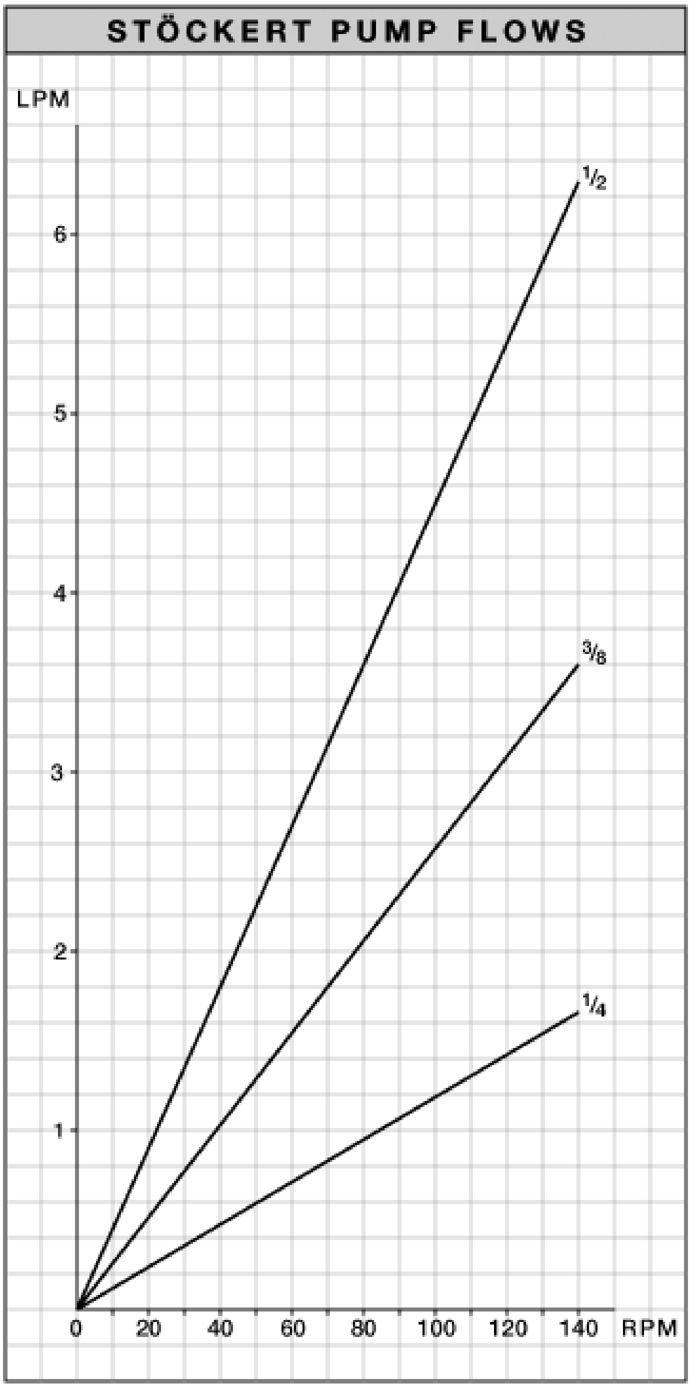
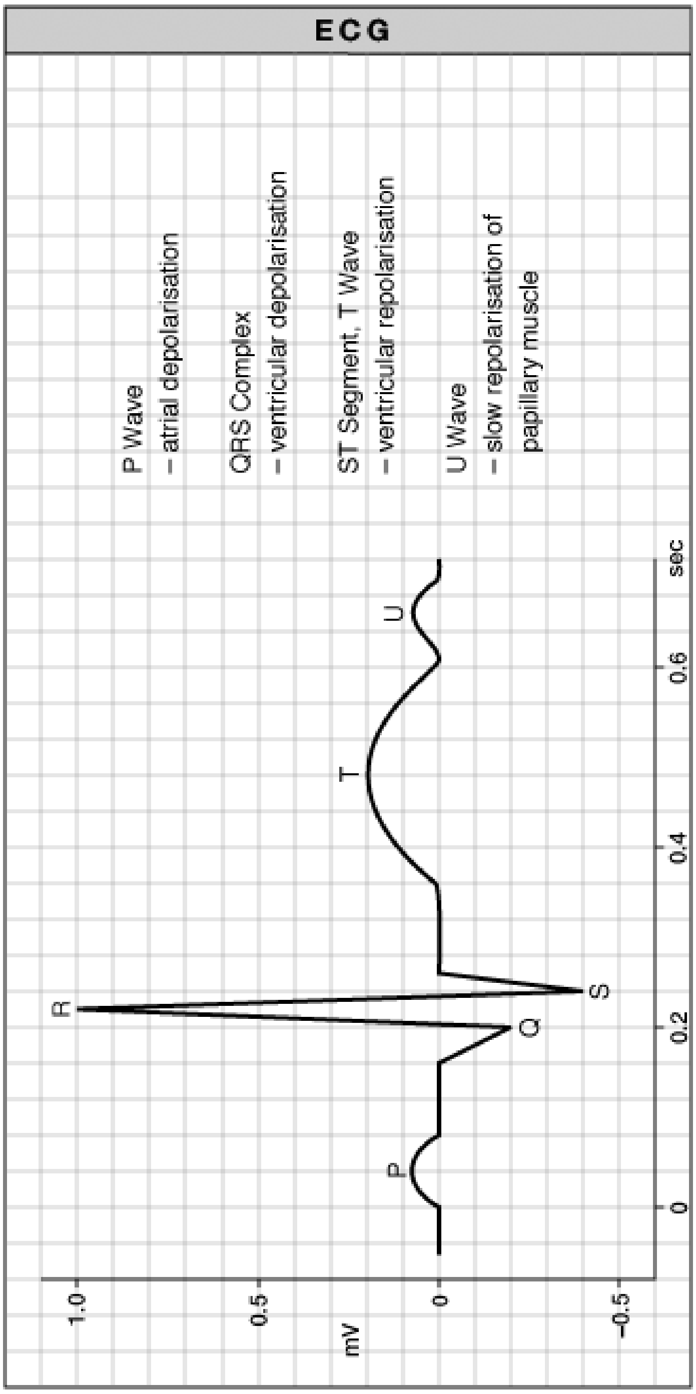
Clinical Data





