hospital laboratories for their own population.⁸

Limitations

The aim of this brochure is to provide a quick guide to healthcare professionals regarding reference intervals and values published in standard clinical chemistry and laboratory textbooks. However, this brochure should be used for information purposes only as the actual reference range values may vary due to differences in assay methodologies, sample type, assay standardization, local population characteristics, assay units used for reporting, and a variety of other circumstances.⁹

Institutions should always set up their own reference ranges and critical values based on the particular population that they serve, thus regional differences may occur. Consequently, values reported by individual laboratories may differ from those listed in this brochure.

Reference Intervals and Values

Analyte	Sample matrix	Reference Intervals and values	
CO Hb (%) Carboxyhemoglobin ^{10,11}	Whole blood	Non Smoker	≤3% (Fraction ≤0.03)
		Smoker	≤10% (Fraction ≤0.10) 0.005 – 0.015
MetHb (% of total Hb) Methemoglobin ³	Whole blood (EDTA, Heparin or ACD)		0.04 – 1.52% 0.0004 – 0.0152
O₂Hb (%) fractional Oxyhemoglobin ³	Blood		90 – 95% 0.90 – 0.95
sO₂(%) Oxygen, saturation ³	Whole blood (Arterial)	Newborn	40 – 90% 0.40 – 0.90
		Thereafter	94 – 98% 0.94 – 0.98
HHb (%) Deoxyhemoglobin ¹³	Whole blood (Heparin)		<3%
tHb (g/dL) Hemoglobin ¹⁰	Capillary blood (Heparin)	In Pregnancy Fetus*	Week 15: 10.9 ± 0.7 g/dL Week 16: 12.5 ± 0.8 g/dL Week 17: 12.4 ± 0.9 g/dL Weeks 18 – 21: 11.7 ± 1.3 g/dL Weeks 22 – 25: 12.2 ± 1.6 g/dL Weeks 26 – 29: 12.9 ± 1.4 g/dL Weeks >30: 13.62 ± 2.2 g/dL
		Children**	Cord blood: 13.5 – 20.7 g/dL Day 1: 15.2 – 23.5 g/dL Days 2 – 6: 15 – 24.0 g/dL Days 14 – 23: 12.7 – 18.7 g/dL Days 24 – 37: 10.3 – 17.9 g/dL Days 40 – 50: 9.0 – 16.6 g/dL 2 to 2.5 months: 9.2 – 15.0 g/dL 3 to 5 months: 9.6 – 12.8 g/dL 5 to 7 months: 10.1 – 12.9 g/dL 8 to 10 months: 10.5 – 12.9 g/dL 11 to 13.5 months: 10.7 – 13.0 g/dL 1.5 to 3 years: 10.8 – 12.8 g/dL 5 years: 11.1 – 14.3 g/dL 10 years: 11.9 – 14.7 g/dL 12 years: 11.8 – 15.0 g/dL 15 years: 12.8 – 16.8 g/dL
		Adults***	Male: 13.5 – 17.8 g/dL Female: 11.5 – 16.0 g/dL Values may be slightly decreased in the elderly
		Conversion of units (tHb)	tHb (mmol/L) = 0.62058 × tHb (g/dL) tHb (g/L) = 16.1140 × tHb (mmol/L)
tBil (µmol/L) Bilirubin Total ³	Serum		Cord (premature): <34.2 µmol/L Cord (full term): <34.2 µmol/L 0 – 1 day (premature): 17 – 187 µmol/L 0 – 1 day (full term): 34 – 103 µmol/L 1 – 2 days (premature): 103 – 205 µmol/L 1 – 2 days (full term): 103 – 171 µmol/L 3 – 5 days (premature): 171 – 240 µmol/L 3 – 5 days (full term): 68 – 137 µmol/L Adults: 0 – 34 µmol/L
		Conversion of units (Bil)	tBil (mg/dL) = 0.0585 × tBil (µmol/L) tBil (mg/L) = 0.585 × tBil (µmol/L)

*depicts $\bar{x} \pm 1s$, ** depict $\bar{x} \pm 2s$, *** central 95% confidence interval,

