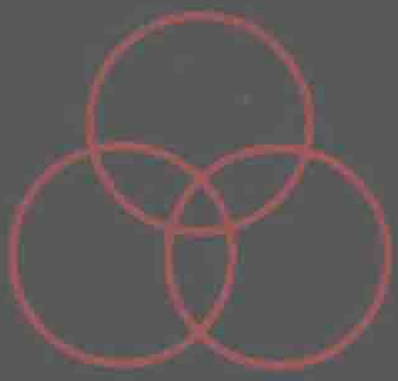
Principles of CRITICAL CARE

SECOND EDITION

Companion Handbook



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To the many students
who have inspired
our teaching

to our wives for their
limitless patience, and

to Cora Taylor, our secretary,
whose skill, efficiency, and spirit
earn our gratitude daily

CONTRIBUTORS

This companion to *Principles of Critical Care* consists of brief summaries of chapters of that textbook, each reduced in length and complexity to be readily available as an introductory bedside guide. The original chapters and authors are listed at the end of each synopsis to guide the interested reader to more complete descriptions. The editors are indebted to the original authors for their most excellent and extensive reviews of these topics.

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PREFACE

Critical care has evolved during the last four decades into a discipline combining the clinical scholarships of anesthesia, medicine, and surgery. In editing the second edition of *Principles of Critical Care* (PCC), we encouraged our contributors to describe the differential diagnosis and management of each disease as the intensivist sees the critically ill patient. Written from this perspective, 108 chapters described the diagnosis and management of critical illness and discussed the organization of critical care in 1767 pages. Because the bulk of this book makes it impractical to have it available at all times, the editors, with the help of critical care colleagues and senior critical care fellows, aimed to condense the clinical portions of PCC into this completely revised and updated pocket-sized *Companion Handbook*, which practitioners of critical care carry with them.

The *Companion Handbook, Second Edition*, is meant to provide a brief introduction to, or reminder of, some aspect of critical care which intensivists may require when they cannot consult PCC. Users of the *Companion Handbook* should be warned that such a condensed, streamlined approach to critical illness can magnify several pitfalls intrinsic to critical care. By its very nature, critical care is exciting and attracts physicians having an inclination to action. Despite its obvious utility in urgent circumstances, this proclivity can replace effective clinical discipline with excessive, unfocused ICU procedures. We believe this common approach inverts the stable pyramid of bedside skills, placing most attention on the least informative source of data while losing the rational foundation for diagnosis and treatment. An associated problem is that ICU procedures become an end to themselves rather than a means to answer thoughtful clinical questions. Too often, these procedures are implemented to provide "monitoring," ignoring the fact that the only alarm resides in the intensivist's intellect. Students of critical care benefit from the dictum:

"Don't just do something, stand there—take time to process the gathered data to formulate a working hypothesis concerning the mechanism(s) responsible for each patient's main problem(s) so that the next diagnostic or treatment intervention can best test that possibility." Without this exhortation to thoughtful clinical decision-making, students of critical care are swept away by the burgeoning tools of the ICU toward the unproductive subspecialty: critical care technology. Furthermore, effective critical care is rarely in brilliant, incisive, dramatic, and innovative interventions but most often derives from meticulously identifying and titrating each of the patient's multiple problems toward improvement at an urgent but continuous pace. This conservative approach breeds skepticism toward innovative strategies that are incompletely evaluated, and demands that the goals and adverse effects of traditional therapies be clarified so that the least amount of each intervention is employed to achieve its stated therapeutic goal, all in order to maximize one principle of patient care—"First, Do No Harm."

These several important principles of critical care necessarily get minimized in the *Companion Handbook,* which we consider to complement PCC as a single educational package. Accordingly, we recommend that relevant subjects in the standard textbook be consulted as soon as time permits. To facilitate this consultation, each of the critical illnesses and procedures discussed in the *Companion Handbook* refers to the relevant chapters in PCC. Used in this way, the companion handbook provides students, residents, fellows, and critical care physicians and nurses with quick access to essential information during the initial presentation or rapid evolution of critical illness in most ICU patients.

I. NORMAL BLOOD GAS AND RESPIRATORY GAS EXCHANGE VALUES

Arterial oxygen saturation (Sa_{O_2})	96–100% (.96–1.0)
Mixed venous oxygen saturation ($S\bar{v}_{O_2}$)	>70% (>.7) <80% (<.8)
pH	7.35–7.45
Pa_{CO_2}	35–45 mmHg (4.7–6.0 kPa)
Pa_{O_2}	75–100 mmHg (10.0–13.3 kPa)
Arterial oxygen content (Ca_{O_2})	18–21 mL O_2/dL (vol %)
Alveolar-arterial differences for O_2 (A-aD_{O_2}) at $F_{I_{O_2}}$ = .21	5–25 mmHg
$F_{I_{O_2}}$ = 1.0	<150 mmHg
Shunt fraction ($\dot{Q}S/\dot{Q}T$)	3–8% (.03–.08)
Dead space fraction (V_D/V_T)	<.35
Oxygen consumption ($\dot{V}_{O_2}$)	3–4 mL/kg/min
CO_2 production ($\dot{V}_{CO_2}$)	3–4 mL/kg/min
Oxygen transport ($\dot{Q}_{O_2}$)	12–16 mL/kg/min
Respiratory quotient (RQ)	.7–1.0
Tidal volume (V_T)	6–8 mL/kg
Respiratory rate (f)	8–16/min
Respiratory system static compliance (Cst, rs)	70–100 mL/cmH_2O
Respiratory system resistance to airflow (Rrs)	<3 mmH_2O/L/s

