2

Endocrinology and Metabolism Facts and Formulas

Alterations in endocrinology and metabolism are common in critically ill patients. Laboratory testing and interpretation of laboratory data play an important part in the management of these disorders.

■ 1. ADRENAL FUNCTION

The question of adrenal insufficiency in critical ill patients arises commonly.

Normal serum cortisol levels vary during the day in normal individuals, the reference ranges are:

– Highest in the early morning 7–8 mcg/dL
– Lowest in the afternoon 2–18 mcg/dL

Blood sample taken at 8 in the morning are 6–23 (mcg/dL).

Formal *ACTH stimulation test* (may be measured while administering dexamethasone 10 mg I.V q6hrs):

– Baseline cortisol
– 0.25 mg Corticotropin I.V. or I.M.
– Cortisol level at 60 min
– <7 mcg/dL increase after doing the ACTH stimulation test suggests primary adrenal insufficiency if the basal cortisol level is <20 mcg/dL

Corticosteroids are commonly used in inflammatory disorders and for replacement therapy. Equivalent doses are shown in Table 2.1:

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Table 2.1 Equivalent corticosteroid doses

Agent	*Dose (mg)*	*Duration (h)*	*Potency*	
			Mineralocorticoid	*Glucocorticoid*
Cortisol	20.0	8	1.0	1.0
Cortisone	25.0	8	1.0	0.8
Dexamethasone	0.75	72	0	25
Hydrocortisone	20.0	8	1.0	0.8
Methylprednisolone	4.0	36	0.5	5
Prednisolone	5.0	24	0.8	4
Prednisone	5.0	24	0.8	4

2. DIABETES INSIPIDUS (DI)

A disorder of fluid homeostasis because of inadequate antidiuretic hormone (ADH) secretion or action:

Neurogenic DI = Inadequate production or secretion of ADH

Nephrogenic DI = Unresponsiveness of renal tubules to ADH

Water Deprivation Test

The *water deprivation test* (Table 2.2) may be performed if the patient is hemodynamically stable and the serum sodium is < 145 mEq/L:

Table 2.2 Water deprivation test

	Maximum U_{osm} (mOsm/kg H_2O)	*Maximum $\underline{U_{osm}}$ P_{osm}*	*% Change after vasopressin*[a]	*Maximum U_{osm}/P_{osm} after vasopressin*[a]
Normal	800–1,200	>1	<9 %	>1
Partial diabetes insipidus	400	>1	>9 %	>1
Complete diabetes insipidus	100–200	<1	>50 %	Variable
Nephrogenic diabetes insipidus	<150	<1	<45 %	<1

[a]5 U subcutaneously

■ 3. SODIUM FORMULAS

Serum Sodium Correction in Hyperglycemia

$$\mathbf{Na^+} = \text{Measured Na}^+ + 0.016\,(\text{serum glucose} - 100)$$

Serum Sodium Correction in Hyperlipidemia and Hyperproteinemia

$$\textbf{Decrease (mEq / L) serum Na}^{+}\textbf{ in hyperlipidemia} = \text{Plasma lipids (mg / dL)} \times 0.002$$

$$\textbf{Decrease (mEq / L) serum Na}^{+}\textbf{ in hyperlipidemia} = 0.25^{*}\,(\text{protein (g / dL)}$$

Estimated Sodium Excess in Hypernatremia

$$\textbf{Na}^{+}\textbf{ excess (mEq / L)} = 0.6 \text{ body weight (kg)} \times (\text{current plasma Na}^{+} - 140)$$

Estimated Sodium Deficit in Hyponatremia

$$\textbf{Na}^{+}\textbf{ deficit (mEq)} = 0.6 \times \text{body weight} \times (\text{desired plasma Na}^{+} - \text{current plasma Na}^{+})$$

■ 4. OSMOLALITY FORMULAS

$$\textbf{Calculated osmolality} = 2(\text{Na}^{+}) + \frac{\text{Glucose}}{18} + \frac{\text{BUN}}{2.8}$$

$$\textbf{Effective osmolality} = 2(\text{Na}^{+}) + \frac{\text{Glucose}}{18}$$

$$\textbf{Osmolal gap} = \text{Measured osmolality} - \text{calculated osmolality}$$

■ 5. DIABETES MELLITUS

Complications of diabetes mellitus may be the presenting condition of a patient in the ICU. However, many other patients may develop glucose intolerance while in the ICU.

Diabetic ketoacidosis (DKA) and non-ketotic hyperosmolar coma (HNKC) may present similarly. The following characteristics (see Table 2.3) may help the clinician differentiate between the two:

Table 2.3 Laboratory presentation of DKA and HNKC

Laboratory test	*DKA*	*HNKC*
Blood glucose (mg/dL)	200–2,000	Usually > 600
Blood ketones	Present	Absent
Arterial pH	<7.4	Normal[a]
Anion gap	↑↑	Normal or ↑↑
Osmolality	↑	↑↑
Urine dipstick	Glucose and ketones	Glucose

DKA = diabetic ketoacidosis; *HNKC* = Hyperglycemic non-ketotic coma; ↑ = slightly elevated; ↑↑ = elevated
[a]May be low if hypovolemia causes poor tissue perfusion

Table 2.4 contains some of the insulins commonly employed in the ICU setting:

