Goal-Directed
Cardiovascular Perfusion
Equations

Patient Data:

Ht: ________ (cms) Wt: ________ (Kg) Sex: ________ Race: ________ Age: ________

Date: __________ Surgeon: _________________ Procedure: _____________________

Pump Time: __________ Cross-Clamp Time: __________ BMI: ___________________

Body Composition:

Body Surface Area (M^2) = $Wt^{0.425} \times Ht^{0.725} \times 0.007184$ ___________

DuBois D, DuBois EF. A formula to estimate the approximate surface area if height and weight be known. Arch Intern Med (Chicago) 1916; 17: 863.
Ht (cms)
Wt (Kg)

± % Desirable Body Weight = (Actual Wt – Desirable Wt) / (Desirable Wt) x 100 ______
*Desirable or Reference Weight Kg at a specific Height departure from desirable weight
**Variations in Blood Volume assumes that individuals who differ equally from their reference weight (± % overweight) are proportional to each other with respect to blood volume
***Blood volume and height, weight, and surface area relations; blood volume increases with respective body dimension, the ratio of blood volume to each independent variable is not a constant value
BV = Body Weight(Kg) x Ratio (ml/Kg)

Ideal Body Weight
Men: 50 + (0.91 × [height in centimeters − 152.4]) _____________

Women as 45.5 + (0.91 × [height in centimeters − 152.4]) _____________
See Height and Weight Chart for Both Genders

Men Wt (kg) = 48 + 1.1 x (Ht – 150 cm) _____________

Women Wt (kg) = 45 + 0.9 (Ht – 150 cm) _____________
Hammond (shorter adult patients)

Body Mass Index = Wt_{Kg} / Ht_{M}^{2} ____________

M: Wt Kg
Ht: Meters, Squared
BMI Categories:
Underweight = <18.5, Normal weight = 18.5–24.9, Overweight = 25–29.9, Obesity = BMI of 30 or greater

BMI	Weight status
Below 18.5	Underweight
18.5-24.9	Normal weight
25.0-29.9	Overweight
30.0-34.9	Obesity class I
35.0-39.9	Obesity class II
Above 40	Obesity class III

Renal Assessments:

COP = TPP x 3.32 – 2.0 ____________

(Normal Range: 23-29, Average: 25 mmHg, Albumin contributes about 80% of COP, 15-20 mmHg in critical ill patients, low teens trigger treatment, below 12.5 high risk for mortality)

COP_{alb} = Serum Albumin x 0.57 x 10 ____________

Poole-Wilson Formula

COP = (2.1 x TPP) + (0.16 x TPP^{2}) + (0.009 x TPP^{3}) ____________

Landis-Pappenheimer Formula

EGFR = (186) x (Serum $Creatinine^{-1.154}$ x $Age^{-0.203}$) ____________

For female multiply x 0.742, for African American multiply x 1.212)
(Normal: 90-120 ml/min/1.73 M^{2})

Stage of Kidney Disease ____________

Stages of Chronic Kidney Disease	GFR ml/min	% Kidney Function
• Stage 1 Kidney Damage with Normal Kidney Function	90 or >	90-100%
• Stage 2 Kidney Damage with Mild Loss of Function	89 to 60	89-60%
• Stage 3a Mild to Moderate Loss of Function	59 to 45	59-45%
• Stage 3b Moderate to Severe Loss of Function	44 to 30	44-30%
• Stage 4 Severe Loss of Function	29 to 15	29-15%
• Stage 5 Kidney Failure	< 15	< 15%

Serum Osmolality = (2 x Na) (+ Glu / 18) + (BUN / 2.8) ___________
Normal: 285-295 mOsm/Kg
Measured should not exceed predicted by more than 10 mOsm/Kg
> than 10 indicates an osmolal gap (e.g., caused by small molecules in high concentration or toxins, Mannitol, Ethanol, Ethylene Glycol, Propylene Glycol, Lorazepam, etc.)

mmol/L; the concentration of a solution expressed as the total number of solute particles per kilogram, Urea concentration is expressed as the nitrogen content of Urea (MW 28) and reported as Blood Urea Nitrogen (BUN) in non-SI units (mg/dL) BUN mg/dL multiplied by 0.357 = urea (mmol/L)
Urea (mmol/L) divided by 0.357 = BUN (mg/dL)
Approximate reference (normal) range:
Serum/plasma urea 2.5-7.8 mmol/L
Serum/plasma BUN 7.0-22 mg/dL