Distribution of Cardiac Output to Body Organs

	Average wt (kg)	*% body weight*	*Blood flow (ml/min)*	*% Cardiac output*	*O_2 consumption (ml/min/organ)*
Brain	1.4	2.00	775	15.0	46
Heart	0.3	0.43	175	3.3	23
Kidneys	0.3	0.43	1100	23.0	18
Liver	1.5	2.10	1400	29.0	66
Lungs	1.0	1.50	175	3.5	5
Muscle	27.8	39.70	1000	19.0	64
Rest	38.7	55.34	375	9.7	33

Adult-Neonatal Cardiac Comparison:

	Adult	*Neonate*
Cardiac output	5 l/min	900 ml/min
O_2 consumption (ml/kg/min)	3.5	7.0
Blood pressure (mmHg)	120	45–75

Cardiovascular Pressures

	Systolic (mmHg)	*Diastolic (mmHg)*	*Mean (mmHg)*
Peripheral venous	—	—	6–12
Right atrium (CVP)	—	—	0–7
Right ventricle	14–32	0–7	12–17
Pulmonary artery	14–32	2–13	8–19
Wedge or left atrium	—	—	6–12
Left ventricle	100–150	2–12	—
Arterial	100–150	60–90	80–100

Oxygen Transfer Rate

O_2 Transfer Rate =
(ART.SAT. –VEN.SAT.) x Hb x 0.134 x FLOW

O_2 Transfer Rate	– mls/min
Hb	– gms/100ml
FLOW (Arterial Pump	– L.P.M.

O_2 Consumption at rest at Normothermia
140mls/min/m^2 (Adult Male)
decreases by 8% per °C cooling.

Haematological Values

Parameters		*Male*	*Female*
WBC	10^9/l	4.0–11.0	
RBC	10^{12}/l	4.5–6.5	3.8–5.8
Hb	g/dl	13.0–18.0	11.5–16.5
HCT	%	0.40–0.54	0.37–0.47
MCV	fl	79–96	
MCH	pg	27–32	
MCHC	g/dl	31.5–36.0	
PLT	10^9/l	150–400	
MPV	fl	7.4–10.4	
NEUTROPHILS	2.5–7.5 x 10^9/l		
LYMPHOCYTES	1.5–3.6 x 10^9/l		
MONOCYTES	0.2–0.8 x 10^9/l		
EOSINOPHILS	0.04–0.4 x 10^9/l		

Clinical Biochemistry Values

CALCIUM (IONISED)	1–1.25 mmol/l
CHLORIDE	95–105 mmol/l
CREATININE	40–120 µmol/l
GLUCOSE	2.5–5.5 mmol/l
FIBRINOGENClinical Biochemistry Values	
CALCIUM (IONISED)	1–1.25 mmol/l
CHLORIDE	95–105 mmol/l
CREATININE	40–120 µmol/l
GLUCOSE	2.5–5.5 mmol/l
FIBRINOGEN	2.0–5.0 g/l
FOLATE	3–20 g/l
LACTATE	0.7–2.0 mmol/l
MAGNESIUM	0.7–1.00 mmol/l
OSMOLAITY	280-295 mosmol/kg
POTASSIUM	3.5–5.0 mmol/l
SODIUM	135–145 mmol/l
UREA	3.3–6.7 mmol/l
uH	36–44 nmol/l (7.35–7.45)

SI Units

In 1960 at the Conference Générale des Poids et Mésures in France, the international units were formulated to standardize methods of denoting units and decimal points.
This was enlarged and developed into the Systeme International d'Unites (SI Units) and came into force in the United Kingdom on 1st October 1975.
The following list gives the basic SI units and their derivations, together with their recognised abbreviations. The letters l, m, t denote the basic concept of Length, Mass, Time from which the definitions of the derived units can be obtained.

e.g. Force can be represented as $\frac{\text{Mass x Length}}{\text{Time}^2}$

or Mass x Acceleration

Metre	m	unit of length (l)
Kilogram	kg	unit of mass (m)
Second	s	unit of time (t)
Kelvin	K	unit of temperature
Candela	cd	unit of light
Decibel	db	unit of sound – 1 decibel = 1/10 bel
Ampere	A	unit of electrical current = 2 x 10^{-7} Newton/metre
Hertz	Hz	unit of frequency per second
Mole	mol	unit of amount of substance in grams
Newton	N	unit of force which gives 1 kilogram mass an acceleration of 1 metre per second^2 (mlt^{-2}) = Joule/metre
Pascal	Pa	unit of pressure force per unit area ($ml^{-1}\ t^{-2}$) = 1 Newton/metre^2
Joule	J	unit of energy or work force through a distance ($ml^2\ t^{-2}$) = 1 Newton metre
Watt	W	unit of power energy per second ($ml^2\ t^{-3}$) = 1 Newton metre/second = Joule/ second
Coulomb	C	unit of quantity of = 1 Ampere second electricity
Volt	V	unit of electrical potential = ($ml^2\ t^{-3}A^{-1}$) = $\frac{\text{1 Watt}}{\text{1 Ampere}}$ = $\frac{\text{1 Joule}}{\text{1 Ampere. second}}$
Ohm	Ω	unit of electrical resistance = ($ml^2\ t^{-3}A^{-2}$) = $\frac{\text{1 Volt}}{\text{1 Ampere}}$

