PHYSIOLOGICAL AND METABOLIC BASIS FOR THE INITIAL TREATMENT OF THE CRITICALLY ILL PATIENT

BY: PAUL K. HANASHIRO, M.D.

Introduction:

The successful management of a critically ill patient is dependent upon a thorough understanding of the underlying pathophysiological process as well as upon the competence with which therapeutic procedures are performed. The understanding of cardiopulmonary dynamics, fluid electrolytes and acid-base balance, and specific organ function is the basis for rational and practical decisions in critical care medicine. By a rapid integration of pathophysiological mechanisms with clinical manifestations, specific life-threatening derangements are detected and corrected expeditiously. Unfortunately, in clinical practice this task is formidable since time is a premium and the urgency for immediate care compels the physician to do "something". When confronted with such critical situations, physicians often revert to empiric or symptomatic treatment. The result is usually one of limited success.

In order to resolve this dilemma a systematic approach must be established. However, the practical guidelines based on objective insights must be simple and easy to execute with minimum delay. Such an approach is being presented based on the concept of O_2 availability and utilization. Practical guidelines are then formulated for the routine management of patients regardless of the underlying pathological process. The diagnostic and therapeutic evaluations proceed simultaneously. The sequence of diagnostic and therapeutic maneuvers are then carried out by a set of priorities based on specific physiological and metabolic derangements, correcting these derangements systematically until the patient is stabilized. This approach of patient care is feasible and practical in all types of critical care situations in a single or

multi-bed facility.

Concept of O_2 Availability and O_2 Utilization:

Any imbalance between oxygen availability and utilization will have profound changes in specific organ dysfunction. Following the course of oxygen in the body from its exchange in the lungs, to its transport to the various tissues via the circulation and finally its utilization into useful energy by the cells enables one to detect specific derangements of any of these factors influencing the course of oxygen in the body. Specific therapeutic procedures are then instituted to correct these derangements or imbalance.

The following is an outline of the factors which influence the balance between oxygen availability and utilization:

A. Factors influencing oxygen availability:

1. Pulmonary function - Oxygen exchange and oxygen saturation of the blood.

2. Cardiovascular function - Oxygen transport via the circulation.

3. Fluid, electrolytes and acid-base balance -- Oxygen carrying capacity of the blood and the hemoglobin dissociation curve.

B. Factors influencing oxygen utilization:

1. Metabolic Demand

   a. Stress
   b. Temperature
   c. Toxins and Infections
   d. Hormones

2. Metabolic Function

   a. Tissue perfusion
   b. Oxygen extraction
   c. Viability of tissue
   d. Mitochondrial function

A change in any one, or combinations of these factors, may alter this balance of oxygen availability and utilization. Therefore, it is important

to assess all of these factors simultaneously in order to assure this balance.

Available Oxygen

A dynamic formula representing the available oxygen per unit time is represented by:

OXYGEN TRANSPORT EQUATION

$$\text{Avail. } O_2 = \text{Cardiac Output} \times \text{Arterial } O_2 \text{ Saturation} \times \text{Hemoglobin Concentration} \times 1.34\ (O_2/\text{gmHg})$$

It should be apparent from this formula that any alteration of one or combinations of factors will affect the available oxygen at any given moment. Examples of these alterations are illustrated below:

EXAMPLES OF OXYGEN TRANSPORT EQUATIONS

	Avail O_2	=	CO		% Sat.		HGB		$HGB\text{-}O_2$ Constant
Rest	1,000 ml ml/min	=	5,250 ml/min	x	95%	x	15 gm	x	1.34
Exercise	2,000	=	10,000	x	100%	x	15 gm		
Hypoxemia (Compensated)	1,000	=	6,667	x	75%	x	15 gm		
Anemia (Anem) (Compensated)	1,000	=	10,000	x	100%	x	7.5 gm		
Heart Failure (HF)	750	=	3,928	x	95%	x	15 gm		
Hypoxemia (Hypox) (Uncompensated)	750	=	5,000	x	75%	x	15 gm		
Hypox-Anem (Uncomp.)	500	=	5,000	x	75%	x	10 gm		
Hypoxia (HF-Hypox.-Anem.)	250	=	2,500	x	75%	x	10 gm		