Serum Osmolarity = 2 (Na + K) + Glu / 18 ____________
Normal: 275 -295 mOsm/L
linear relationship exists between the effective osmolarity and mental state in HHS, with deficits beginning to occur at values above 320 mOsm/L and coma above 340 mOsm/L
Stupor or Coma in a patient with hyperglycemia with values below 320 mOsm/L
Mortality also rises substantially with levels above 350 mOsm/L

The concentration of osmotically active particles in solution, which may be quantitatively expressed in osmoles of solute per liter of solution; mmol/L, ≥ 296 mmol/L (dehydration), older patients 65 years or >, Panic Values: < 240, > 321 mmol/L, 384 produces stupor,
400 or > grand mal seizures, > 420 fatal

Serum Osmolarity = (1.86 x Na^+ + K^+) + Glucose + Urea + 9 ___________
mmol/L, for patients with chronic renal failure

Creatinine Clearance = 140 – Age_{yrs} x Wt_{Kg} / 72 ___________
(Females: multiply x .85)
Males: 97-137
Females: 88-128

Blood Volume Estimations:

These estimated blood volume equations vary greatly. This directly influences estimated plasma volume, red cell volume, total circulating volume and hence, dilution rate and other physiological equations incorporating blood volume and so on. It is my belief that we over-estimate blood volume with routine use of weight based estimations (ml/Kg). For all calculations involving blood volume I have found more reliability on the Nadler (Gilcher's Rule of Five) and Lemmens-Bernstein-Brodsky Equations. Weight-based is typically much higher than these, yet in some instances such as morbid obesity weight-based may be appropriate (55 ml/Kg). The Allen Equation I felt also over-estimated blood volume. I calculate them all to develop a contrast for reference purposes.

Total Blood Volume (TBV) = $70_{mls/Kg}$ x Wt_{Kg} ___________
70 mls/Kg Male
65 mls/Kg Female
55 mls/Kg Obesity

Allen’s BV Formula Males = $(0.000417 \times Htcm^3) + (45 \times Wt_{Kg}) - 30$ ______
Allen’s BV Formula Females = $(0.000414 \times Htcm^3) + (45 \times Wt_{Kg}) - 30$
Ht:

____

Nadler’s Formula (Male) TBV = $(0.3669 \times Ht^3) + (0.03219 \times Wt + 0.6041)$
Nadler’s Formula (Female) TBV = $(0.3561 \times Ht^3) + (0.03308 \times Wt + 0.1833)$

Ht: meters, Wt: Kg ____________
* For obese individuals, you can use Gilcher's Rule of Five: The average blood volume is decreased by 5 mL per kilogram.
Nadler equation is built upon the work of Dr. Allen in 1962

Blood Volume = $70 / [\sqrt{(\text{body mass index}/22)}]$ ____________
Lemmens-Bernstein-Brodsky Equation
Yields mls / Kg, multiply value derived by weight in Kg

Blood Volume = $PV \times 100 / [100 - (0.87 \times HCT)]$ ____________
0.87 is a correction factor (about 4% of the Hct is trapped plasma; therefore, the true volume of packed cells is 0.96 Hct; whole-body Hct is 0.91 x true packed cell volume; hence, 0.96 x 0.91 = 0.87), and Hct is the raw Hct.
Do we over estimate Blood Volume? This equation indicates that!

Blood Volume = Plasma Volume / (1 – HCT) ____________

Blood Volume = Red Cell Volume x (100/HCT) ____________

Blood / Flow Volume Ratio = CI / BV ____________

TCV = TBV + Prime Volume + I.V. Volume + CP Volume ____________

Δ BV % Change = $100 (BV_a - BV_b) / BV_b$ ____________

$BV_a = [BV_b \times Hb_b / Hb_a]$ ____________
a: after fluid shift
b: before fluid shift

RBC Volume = (.HCT) x (TBV) ____________
Red Blood Cell Corpuscular Volume
(minimal HCT: 18-20%)

Δ RBC Volume % Change = $100 (CV_a - CV_b) / CV_b$ ____________
CV (Cell Volume) Red Blood Cell Volume