SI fractions or multiples

10^{18}	exa	E	10^{-18}	atto	a
10^{15}	peta	P	10^{-15}	femto	f
10^{12}	tera	T	10^{-12}	pico	p
10^{9}	giga	G	10^{-9}	nano	p
10^{6}	mega	M	10^{-6}	micro	µ
10^{3}	kilo	k(K)	10^{-3}	milli	m
10^{1}	deca	da(D)	10^{-1}	deci	d

Area

1 mm^2	= 0.00155 in^2
1 m^2	= 10.764 ft^2
1 m^2	= 1.1960 yd^2
10000 m^2	= 1 hectare = 2.4711 acres
1 km^2	= 100 hectares = 0.3861 $miles^2$
4046.86 m^3	= 1 acre = 4840 yd^2
1 in^2	= 645.16 mm^2
1 ft^2	= 144 in^2 = 0.0929 m^2
1 yd^2	= 9 ft^2 = 0.8361 m^2
1 $mile^2$	= 2.5899 km^2

Volume

1 litre (l)	= 1 dm^3
1000 ml	= 0.03531 ft^3
1 m3	= 1.3080 yd^3
1 l	= 0.22 gallons
1 ml	= 16.9 minims
1 l	= 1.76 pints
1 ml	= 0.282 fluid drachm
1 fluid drachm	= 3.55 ml
1 ml	= 0.0352 fluid oz
1 fluid oz	= 28.42 ml
1 in^3	= 16.387 cm^3
1 ft^3 = 1728 in^3	= 0.028317 m^3 = 28.317 litres
1 yd^3 = 27 ft^3	= 0.7646 m^3
1 gallon (UK)	= 4.5461
1 minim	= 0.0592 ml
1 pint	= 0.5683l = 20 fluid oz
1 teaspoon	= 4.5 ml (approx.)
1 tablespoon	= 15 ml (approx.)
1 teacup	= 120 ml (approx.)
1 dessertspoon	= 8 ml (approx.)
1 wine glass	= 60 ml (approx.)
1 tumbler glass	= 240 ml (approx.)

Speed

1 km/h	= 0.2778 m/s
1 knot	= 1.852 km/h = 1.6 mph
1 km/h	= 0.625 mph
1 m/s	= 3.6 km/h
1 mph	= 1.6 km/h

Pressure

1 mmHg	= 1.36 cmH_2O = 133.3 N/m^2 = 0.0194 psi = 0.133 kPa
1 cmH_2O	= 98.06 N/m^2 = 0.09806 kPa
1 psi	= 0.070 kg/cm^2 = 51.7 mmHg = 70.3 cmH_2O = 6894.76 N/m^2 = 6.895 kPa
1 atmosphere absolute	= 760 mmHg = 14.7 psi = 29.9 inHg = 1.03 kg/cm^2
	= 1.0133 x 10^5 N/m^2 = 101.33 kPa = 1035 cmH_2O
	= 1 bar = 1000 millibars
1 kPa	= 0.146 psi = 1.0 x 10^3 N/m^2

Work/Energy

1 Joule (J)	= 1 Nm
1 J	= 10^7 ergs = 0.239 calories (cal)
1 cal	= 4.1868 J
1 BTU	= 1055 J
1 kilowatt hour (kwh)	= 3.6 x 10^5 J

Power

1 Watt	= 1 Newton metre/second = 1 J/s
1 horse power	= 746 Watts = 550 foot pound/second = 746 Nm/s
1 metre kg/sec	= 9.81 Watts = 9.81 Nm/s

Force

1 Newton (N)	= 10^5 dynes
1 kilogram force (kgf)	= 9.807 N
1 pound force (lbf)	= 4.44 N

Conversion tables for physical units

1 mm	= 0.0394 inches
1 metre	= 1.0936 yards (yd)
1 km	= 0.6214 miles
1 Angstrom (Å)	= 10^{-1} nanometres (nm)
1 inch (in)	= 25.4 mm
1 foot (ft)	= 304.8 mm
1 yard (yd)	= 0.9144 m
1 mile	= 1.6093 km
1 nautical mile	= 1.852 km

Weight

1g	= 0.0353 oz
1 kg	= 2.2046 lb
1000 kg	= 0.9842 tons
1 mg	= 0.0167 grains
1 kg	= 0.1575 stones
1 tonne (t)	= 1000 kg
1 ounce	= 0.4725 grains = 0.02835 kg
1 pound (lb)	= 0.4536 kg
1 ton	= 2240 lb = 1016.06 kg
1 grain	= 64.79 mg
1 stone	= 6.35 kg
1 cwt	= 112 lb = 50.8 kg

Temperature

O Kelvin (K)	= –273°C (Absolute zero)	
273.15K	= 0°C = 32°F	°C = (°F –32) x 5/9
373.16K	= 100°C = 212°F	°F = (°C x 9/5) + 32