By utilizing this physiological equation as a guide, specific derangements are detected and therapy is instituted to correct these derangements in order to maximize the available oxygen. In clinical situations the VIP approach developed by Weil and Shubin, for the simultaneous evaluation of diagnostic and therapeutic maneuvers is the important practical guide, because the VIP approach reflects the oxygen transport equation (Table I). The highest order of diagnostic and therapeutic priorities are based on this triad of physiological factors.

A postscript (P.S.) is included only to indicate that pharmacologic and specific forms of therapy are secondary priorities to be considered only after the VIP priorities have been secured.

It is important to note that these physiological guides reflecting the available oxygen do not necessarily indicate specific pathological processes. They must always be correlated with the clinical setting. The physician must also select appropriate studies that will provide these insights with the least amount of effort and delay.

Oxygen Utilization

Survival is ultimately dependent on the utilization of oxygen by the cells. Thus, available oxygen must always be considered in conjunction with oxygen utilization. Oxygen utilization is influenced by the metabolic requirements and the functional state of the cells and in turn by specific organ functions. Thus, objective guides which reflect specific organ functions may give us insights as to the functional integrity of organ systems as they are affected by the pathological processes as well as in response to the stresses of the disease.

The following outline lists a number of key parameters that are monitored to assess the function of specific organ systems as well as those factors that affect the utilization of oxygen.

A. DIAGNOSTIC ASSESSMENT

1. GENERAL

a. Temperature

b. Metabolic rate

c. Oxygen consumption

d. Carbon dioxide production

e. Lactic acid production

2. SPECIFIC ORGAN FUNCTION

a. Arterial and venous blood gases

b. Blood and urine glucose, amylase and diastase, acetone

c. EKG, CVP - Pulmonary wedge, blood pressure, heart rate

d. (1) Urinalysis, BUN, creatinine, uric acid

(2) Renal clearances: urea, creatinine, osmolar, free water

e. SGOT, SGPT, LDH, CPK, Isoenzymes, Alk Phos - Bilirubin

f. Platelets, CBC, Prothrombin Time, Fibrinogen Coagulation Time, Partial Thromboplastin Time

g. Calcium, phosphorus

h. Electroenchephalogram, L.P., CT Scan

In many instances systematically correcting the physiological and metabolic derangements also corrects the initiating problem such as: hemorrhage, respiratory failure or cardiac failure. On the other hand, if the primary problem needs to be corrected, the M.D. can focus on specific reparative procedures once the patient has been stabilized.

In this overview of critical care based on physiological and metabolic guidelines, a simple concept revolving around the balance of O_2 is presented which is applicable in the Emergency Room or Admitting Area. In this approach the diagnostic and therapeutic maneuvers are evaluated simultaneously based on any imbalance between oxygen availability and oxygen utilization. With this insight, the physician defines priorities for management, correcting specific physiological and metabolic derangements systematically until the patient is stabilized. The physician then focuses on the correction of the underlying pathological process. The VIP approach and the monitoring of key variables which reflect specific organ function provides the practical guidelines which are applicable to any patient regardless of the underlying pathological process. This approach ultimately provides a foundation for sound clinical judgment and greater assurance for effective patient management.

TABLE I

PRIORITIES OF THERAPEUTIC MANEUVERS

V.I.P.		Available Oxygen
Ventilation	Pulmonary O_2, and CO_2 Exchange	% Arterial O_2 Sat.
Infusion	Fluid, Electrolyte, Acid-Base Balance	Hemoglobin
Perfusion	Cardiac Competence Organ Perfusion	Cardiac Output
P. Pharmacological	Vasoactive, Steroids, Diuretics	
S. Specific	Surgical, Antibiotics, Dialysis	