Total Body HCT (BH) = RCV / RCV + PV ____________

$PV = (1 – HCT) X BV$ ___________

Plasma Volume = $(1 – .HCT) x [a + (b x Wt)]$ ___________
Hakim Formula Wt: Kg
a: 1530 for males and 864 for females
b: 41 for males and 47.9 for females

Plasma Volume = BV – RBCV ___________

Plasma Volume = $(0.065 x Wt_{Kg}) x (1 – HCT)$ ___________
Kaplan Formula

Δ PV % Change = $100 (PV_a – PV_b) / PV_b$ ___________
Subscripts b and a refer to Before and After

% PV Change = [100 / (100 – Hctb)] x [100 (Hctb – Hcta) / Hcta] _________
Subscripts b and a refer to Before and After

% Decrease In Plasma Volume =
$10 [1- (HCT_1 / 100 – HCT_1) x 100 – HCT_2 / HCT_2)]$ ___________

% Decrease In Plasma and ECF Volume = $100 (1 – Pr_1 / Pr_2)$ ___________
Pr_1 Initial Plasma Protein
Pr_2 Measured Plasma Protein after ECF Loss

Hemodilution HCT = TBV x (.HCT / TCV) ___________
(minimal HCT: 18-20%)

MCHC = Hb / HCT ___________
Concentration of hemoglobin in red blood cells
g/100 ml^{-1}

Hemodilution Estimations:

Predicted Dilution % = Prime Volume / (Prime Volume + TBV) ___________
(minimal HCT 18-20%)

Actual Dilution Rate = $(HCT_{pre\ dilution} – HCT_{post\ dilution} / HCT_{pre\ dilution})$ ___________
(Minimal HCT 18-20%)

Required RBC Volume = $(TBV + Prime Volume x HCT_{rise}) / PRBC HCT)$
PRBC HCT: 60%-80% ___________

Volume PRBC's to Transfuse = ___________
Total Blood Volume x (Target Hb – Current Hb) / Hb Donor Unit

Oxygenation / Perfusion Assessments:

Oxygen Capacity = (1.34 x Hb) ___________

CaO_2 Content = (1.34 x Hb x SaO_2) + (PaO_2 x 0.003) ___________
(minimal = (1.34 x minimal HCT x SaO_2) + (PaO_2 x 0.003)
(Normal: 16-22 ml/dL)
(Pasteur Point is the critical PaO_2 at which delivered O_2 is utilized by the tissue
And below which the O_2 Delivery is unable to meet tissue demands)
(Normal Alveolar PAO_2 100-110 mmHg, PaO_2 80-100 mmHg,
Capillary PO_2 50-80mmHg, Tissue PO_2 30-50 mmHg, Mitochondria PO_2 10-20 mmHg)

CvO_2 Content = (1.34 x HB x SvO_2) + (PvO_2 x 0.003) ___________
(Normal: 12-15 ml/dL)
(Normal a-v O_2 Content Difference: 4-6 ml/dL)

a-vO_2 Content Difference = CaO_2 – CvO_2 ___________

RCFR = CI x HCT ___________
.HCT (fractional)
Red Cell Flow Rate (ml/min/M^2)
Normal: 0.9 – 1.7 ml/min/M^2

TOEI = a-vO_2 content diff / RCFR x 10 ___________
Tissue Oxygen Extraction Index
Normal: 35 – 45
a-v O_2 Diff: 4-5 ml/dL
RCFR: 0.9-1.7 L/min/M^2

O_2 Transport / Red Cell Flow Ratio = CvO_2 / RCFR ___________
Ratio: 0.08-0.16

RCM L/M^2 = RBC Volume (Liters) / BSA (M^2) ___________

RCM = PV / [1.157 / HCT] -1 ___________
PV in L
.HCT
Important in Polycythemia, as RCM is increased and PV is not!

Oxygen Transport / Red Cell Mass Ratio = CvO_2 / RCM x 10 ___________
RCM in mls
Ratio: 0.08-0.16

TOEE = a-vO_2content diff / RCM x 10 ____________

Tissue Oxygen Extraction Efficiency Ratio
Red Cell Mass L/M^2 (Normal: 0.95-1.21)
RBCV in L/BSA = $RCM_M{}^2$
Normal: 35 – 45