°C	*°F*	*°C*	*°F*
30	86.0	36	96.8
31	87.8	37	98.6
32	89.6	38	100.4
33	91.4	39	102.2
34	93.2	40	104.0
35	95.0	41	105.8

Atoms, molecules and electrolytes

Milligrams to Millmole to Milliequivalent Conversion Equations

Milliequivalents/l

$$= \frac{\text{mg\% x 10 x valency}}{\text{molecular weight}} = \text{millimole/l x valency}$$

Milligrams %

$$= \frac{\text{mEq/l x mol. wt}}{\text{10 x valency}} = \frac{\text{millimoles/l x mol. wt}}{10}$$

Millimoles/l

$$= \frac{\text{10 x mg \%}}{\text{mol. wt}} = \frac{\text{mEq/l}}{\text{valency}}$$

Commonly Used Formulas for Perfusionists

Oxygen Transfer or Oxygen Consumption (mL/min

(a) When venous blood gas values are available:
$VO_2 = [(1.39 \text{ x Hgb x } (SaO_2–SvO_2)) + (.0031 \text{ x } (PaO_2– PvO_2))] \text{ x Qb x } 10$

(b) When only venous saturation is available:
$VO_2 = 1.39 \text{ x Hgb x } (SaO_2–SvO_2) \text{ x Qb x } 10$

Shunt Fraction ($\dot{Q}s/\dot{Q}t$):

Percent of blood which enters the arterial system but did not undergo gas exchange

$$\frac{\dot{Q}s}{\dot{Q}t} = \frac{PAO_2 – PaO_2)\ (0.003)}{(CaO_2 – CvO_2) + (PAO_2 – PaO_2)\ (0.003)}$$

where $PaO_2 = P_{ATM} \text{ x } FiO_2$

Normal Oxygen Consumption

(mL/min/m²)		
	25°C	29–34
	30°C	43–50
	34°C	69–78
	37°C	88–100

Heat Transfer Coefficient

$$\frac{\text{Temp. Blood}_{out} – \text{Temp. Blood}_{in}}{\text{Temp. Water}_{in} – \text{Temp. Blood}_{in}} = \text{efficiency factor}$$

1.667 gm/dL Hemoglobin = 1.00 mmolL Hemoglobin

Conversion Factors

Length	1 in = 2.54 cm	1 cm = .3937 in
Weight	1 lb = 0.45 kg	1 kg = 2.2 lbs
Temperature	°F = °C x 9/5 + 32	°C = (°F –32) x 5/9

Pressure

1 mmHG = 1.36 H_2O = 0.019 psi = 0.132 Kilo Pascal

1 psi = 51.70 mmHg = 70.34 H_2O

1 kilo Pascal = 7.5 mmHg

1 cm H_2O = 0.0142 psi = 0.735 mmHg

1 atm = 760 mmHg = 1,034 cm H_2O = 14.7 psi = 29.9 inHg

Activated Clotting Time (ACT)*:

Pre-heparinization	approx. 100–120 sec
On bypass	> 480 seconds

**values may vary with different techniques*

Acid – Base Regulatory Strategies

Aim	pH STAT constant pH	ALPHA STAT constant $OH^–/H^+$
Total CO_2 Content	increases	constant
pH and $PaCO_2$ Maintenance	normal (corrected values)	normal (uncorrected values)
Intracellular State	acidotic (excess H^+)	neutral ($H^+ = OH^–$)

pH Changes with Hypothermia

$$\Delta \text{ pH} = (\Delta°C) \text{ x } 0.0147$$

Cardiac Index (L/min/m² = Blood Flow Rate (L/min) + BSA (m²):

Perfusion Flow Rate	Adult	Infant
(mL/min/kg)	50–75	80–100
(mL/min/m²	2.2–2.4	2.8–3.0
Heparin Loading Dose	3 mg/kg	3 mg/kg

Body Surface Area (BSA) Formulas

Dubois Formula:

$$BSA = \frac{Wt^{.425} \text{ x } Ht^{.725} \text{ x } 71.84}{10{,}000}$$

Height in cm
Weight in kg
BSA in m²

Boyd Formula:

$$BSA = \frac{3.207 \text{ x } (Ht)^{.3} \text{ x } (Wt \text{ x } 1000)^{0.7285–0.0188 \text{ Log } (Wt \text{ x } 1000)}}{10{,}000}$$

Infant (Journal of Paediatric Research):

$BSA = Wt^{.5378} \text{ x } Ht^{.3964}) \text{ x } .024265$

Patient Blood Volume (PBV)

if pt. weight < 10 kg	PBV = 80 mL x wt (kg)
if pt. weight 10–20 kg	PBV = 75 mL x wt (kg)
if pt. weight > 20 kg	PBV = 70 mL x wt (kg)

Hemodilution

(a) System Volume = Prime Vol. + Pt Blood Volume (PBV)
(b) Red Cell Volume = PBV x Pre-op Hct
(c) On pump Hct = Red Cell Volume/System Volume

Peripheral Vascular Resistance (dyne-sec/cm⁵)

$$PVR = \frac{\text{Mean Arterial B.P. – Mean CVP}}{\text{Cardiac Output}} \text{ x } 79.92$$

Normal PVR during bypass = 1100 ± 200 dyne-sec/cm^5

Rate – Pressure Product (R.P.P.)

RPP = Systolic B.P. x Heart Rate

Normal RPP < 12,000

Triple Index (T.I.)