Reference Intervals and Values

Analyte	Sample matrix	Reference Intervals and values			
pH (37°C)³	Whole blood (Arterial)	Cord blood	Arterial: 7.18 – 7.38 Venous: 7.25 – 7.45		
		Newborn premature	48 hours: 7.35 – 7.50		
		Newborn full term	Birth: 7.11 – 7.36		
			5 – 10 minutes: 7.09 – 7.30		
			30 minutes: 7.21 – 7.38		
			1 hours: 7.26 – 7.49		
		1 day: 7.29 – 7.45			
		Children, Adults	Arterial: 7.37 – 7.45 Venous: 7.32 – 7.43		
		Adults	60 – 90 years: 7.31 – 7.42 >90 years: 7.26 – 7.43		
		pCO₂ (mmHg) Partial pressure of carbon dioxide³	Whole blood, Arterial (Heparin)	Newborn	27 – 40 mmHg
Infant	27 – 41 mmHg				
Male adults	35 – 48 mmHg				
Female adults	32 – 45 mmHg				
Conversion of units (pCO ₂)	pCO ₂ (kPa) = 0.133322 × pCO ₂ (mmHg)				
pO₂ (mmHg) Oxygen, partial pressure³	Cord blood			Arterial: 5.7 – 30.5 mmHg	
		Venous: 17.4 – 41.0 mmHg			
	Whole blood (Arterial)	Newborn	Birth: 8 – 24 mmHg 5 – 10 minutes: 33 – 75 mmHg 30 minutes: 31 – 85 mmHg 1 hour: 55 – 80 mmHg 1 day: 54 – 95 mmHg		
		Children, Adults	2 days – 60 years: 83 – 108 mmHg		
		Adults	>60 years: >80 mmHg >70 years: >70 mmHg >80 years: >60 mmHg >90 years: >50 mmHg		
		Conversion of units (pO ₂)	pO ₂ (kPa) = 0.133322 × pO ₂ (mmHg)		
		Sodium (mmol/L) Na^{3,11}	Serum or plasma	Premature	Cord: 116 – 140 mmol/L 48 hours: 128 – 148 mmol/L
	Newborn			133 – 146 mmol/L	
	Infant			Cord: 126 – 166 mmol/L 139 – 146 mmol/L	
	Child			138 – 145 mmol/L	
Adult	136 – 145 mmol/L				
>90 years:	132 – 146 mmol/L				
Potassium (mmol/L) K³	Serum			Premature	Cord: 5 – 10.2 mmol/L 48 hours: 3 – 6 mmol/L
				Newborn	Cord: 5.6 – 12 mmol/L 3.7 – 5.9 mmol/L
		Infant	4.1 – 5.3 mmol/L		
		Child	3.4 – 4.7 mmol/L		
		Adults	3.5 – 5.1 mmol/L		
		Conversion of units (K)	mmol/L = meq/L		
Calcium, ionized (free)³	Serum or Plasma (Heparin)	Adults	1.15 – 1.33 mmol/L 4.6 – 5.3 mg/dL 2.33 – 2.66 meq/L		
		Conversion of units (Ca)	meq/L = 2 mmol/L mg/dL = 4.008 mmol/L		
		Chloride (mmol/L) Cl³	Plasma	Cord	96 – 104 mmol/L
Premature	95 – 110 mmol/L				
0 – 30 days	98 – 113 mmol/L				
Adult	98 – 107 mmol/L				
>90 years:	98 – 111 mmol/L				
Conversion of units (Cl)	mmol/L = meq/L				

Analyte	Sample matrix	Reference Intervals and values			
Hematocrit (%) ¹⁰	Whole blood	Adults	Caucasian Female: 42 (36–48)% Caucasian Male: 46 (40–53)% Black Female: 38 (34–43)% Black Male: 41 (34–48)% Athletes Female: 41 (37–45)% Athletes Male: 45 (40–50)% <i>depicts $\bar{x} \pm 2s$ or in blacks area between 5–95% percentile</i>		
		In Pregnancy Fetus	Week 15: 28–42% Week 16: 34–42% Week 17: 31–43% Weeks 18–21: 31–45% Weeks 22–25: 31–47% Weeks 26–29: 32–50% Weeks ≥ 30 : 30–58%		
		Cord blood	48–56%		
		Venous blood After Delivery	2 hours after delivery: 49–71% 6 hours after delivery: 44–68%		
		Children	2–6 days: 40–70% 1–2 weeks: 38–70% 2–3 weeks: 38–60% 3–7 weeks: 36–46% 7–12 weeks: 30–38% 10–12 months: 35–43% 4–5 years: 32–40% 6–8 years: 32–41% 10–13 years: 34–44%		
		14–16 years	Females: 35–43% Males: 38–49% <i>depicts $\bar{x} \pm 2s$ or central 95% mass</i>		
		Glucose (mmol/L) ³	Serum, fasting	Cord	2.5–5.3 mmol/L
				Premature	1.1–3.3 mmol/L
				Neonate	1.7–3.3 mmol/L
				Newborn	1 day: 2.2–3.3 mmol/L >1 day: 2.8–4.5 mmol/L
Child	3.3–5.6 mmol/L				
Adult	4.1–5.6 mmol/L >60 years: 4.6–6.4 mmol/L >90 years: 4.2–6.7 mmol/L				
Whole blood (Heparin)	Adult			3.5–5.3 mmol/L	
Conversion of units (Glu)	mmol/L = meq/L				
L-Lactate (mmol/L) ³	Whole blood (Heparin)			At bed rest	Venous: 0.56–1.39 mmol/L Arterial: 0.36–0.75 mmol/L
				Conversion of units (Lac)	L-Lactate (mg/dL) = 9.008 × L-Lactate (mmol/L)
Urea nitrogen (mmol/L) ³	Serum	Cord	7.5–14.3 mmol/L		
		Premature (1 week)	1.1–8.9 mmol/L		
		Newborn	1.4–4.3 mmol/L		
		Infant/child	1.8–6.4 mmol/L		
		Adult	2.1–7.1 mmol/L >60 years: 2.9–8.2 mmol/L		