$O_2ER = VO_2 / DO_2 \times 100$ ____________

Use: VO_2 / DO_2
VO_2 is approximately 250 ml/min (VO_2max in a non-athlete 75kg person is about 3L/min)
DO_2 is approx 1 L/min
O_2ER is 25% (increases to ~70% during maximal exercise in an athlete)
SvO_2 70%
O_2ER varies for different organs:
cardiac O_2ER = >60%
hepatic O_2ER = 45-55%
renal O_2ER = <15%

O_2 Extraction Ratio = VO_2 / DO_2 ____________

Normal 0.2 – 0.3, corresponds to $ScVO_2$ 70-80%
↑ Tissues are extracting excessive amounts since oxygen delivery is inadequate due to inadequate cardiac output or perfusion flow rate
↓ Low normal or below indicates failure of microcirculation with adequate oxygen uptake due to shunting and microvascular occlusion resulting in tissue ischemia, confirmed by increased lactate level
OER of 0.5 suggests that about 50% of arterial oxygen is gone by the time the blood returns to the heart
OER of 20% suggests something is wrong with the circulation (it might be too fast), unfortunately, there is nothing specific about the OER; it only describes the matching of supply and demand, but it is powerless to identify the cause of a mismatch

$VO_2 = CO \times (CaO_2 – CvO_2) \times 10$ ____________

CO L/min...this is the global oxygen consumption
(VO2 normally 25% of DO2)
(Normal: 200-250 ml/min), (CPB: > 150 ml/min)

$DO_2 = CO \times CaO_2 \times 10$ ____________

CO L/min...this is the global oxygen delivery

O_2 Extraction Ratio = 100% - SvO_2 (in percent) ____________

Assuming SaO_2 100%

O_2 Extraction Ratio = $(SaO_2 – SvO_2) / (SaO_2)$ ____________

(Normal: 22-30%, Range: 0.2-0.3, the point where O_2 Extraction is maximal is the anaerobic threshold)

O_2 Extraction Ratio = $(CaO_2 – CvO_2) / CaO_2 \times 100$ ____________

(Normal: 20-30%)

O_2 Extraction Index = $(SaO_2 - SvO_2) / SaO_2 \times 100$ ____________
(Normal: 20-25%)

O_2 Extraction Index = $VO_2 / DO_2 = (CaO_2 - CvO_2) / CaO_2$ ____________

An abnormally HIGH O_2ER	An abnormally LOW O_2ER

Inadequate oxygen delivery:
• Hypoxia
• Anaemia
• Blood flow insufficiency: shock states of all sorts
	Increased oxygen delivery:
	• Hyperbaric oxygen
	• Polycythaemia
	• Hyperdynamic circulation
	  ◦ Artificial circulation, eg. ECMO
	  ◦ High cardiac output state, eg. sepsis, cirrhosis, anxiety,

Increased oxygen consumption:
• Increased muscle activity:
  ◦ Exercise, including respiratory effort
  ◦ Shivering
  ◦ Seizures
• States of inflammation, eg. sepsis
• Increased metabolic rate:
  ◦ Hyperthermia
  ◦ Hyperthyroidism
  ◦ Catecholamine excess
  ◦ Response to massive injury or burns
	Decreased oxygen consumption:
	• Decreased muscle activity:
	  ◦ Sedation
	  ◦ Paralysis
	  ◦ Atrophy
	  ◦ Mechanical ventilation
	• Decreased metabolic rate:
	  ◦ Hypothermia
	  ◦ Hypothyroidism
	  ◦ Starvation
	• Failure of oxygen utilisation
	  ◦ Mitochondrial dysfunction in sepsis
	  ◦ Cyanide toxicity (among others)

Abnormal circulation: • Right-to-left shunt (cyanotic defect) • Arteriovenous malformations • Portosystemic shunts (in liver disease)	*Abnormal circulation:* • Left-to-right shunt (non-cyanotic defect) • Microcirculatory shunt (eg. in sepsis) • Tourniquet (large fraction of the circulation excluded by occlusion, eg. aortic crossclamp)
Measurement artifact: • Post-collection error in the VBG (prolonged sample-to-machine transit time)	*Measurement artifact:* • Central venous rather than mixed venous samples (SvO_2 is frequently higher) • Inadequate mixing of blood (PA catheter in the wrong position)

O_2 Availability = $(CaO_2 \times CI) \times 10$ ____________

$DO_2 = (Q \times CaO_2 \times 10)$

CO L/min ____________
(Normal: 950-1150 ml/min)
(CPB: > 400 ml/min)