TI = Systolic B.P. x Heart Rate x Pul. Wedge Pressure

Normal TI < 150,000

Note above values are approximate

Acid-base balance during Cardiopulmonary bypass

Acid-Base Balance during cardiopulmonary bypass is determined by:

I The Adequacy of Cellular Metabolism

II The Adequacy of Gas Exchange

III Previous Acid-Base Balance of the Patient

IV Treatment of Acid Base Imbalance

During cardiopulmonary bypass, many factors tend to upset acid-base balance. If significant imbalance is allowed to occur, the resultant physiologic responses may cause irreparable damage during the bypass and make post-pump resuscitation difficult or impossible.

During the pump-run there is usually a tendancy towards metabolic acidosis and respiratory alkalosis. In general, low perfusion rates and perfusion times exceeding 1–2 hours tend to generate a metabolic acidosis. High gas flows in the oxygenator, lower perfusion rates, and low temperatures tend to produce respiratory alkalosis.

1. Cellular Metabolism During Cardiopulmonary Bypass is determined by:
   A. Oxygen demands of the tissue.
   B. Oxygen available in the blood.
   C. Adequacy of tissue perfusion.
   D. Changes in the body during C-P bypass.
   E. Changes in the blood.

Oxygen demands of the tissue are determined by (normal 200 mi – 250 ml O_2/ml)

1. temperature
2. activity
3. Basal oxygen requirement (BOR) may be determined by a factor of 4ml O_2 x pt. weight in kg. at 37°C (awake). The other method is 130 ml/m^2 of patient.

Venous PO_2 – 35–40

Causes of decreased PO_2:

1. Poor tissue perfusion (peripheral vasoconstriction due to shivering, cold, etc).
   (a) Patient needs to be warmed.
2. Decreased blood volume – give blood.
3. Decreased cardiac output:
   (a) Give blood for decreased blood volume.
   (b) Give drugs to strengthen myocardium.
4. Poor gaseous exchange:
   (a) Suction airway.
   (b) Give oxygen.

Metabolic Acidosis: pH & PCO_2

Low PCO_2 usually caused by hyperventilation which often accompanies metabolic acidosis as a compensatory mechanism.

Respiratory Acidosis: pH & PCO_2

1. Indicates poor lung exchange causing CO_2 retention.
2. CO_2 increases acidity of blood; forcing pH downward.
3. Causes of acidosis are different; and correcting them is different; however, Sodium bicarbonate may be given initially because acidosis is so detrimental to metabolism.
4. With repiratory acidosis, positive pressure must be used to help patient blow off the CO_2.

Metabolic Alkalosis: pH & PCO_2

Etiology is NOT related to gaseous exhange in the lungs. This time the lungs are attempting to correct pH by retaining CO_2.

A patient may have metabolic alkalosis because of excessive treatment with alkaline salts, perlonged vomiting or postasium depletion.

Respiratory Alkalosis: pH & PCO_2

As with respiratory aciodsis, etiology is interference with gaseous exchange. Something is causing hyperventilation such as atalectasis or pneumothorax.

Acid-Base Parameters

All normal values refer to 37°C temperature

	Arterial	*Venous*
pH	7.35–7.45	7.32–7.42
PCO_2	35–45 mmHg	41–51 mmHg
Actual bicarbonate (plasma HCO_3^-)	22–26 mmol/L	24–28 mmol/L
CO2 content (plasma TCO_2)	23–27 mmol/L	25–29 mmol/L
Standard bicarbonate (plasma SBC)	22–26 mmol/L	
Bufter bases (whole blood BB)	46–54 mmol/L	44–52 mmol/L
Base excess (whole blood BE_b)	O ± 2	
pO_2 (young adults)	80–90 mmHg	20–40 mmHg
PO_2 (past age 65)	75–85 mmHg	
PO_2 (newborns)	60–70 mmHg	
O_2Hb	96–97%	40–70%
O_2 content (men)	17.5–23 vol%	
O_2 content (women)	16–21.5 vol%	
P_{50}	26.8 mmHg	
THb (men)	13.5–18.0 g/dl	
THb (women)	12.0–16.0 g/dl	
COHb (nonsmokers)	< 1.5%	
COHb (smokers)	1.5–5.0%	
MetHb	0.4–1.5%	
Hematocrit (adult males)	41–53%	
Hematocrit (adult females)	36–46%	
Plasma sodium	136–146 mmol/L	
Urinary sodium	40–220 mmol/24 h *	
Plasma potassium	3.5–5.1 mmol/L	
Urinary potassium	25–125 mmol/24 h *	
Plasma chloride	98–106 mmol/L	
Urinary chloride	110–250 mmol/24 h *	
Free plasma calcium	1.18–1.35 mmol/L	

** Subject to wide variation with diet*

Symbols

pO_2	=	partial oxygen pressure
pAO_2	=	partial oxygen pressure in alveolar air
paO_2	=	partial oxygen pressure in arterial blood
pvO_2	=	partial oxygen pressure in mixed venous blood

1 mmHg	=	0.133 KPa (SI units)
1 KPa	=	7.5 mmHg

CaO_2	=	total oxygen content in arterial blood
CcO_2	=	total oxygen content in capillary blood
CvO_2	=	total oxygen content in mixed venous blood

P_{50}	=	partial oxygen pressure at which hemo-globin shows 50% oxygen saturation
% sO_2c	=	per cent oxygen saturation of hemo-globin (calculated)
FIO_2	=	fraction of inspired oxygen
R	=	respiratory quotient (normally = 0.8)