Critical values

Test	Sample matrix	Critical values	
CO Hb (%) Carboxyhemoglobin ¹⁰	Whole Blood (Heparin)	0 – 10 % (Fraction: 0 – 0.10)	No major complaints (smokers)
		10 – 15 % (Fraction: 0.10 – 0.15)	No major complaints. Possibly shortness of breath during physical exertion (heavy smokers)
		15 – 25 % (Fraction: 0.15 – 0.25)	At rest mostly no effect, shortness of breath during physical exertion, possibly dizziness and headache, expansion of the skin capillaries
		25 – 35 % (Fraction: 0.25 – 0.35)	Headache, dizziness, vomiting, rapid pulse, irritability, loss of judgment occur, easy fatigability, blurred vision
		35 – 45 % (Fraction: 0.35 – 0.45)	Similar to 25 – 35 %, but intensification, in addition confusion, paralysis, fainting with minor exertion
		45 – 55 % (Fraction: 0.45 – 0.55)	Restriction up to loss of consciousness, increase of respiratory and heart rate, collapse, death risk with prolonged exposure
		55 – 65 % (Fraction: 0.55 – 0.65)	Cause convulsions, respiratory paralysis
Met Hb (%) Methemoglobin ¹⁰	Whole blood (EDTA, Heparin or ACD)	>65 % (Fraction: >0.65)	Immediate threat of death
		<15 % (Fraction: <0.15)	Usually asymptomatic
		15 – 20 % (Fraction: 0.15 – 0.20)	Cyanosis, headache, dizziness
		20 – 45 % (Fraction: 0.20 – 0.45)	Significant cyanosis, nausea
		45 – 70 % (Fraction: 0.45 – 0.70):	Severe cyanosis, vomiting, confusion, seizures
		>70 % (Fraction: >0.70)	Lethal level
sO₂(%) Oxygen, saturation ¹⁴ Hb (g/dL) Hemoglobin ³	Whole blood (Arterial)	<90 % (Fraction: <0.90)	
		Newborn	Lower limit: 10 g/dL Upper limit: 22 g/dL
		Adults	Lower limit: 7 g/dL Upper limit: 20 g/dL
		Conversion of units (Hb)	mmol/L = 0.62058 × Hb (g/dL)
Bilirubin (mg/dL) Total ¹⁵	Serum	Newborn	Lower limit: - Upper limit: >15 mg/dL
		Adults	Lower limit: - Upper limit: >12 mg/dL
		Conversion of units (Bil)	Bil (µmol/L) = 1.71 × Bil (mg/L) Bil (mg/L) = 0.585 × Bil (µmol/L)

Test	Sample matrix	Critical values
pH ³	Arterial, capillary	Lower limit: 7.2 Upper limit: 7.6
pCO₂ (mmHg) ³	Arterial, capillary	Lower limit: 20 mmHg Upper limit: 70 mmHg
		Conversion of units (pCO ₂) $pCO_2(kPa) = 0.133322 \times pCO_2 (mmHg)$
pO₂ (mmHg) ³	Arterial	Lower limit: 40 mmHg Upper limit: -
		Conversion of units (pO ₂) $pO_2(kPa) = 0.133322 \times pO_2 (mmHg)$
Sodium (mmol/L) ³	Serum or plasma	Lower limit: 120 mmol/L Upper limit: 160 mmol/L
Potassium (mmol/L) ³	Serum or plasma	Lower limit: 2.8 mmol/L Upper limit: 6.2 mmol/L
Ionized Calcium (mmol/L) ³	Plasma	Lower limit: 0.75 mmol/L Upper limit: 1.6 mmol/L
Chloride (mmol/L) ³	Serum or plasma	Lower limit: 80 mmol/L Upper limit: 120 mmol/L
Hematocrit (%) ³	First report only	Adults Lower limit: 20 % Upper limit: 60 % Newborn Lower limit: 33 % Upper limit: 71 %
Glucose (mg/dL) ³	Serum or plasma	Lower limit: 40 mg/dL Upper limit: 450 mg/dL Children Lower limit: 46 mg/dL Upper limit: 445 mg/dL Newborn Lower limit: 30 mg/dL Upper limit: 325 mg/dL Conversion of units (Glu) $Glucose (mg/dL) = 18.016 \times Glucose (mmol/L)$
L-Lactate (mmol/L) ³	Whole blood (Heparin)	Lower limit: - Upper limit: 3.4 mmol/L Children Lower limit: - Upper limit: 4.1 mmol/L Conversion of units (Lac) $L-Lactate (mg/dL) = 9.008 \times L-Lactate (mmol/L)$
Urea Nitrogen ³	Serum or plasma	Lower limit: - Upper limit: 80 mg/dL Children Lower limit: - Upper limit: 55 mg/dL

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