DO_2 Index = (CaO_2 x CI x 10)
(Normal: 550-650 ml/min/M^2)
(CPB: > 272 ml/min/M^2)

VO_2 = DO_2 x (SaO_2 – SvO_2)
Fractional Saturations

VO_2 = (1.34 x Hb) (Q x SaO_2 – SvO_2) x 10
Q L/min, Normal: 200 – 280 ml/min

VO_2 Index = (Pump Flow) (a-v $O_{2\text{Content Difference}}$) / BSA x 10
ml O_2/min/M^2

VO_2 Index = (CaO_2 – CvO_2) x (CI) x 10
(Normally 115-165 ml/min/M^2)
(PvO_2 of 28 is required to cause oxygen to diffuse into cells, below this point anaerobic metabolism occurs. This is equivalent to an SvO_2 of 50% unless the oxyhemoglobin curve is shifted.)

OTRCF = $VO_{2\text{ Index}}$ / RCFR x 0.001
Oxygen Transport Red Cell Flow Rate Ratio
Normal: 0.08 – 0.16

OTRCM = VO_2 Index / Red Cell Mass x 0.001
Oxygen Transfer Red Cell Mass Ratio
Red Cell Mass (Normal: 0.95 – 1.21 L/M^2 or ml/M^2)
Normal: 0.08 – 0.16

O_2 Utilization Coefficient = (VO_2 / DO_2)
(Normal: ~ 70%)
(Predictor of severity of critical illness)

CO_2 GAP = ($PvCO_2$ – $PaCO_2$)
(Normal: 5 mmHg or <)

O_2 Index = (MAP x FiO_2 x 100) / (PaO_2)
(very good < 5, medium 10 - 20, poor > 25)

VCO_2 = Wt_{Kg} x VCO_2
Normal: 2.9 – 3.5 ml/Kg/min
VCO_2 mls/Kg/min ~ 3.2ml/Kg/min
Normal VCO_2: 120 – 320 ml/min
3.2 x Wt_{Kg} to estimate since if is not measured

PaO_2 / FiO_2 Ratio
(used as an indirect estimate of shunt fraction, PaO_2/FiO2 < 200, QsQt > 20%,
PaO_2 / FiO_2 > 200, QsQt < 20%)

Red Blood Cell Indices:

RDW (Red Cell Distribution Width) ______________
The coefficient of variation of the red cell volume – distribution histogram

MCV = HCT x 10 / RBC (x 10^{12}/L) ______________
Mean Cell (Corpuscular) Volume
Average Volume of the RBC(Femtoliters [fL] or 10^{-15}Liter)
Normal: 78 -100 fL
Low MCV = Microcytic
High MCV = Macrocytic
MCV: reflects the Cell Volume in femtoliters, Small vs Big

MCH = Hb x 10 / RBC (x10^{12}/L) ______________
Mean Cell Hemoglobin
Average weight of Hb in the RBC (Picograms [pg] or 10^{12} grams)
red cell hemoglobin content in picograms
Normal: 26 - 32 pg per red cell
MCH: reflects the Hb CONTENT (in picograms) of each red cell

MCHC = Hb x 100 / HCT ______________
Mean Cell Hemoglobin Concentration
Average concentration of Hb in the RBC Volume (g/dL)
Hemoglobin concentration of the packed red cells (minus plasma)
Normal: 31-37 g/dL (of erythrocytes)
Low MCHC: Hypochromic
High MCHC Hyperchromic
reflects the
concentration of Hb in
the red cell (g/dL)
MCH: reflects the Hb CONTENT (in picograms) of each red cell
"Pale" vs "Deep Red"
Hypo- vs Hyperchromic

RBC indices explained

The above calculator estimates the three RBC indices based on hemoglobin and hematocrit values and on red blood cell count. RBC indices reflect characteristics of the circulating red blood cell population: size, shape or Hb composition. These can be measured directly in laboratory based on a small venous blood sample, obtained following a normal blood test. They help differentiate between types of anemia, a condition in which the number of red blood cells or the quantity of hemoglobin fall below normal. There are three variables that are used to calculate the RBC indices:

- Hemoglobin: The protein responsible with oxygen transport in the blood with normal values between 12 and 18 g/dL, with slight variation for gender.
- Hematocrit: The ratio of RBC to total blood volume, with normal values between 37 and 52% and determined via centrifugation of blood.
- Red blood cell count: The number of RBC in the sample, with normal range between 4.2 and 6.3 x10^{12}/L.