Pressure Conversion

mmHg	*kPa*	*mmHg*	*kPa*
1	0.132	204.1	27
7.6	1	211.7	28
15.1	2	219.2	29
22.7	3	226.8	30
30.2	4	234.4	31
38	5	241.9	32
45.4	6	249.5	33
53	7	257	34
60.5	8	264.6	35
68	9	272.2	36
75.6	10	279.7	37
83.2	11	287.3	38
90.7	12	294.8	39
98.3	13	302.4	40
105.8	14	310	41
113.4	15	317.5	42
121	16	325	43
128.5	17	332.6	44
136	18	340.2	45
143.6	19	347.8	46
151.2	20	355.3	47
158.8	21	362.9	48
166.3	22	370.4	49
173.9	23	378	50
181.4	24	385.6	51
189	25	393.1	52
196.6	26		

Temperature Conversion

C°	F°	C°	F°
18	64.4	31	87.8
19	66.2	32	89.6
20	68.0	33	91.4
21	69.8	34	93.2
22	71.6	35	95.023
73.4	36	96.8	
24	75.2	37	98.6
25	77.0	38	100.4
26	78.8	39	102.2
27	80.6	40	104.0
28	82.4	41	105.8
29	84.2	42	107.6
30	86.0		

F°–C° Substract 32 and multiply by 0.55
C°–F° Multiply by 1.8 and add 32

Tubing Priming Volume

Internal Diameter (inches)	*Length (cm)*	*Volume (ml)*
1/16	100	10
1/4	100	28
3/8	100	68
1/2	100	110

Vasodilatation

$$R_S = \frac{P_{AO}}{Q_S}$$

R_S	=	Systemic Resistance
P_{AO}	=	Average Aortic Pressure (mmHg)
Q_S	=	Arterial Flow Rate (LPM)

Conversion

French	mm	French	mm
10	3.3	24	8.0
12	4.0	26	8.7
14	4.7	28	9.3
16	5.3	30	10.0
18	6.0	32	10.7
20	6.7	34	11.3
22	7.3	36	12.0

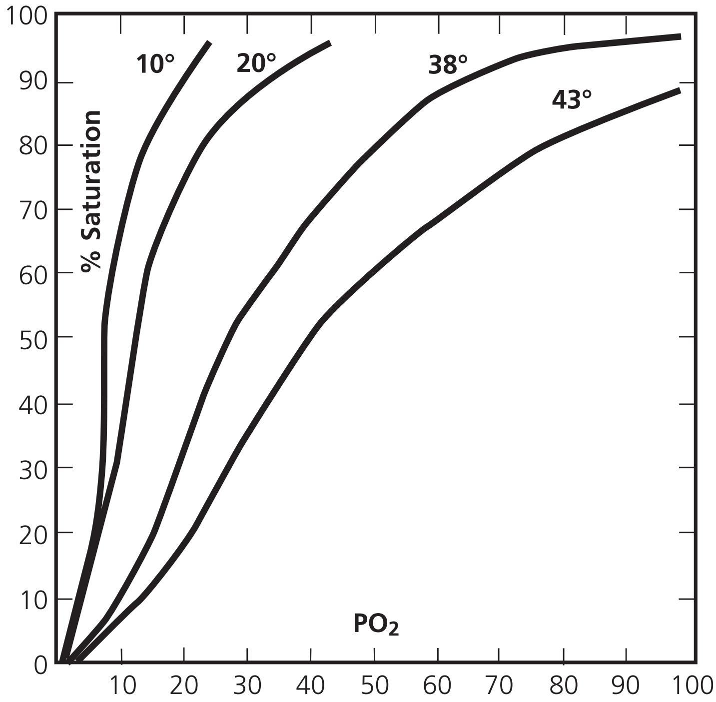
Conversion

Milligram (mg) – Milliequivalent (mEq)

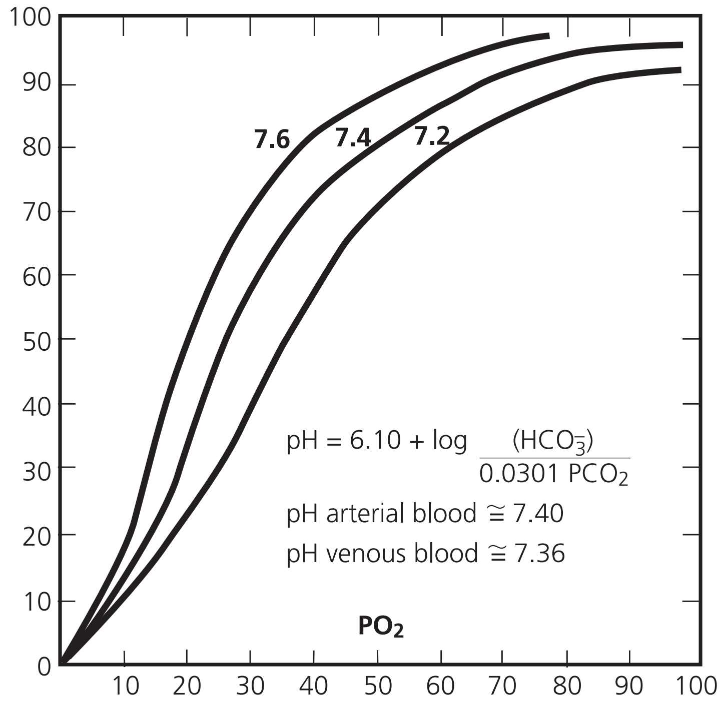
$$mEq/l = \frac{mg/100 \times 10 \times Valence}{Atomic\ Weight}$$