Table 2.4 Types of insulins commonly employed in the ICU

Type of insulin	*Onset of action (min)*	*Peak (min)*	*Duration (min)*
Regular (I.V.)	5	20–25	40–45
Regular (I.M.)	30	60	90–100
Regular (S.Q.)	60	180	360
NPH (S.Q.)	240	360–480	600–960
Lente (S.Q.)	240	360–480	600–960
Ultralente (S.Q.)	480–720	720–1,080	1,080–1,680

6. HYPOGLYCEMIA (TABLE 2.5)

Table 2.5 Differentiating exogenous insulin administration, insulinoma, and oral hypoglycemic agent-induced hypoglycemia

Laboratory test	*Insulinoma*	*Exogenous insulin*	*Sulfonylureas*	*Insulin autoimmune*
Plasma insulin level	↑	↑↑	↑	↑
Insulin antibodies	None[a]	Present	None[a]	↓
Plasma/urine sulfonylurea levels	Absent	Absent	Present	Absent
C-peptide	↑	N/↓	↑	↑

Other causes of hypoglycemia such as hepatic failure should be considered in the ICU
↑ = increased; ↓ = decreased; *N* = normal
[a]May be present if the patient has had prior insulin injections

7. THYROID FUNCTION TESTS (TABLES 2.6 AND 2.7)

Table 2.6 Thyroid function tests

Direct methods	*Indirect methods*
Circulating levels of total hormones:	*Thyroid hormone binding test:*
Total thyroxine (T_4)	Resin uptake of $^{125}I–T_3$
Total triiodothyronine (T_3)	
Protein-bound iodine (PBI)	
Circulating levels of free hormones:	*Free thyroxine index (FTI):*
Free thyroxine (fT_4)	$\mathbf{FTI} = \dfrac{T_4 \times \text{patient triiodothyronine } (T_3)}{\text{Control triiodothyronine } (T_3)}$
Free triiodothyronine (fT_3)	
Thyroid hormone-binding proteins:	
Thyroxine-binding globulin (TBG)	

Table 2.7 Interpretation of thyroid function tests in the ICU

Test	*Hypothyroid*	*High T_4 syndrome*	*Hyperthyroid*	*Low T_3 syndrome*	*Low T_3/T_4 syndrome*
TSH	High[a]	Nl/low	Low	Low to sl ↑	Low to sl ↑
Total T_4	Low	High	High	Nl	Low
Total T_3	Low to low Nl	Low/Nl/high	High	Low	Low
Reverse T_3	Nl/low	Nl/high	High	High	High
Free T_4	Low	Nl/high	High	Nl	Nl
T_3RU	Low	Nl/low	High	Nl/high	High

Nl = normal; *sl* = slight
[a]Except TSH is low in hypothyroidism of secondary and tertiary causes

8. CALCIUM METABOLISM AND DISORDERS

$$\textbf{Corrected Ca}^{++} = \text{Measured Ca}^{++} + 0.8 \times (4 - \text{plasma albumin})$$

$$\textbf{Corrected Ca}^{++}\ (\textbf{quick method}) = \text{Ca}^{++} - \text{albumin} + 4$$

In the differential diagnosis of hypercalcemia, the use of urinary cyclic AMP and parathyroid hormone may confirm a diagnosis (see Table 2.8):

Table 2.8 Use of iPTH and urinary cyclic AMP in the differential diagnosis of hypercalcemia

iPTH	*Urinary cyclic AMP*	*iPLP*	*Diagnosis*
↑↑	↑↑	N	Primary hyperparathyroidism
N or ↓	N or ↓	↑	Probable occult malignancy

↑ = increased; ↓ = decreased; *N* = normal
iPTH = Parathyroid hormone by radioimmunoassay; *iPLP* = parathyroid hormone-like protein by radioimmunoassay

9. NUTRITION FORMULAS

Please refer to Chap. 8 for additional formulas.

Body Mass Index
The *body mass index* (BMI) is frequently utilized when dealing with nutrition in the critically ill patient:

$$\mathbf{BMI} = \frac{(\text{Body weight [kg]})}{(\text{Height [m]}^2)}$$

Harris–Benedict Equation
It measures the basal energy expenditure (BEE), which represents the resting basal metabolic rate:

Men:

$$66 + (13.7 \times W) + (\% \times H) - (5.0 \times A) = \text{kcal / day}$$

Women:

$$655 + (9.6 \times W) + (1.85 \times H) - (4.7 \times A) = \text{kcal / day}$$

where

W = body weight in kilograms
H = height in centimeters
A = age in years

Nitrogen Balance (NB)
Requires knowledge of protein intake urine urea nitrogen (UUN). For patients with normal renal function, the following formula is utilized:

$$\mathbf{NB} = (\text{Dietary protein} \times 0.16) - (\text{UUN} + 2\text{ g stool} + 2\text{ g skin})$$

In patients with renal dysfunction, the increased blood urea pool and extrarenal losses must be accounted for, and the following formula is used:

$$\mathbf{NB} = \text{Nitrogen in} - (\text{UUN} + 2\text{ g stool} + 2\text{ g skin} + \text{BUN change})$$

Catabolic Index (CI)
The *catabolic index* (CI) is derived from the same variables:

$$\mathbf{CI} = \text{UUN} - [(0.5 \times \text{dietary protein} \times 0.16) + 3\text{ g}]$$

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