The table below summarizes the formulas (in which the variables discussed above are employed) and normal values for each RBC index:

RBC indices	Formula	Normal range	Reporting unit
MCV	MCV = (Hematocrit %) / (RBC x 10^{12}/L) x 10	80 – 96 fL	fL (femtoliter)
MCHC	MCHC = (Hemoglobin in g/dL) / (Hematocrit %) x 100	33.4 - 35.5 g/dL	g/dL
MCH	MCH = (Hemoglobin in g/dL) / (RBC x 10^{12}/L) x 10	27 - 33 pg	pg (picogram)

Mean Corpuscular Volume

MCV offers information about the average size of red blood cells and is measured in femtoliters, which is equivalent to 10^{-15} L. Reference values are between 80 and 96 fL, according to the American Association for Clinical Chemistry. Other sources provide normal values between 80 and 100 fL or 83 and 97 fL and there may be some laboratory variation too. MCV in fL = (Hematocrit %) / (RBC x 10^{12}/L) x 10
Erythrocytes with normal MCV are called normocytic, those with high MCV are called macrocytic and those with low MCV are microcytic. The following table describes the types of anemia reflected by the erythrocyte size:

MCV	Type of anemia	Likely causes
Elevated	Macrocytic	B12 deficiency, folate deficiency, chemotherapy
Normal	Normocytic	Sudden blood loss, sepsis, malignancy, kidney failure
Low	Microcytic	Iron deficiency, chronic diseases, thalassemia

This is deemed the most important of the RBC indices because it also contributes to the calculation of and the red blood cell distribution width.

Mean Corpuscular Hemoglobin
MCH indicates the average weight of hemoglobin in the RBC blood sample. The measurement unit is picogram, which is equivalent to 10^{-12} grams. The normal range for adults is between 27 and 33 pg according to the American Association for Clinical Chemistry but other sources also provide 27 - 31 pg.
The formula is:
MCH in pg = (Hemoglobin in g/dL) / (RBC x 10^{12}/L) x 10
Macrocytic erythrocytes tend to have a larger concentration of hemoglobin. MCH levels in the PLT/MCH ratio can help in the differentiation of microcytic anemia causes: iron deficiency anemia (IDA) vs combined deficiency B12 and iron, IDA-B12 anemia.

Mean Corpuscular Hemoglobin Concentration
MCHC determines the average concentration of hemoglobin in the red blood cell sample in g/dL. According to the American Association for Clinical Chemistry, normal adult values are between 33.4 and 35.5 g/dL. Other sources indicate a wider range: 32 - 36 g/dL. MCHC in g/dL = (Hemoglobin in g/dL) / (Hematocrit %) x 100
Lower than normal MCHC values indicate hypochromic RBCs, normal values are characteristic for normochromic erythrocytes whilst greater than normal MCHC values indicate hyperchromic cells.

Blood Loss Assessment:

Allowable Blood Loss = [EBV x (Hi – Hf)] / Hi ____________

EBV=Estimated Blood Volume
Hi= initial hemoglobin
Hf= final hemoglobin

Cell Saver Blood Loss = (Bowl volume/2) / avg .HCT) X (# of Bowls returned to the Pt.) ___________

Average Blood Volumes:
Premature Neonates 95 mL/kg
Full Term Neonates 85 mL/kg
Infants 80 mL/kg
Adult Men 75 mL/kg
Adult Women 65 mL/kg

Normal Hct Values:
Men 42-52%
Women 37-47%

Example:
Question: Before surgery is to take place, what is the estimated blood volume (EBV) of a female patient weighing 50 kg? Also, what is the allowable blood loss (ABL) of this patient if her Hct is 45?

In the example above, EBV = 50kg x 65 (if using weight-based equation, adult woman's blood volume) = 3250

The initial Hct (Hi) = 45%, her current Hct, the final lowest acceptable Hct (Hf) = 30% (What ever cut off is used clinically to decide how low the individual's Hct will be allowed to drop. Thirty percent is used in this calculator but in reality this will vary from case to case.) So the example would look like this:

(3250 x (45 – 30))/45 = 1083 Using this rough estimate, the patient in this example could lose 1083 mL of blood without needing a transfusion.