Element	*Atomic Weight*	*Valence*
Sodium (Na)	23	1
Potassium (K)	39	1
Calcium (Ca)	40	2
Chlorine (Cl)	35	1
Magnesium (Mg)	24	2
Phosphorus (P)	31	3
SO_4	32	2
HPO_4	31	1.8

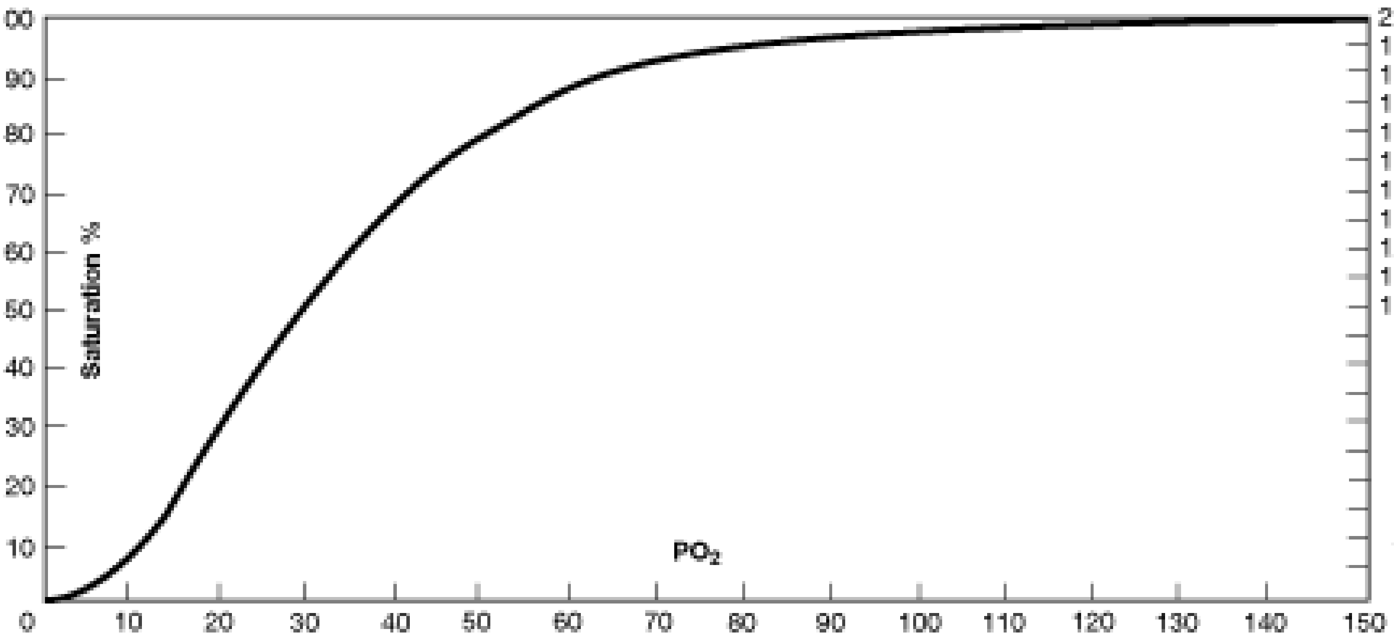
Effect of Temperature



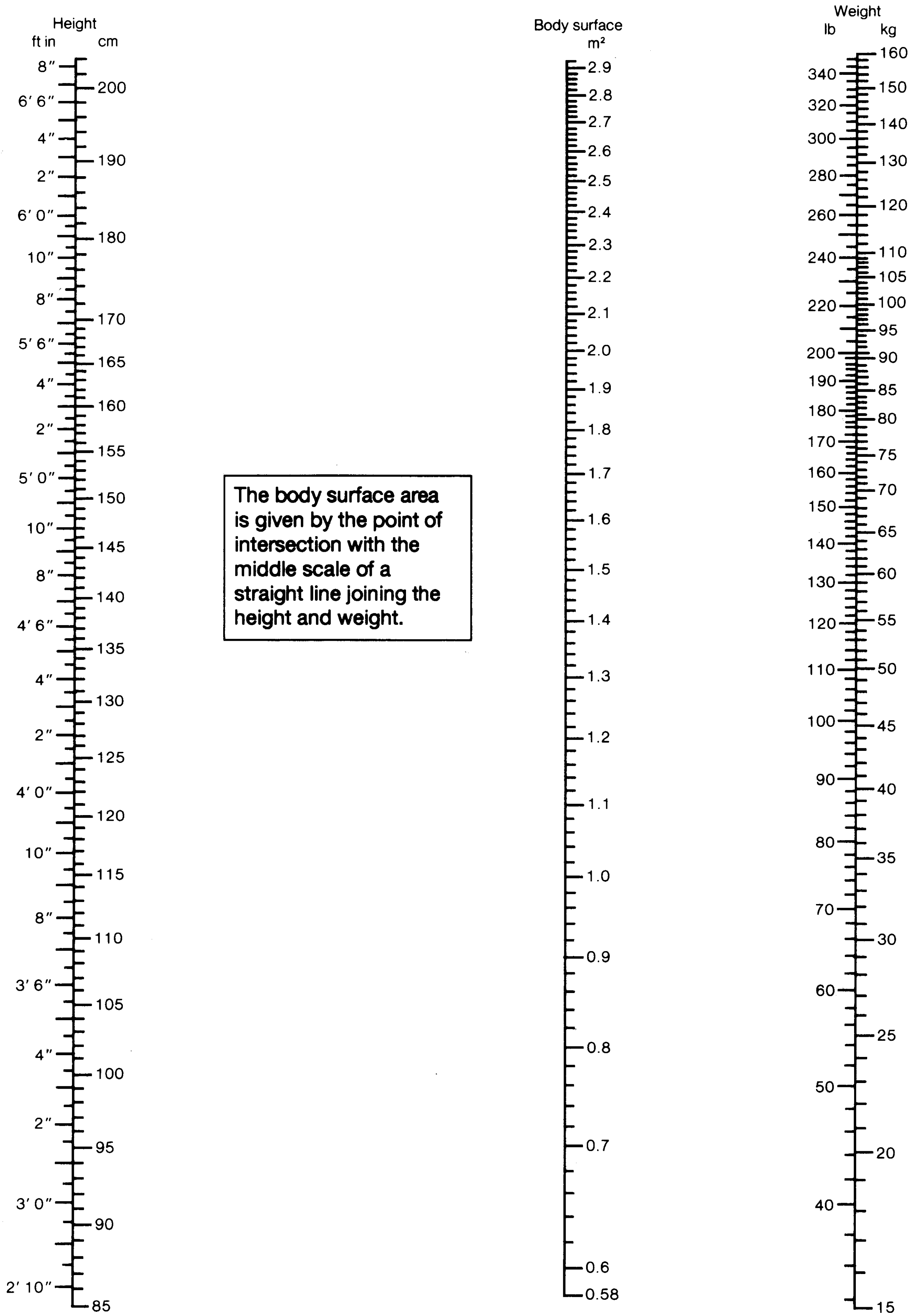
Effect of pH



Oxygen Hemoglobin Dissociation Curve

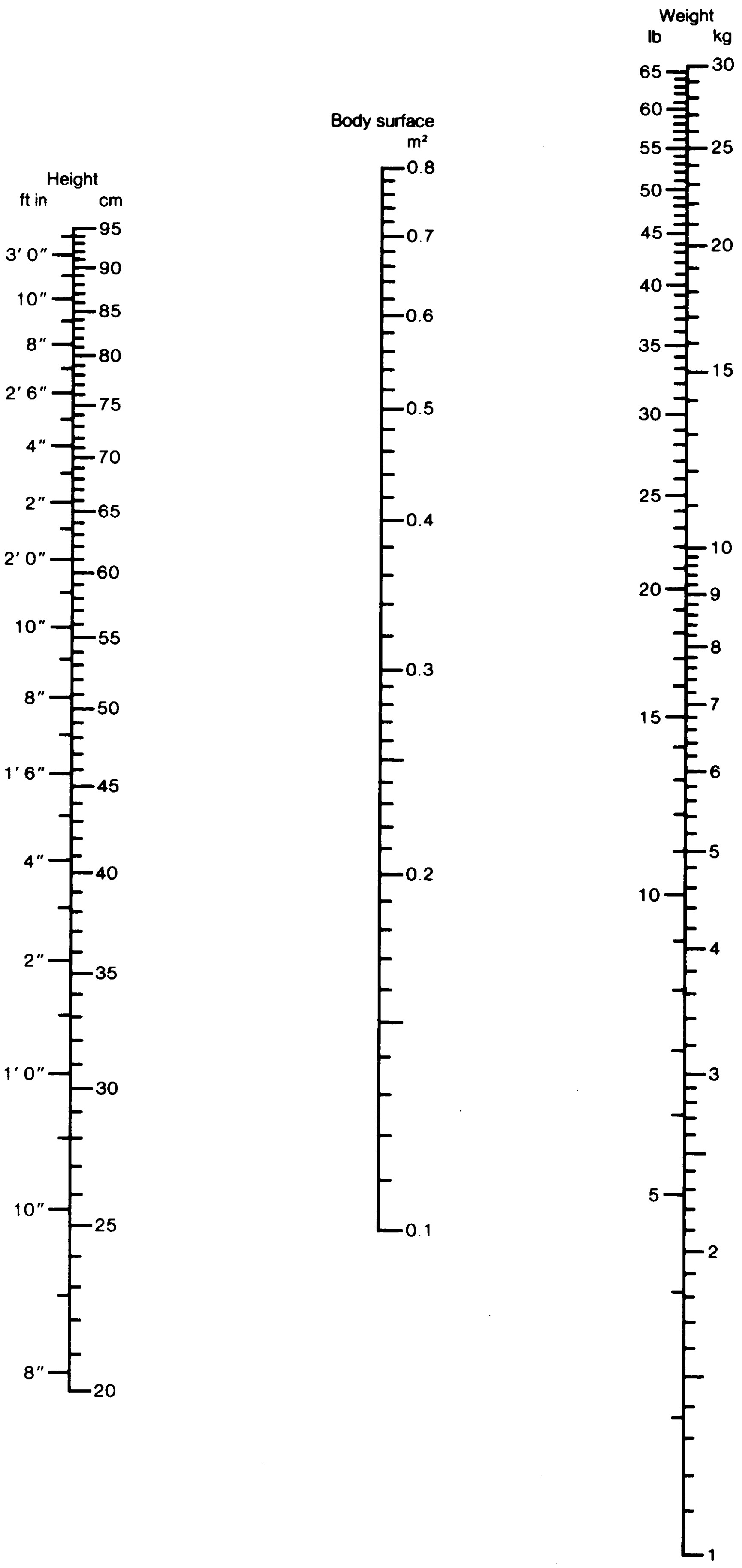


Adult Nomogram



The body surface area is given by the point of intersection with the middle scale of a straight line joining the height and weight.

Child Nomogram



The body surface area is given by the point of intersection with the middle scale of a straight line joining the height and weight.