Replacing Blood Loss:
"Ideally, blood loss should be replaced with crystalloid or colloid solutions to maintain intravascular volume (normovolemia) until the danger of anemia outweighs the risks of transfusion. At that point, further blood loss is replaced with transfusions of red blood cells to maintain hemoglobin concentration (or hematocrit) at that level. For most patients, that point corresponds to a hemoglobin between 7 and 10 g/dL (or a hematocrit of 21-30%). Below a hemoglobin concentration of 7 g/dL, the resting cardiac output has to increase greatly to maintain normal oxygen delivery" (Morgan & Mikhail, 1996).

Estimating blood loss:
Dry sponges:
4×4 hold ~ 10 mL blood
Ray-techs ~ 10-20 mL blood
Lap sponges ~ 50-100 mL blood

Blood loss replacement:
Replace 1 mL blood with:
3 mL crystalloid (i.e. NS, Dextrose, LR) 1 mL colloid (i.e. albumin**, Hespan®, Dextran®) 1 mL whole blood 1 mL PRBC

Physiology / Body Water Distribution:

Henderson-Hasslebach:

$pH = pK\ (6.1) + \log [HCO_3] / [H_2CO_3]$

$HCO_3 = pH - 6.1^{10x(\text{anti log})} + [X] / [H_2CO_3] = (\text{anti log} \times H_2CO_3)$

$PaCO_2 = pH - 6.1^{10x(\text{anti log})} + [HCO_3] / [X \times 0.03] = (HCO3 / \text{anti log} \times 0.03)$

Extracellular Volume = $Wt^{0.6469} \times Ht^{0.7236} \times 0.02154$

Plasma Volume ¼ ECF 93% water (& 7% 'plasma solids'), Interstitial Fluid ¾ ECF, Lymph is part of ECF, it is interstitial fluid collected by lymphatic vessels and returned to plasma
1/3 Body H_2O

PV = 0.065 x Weight x (1 – Hct) ___________

Plasma Volume = % of H_2O x Wt x 0.074 ___________

Intracellular Volume 2/3 Body H2O

Intracellular Volume = % of H_2O x Wt x 0.666 ___________

The volumes of the various body fluid compartments can be estimated in the normal adult as:

Total Body Water (Males) = $2.447 - [(0.09516 \times Age_{yrs}) + (0.1074 \times Ht_{cm}) + (0.3362 \times Wt_{Kg})]$

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Total Body Water (Females) = $2.097 - [(0.1069 \times Ht_{cm}) + (0.2466 \times Wt_{Kg})]$

Total Body Water (TBW) = 0.6 x body weight

Extracellular Fluid Volume (ECF) = 0.2 x body weight

Intracellular Fluid Volume (ICF) = 0.4 x body weight

Plasma Volume (P) = 0.25 x ECF volume

Interstitial Fluid Volume (IF) = 0.75 x ECF volume

Most tissues are water-rich and contain 70-80% water. The three major exceptions to this are:
Plasma: 93% water (& 7% 'plasma solids')
Fat: 10-15% water
Bone: 20% water

Transcellular Fluid, which is not part of
ICF or ECF. Transcellular fluids are separated from the rest of the body fluids by a layer of cells, and they include gastrointestinal, peritoneal, pleural, and cerebrospinal fluids. Collectively, the volume of transcellular fluids is small, so they are ignored in the above summary numbers.

Volume = Amount / Concentration

Body Fluid Compartments (70 kg male)

	% of Body Weight	**% of Total Body Water**	**Volume (Litres)**
ECF	**27**	**45**	**19**
Plasma	4.5	7.5	3.2
ISF	12.0	20.0	8.4
Dense CT water	*4.5*	7.5	3.2
Bone water	*4.5*	*7.5*	3.2
Transcellular	1.5	2.5	1.0
ICF	**33**	**55**	**23**
TBW	**60%**	**100%**	**42 liters**

Typical Electrolyte Concentrations in Some Transcellular Fluids (in mmol/l)

	[Na^+]	[K^+]	[Cl^-]	[HCO_3^-]
Saliva	20-80	10-20	20-40	20-60
Gastric juice	20-100	5-10	120-160	0
Pancreatic juice	120	5-10	10-60	80-120
Bile	150	5-10	40-80	20-40
Ileal fluid	140	5	105	40
Colonic fluid	140	5	85	60
Sweat	65	8	39	16
CSF	147	3	113	25