II. RESPIRATORY PARAMETERS

$$Pa_{CO_2} = \frac{k\dot{V}_{CO_2}}{\dot{V}_A} = \frac{k\dot{V}_{CO_2}}{(f)(V_T) \times (1 - V_D/V_T)}$$

where f = Breathing frequency
V_T = Tidal volume
V_D/V_T = Dead space fraction
k = 0.863

Dead space fraction $(V_D/V_T) = \frac{Pa_{CO_2} - PE_{CO_2}}{Pa_{CO_2}}$

where PE_{CO_2} = partial pressure of carbon dioxide in expired gas

Modified alveolar gas equation: $P_{A_{O_2}} = F_{I_{O_2}}(P_{ATM} - P_{H_2O}) - \frac{Pa_{CO_2}}{RQ}$

Static compliance (Cst,rs) $= \frac{V_T}{(Pplat - PE^{T}}$

Resistant to airflow (Rrs) $= \frac{Ppeak - {}^{T}\ .at}{FLOW}$

Pulmonary capillary content (Cc'_{O_2}) $= ([Hgb] \times 1.39) + P_{A_{O_2}} \times .0031$

Shunt fraction $(\dot{Q}s/\dot{Q}T) = \frac{Cc'_{O_2} - Ca_{O_2}}{Cc'_{O_2} - C\bar{v}_{O_2}}$

III. RESPIRATORY GAS TRANSPORT

Oxygen delivery ($\dot{O}_{O_2}$)	$= \dot{Q}_T \times Ca_{O_2}$
Aterial oxygen content (Ca_{O_2})	$= 1.39 \times Sa_{O_2} \times [Hgb] + .0031 \times Pa_{O_2}$
Mixed venous oxygen content ($C\bar{v}_{O_2}$)	$= 1.39 \times S\bar{v}_{O_2} \times [Hgb] + .0031 \times P\bar{v}_{O_2}$
Arterio-venous oxygen content difference	$= Ca_{O_2} - C\bar{v}_{O_2}$
Oxygen consumption ($\dot{V}_{O_2}$)	$= \dot{Q}_T(Ca_{O_2} - C\bar{v}_{O_2})$
Extraction fraction	$= \dfrac{Ca_{O_2} - C\bar{v}_{O_2}}{Ca_{O_2}}$
Respiratory quotient (RQ)	$= \dfrac{\dot{V}_{CO_2}}{\dot{V}_{O_2}}$
CO_2 production ($\dot{V}_{CO_2}$)	$= f \cdot V_T \cdot F_{E_{CO_2}}$
O_2 consumption ($\dot{V}_{O_2}$)	$= f \cdot V_T \cdot (F_{I_{O_2}} - F_{E_{O_2}})$, when RQ = 1.0

IV CIRCULATORY PARAMETERS AND CALCULATIONS

Systemic systolic pressure (SP)	100–140 mmHg
Systemic diastolic pressure (DP)	60–90 mmHg
Pulse pressure (SP − DP)	30–50 mmHg
Mean arterial pressure (BP, mmHg)	$\frac{(SP + 2DP)}{3}$ at normal heart rate
Heart rate (HR)	60–90/min
Stroke volume (SV)	50–100 mL
Stroke index (SI)	SV/body surface area (BSA) = 35–50 mL/m^2
Right atrial pressure (Pra)	2–8 mmHg
Pulmonary systolic pressure	16–24 mmHg
Pulmonary diastolic pressure	5–12 mmHg
Pulmonary pulse pressure	8–15 mmHg
Mean pulmonary artery pressure ($\overline{Ppa}$)	9–16 mmHg
Mean pulmonary capillary wedge pressure (Ppw)	5–12 mmHg
Cardiac output ($\dot{Q}_T$ = SV × HR)	4–6 L/min
Cardiac index (CI = $\dot{Q}_T$/BSA)	2.5–3 L/min/m^2
Systemic vascular resistance $SVR = \frac{\overline{BP} - Pra}{\dot{Q}_T}$	10–15 mmHg/L/min (to convert to c.g.s. units, multiply × 80) (900–1200 dyne · s/cm^5)
Pulmonary vascular resistance $PVR = \frac{Ppa - Ppw}{\dot{Q}_T}$	1.5–2.5 mmHg/L/min (120–200 dyne · s/cm^5)
Venous return (VR) = $\frac{Pms - Pra}{Pvr}$	4–6 L/min
where PMS = mean systemic pressure	10–15 mmHg
Rvr = resistance to venous return	1–2 mmHg/L/min

V. THE INTERNAL MILIEU

Normal Body Water Distribution

Total body water (TBW) in liters	= 0.6 (female) − 0.7 (male) × body weight (kg)
Intracellular fluid (ICF)	= 0.67 TBW
Extracellular fluid (ECF)	= 0.33 TBW
Vascular volume (L)	= 0.33 ECF

Normal Electrolyte Concentration Ranges

Na^+	136–146 meq/L
Ka^+	3.5–5.1 meq/L
Cl^-	98–106 meq/L
HCO_3^-	22–26 meq/L
Mg^{2+}	1.3–2.1 meq/L (0.65–1.05 mmol/L)
PO_4^{3-}	2.7–4.5 mg/dL (0.87–1.45 mmol/L)
Ca^{2+}	8.4–10.2 mg/dL (2.1–2.55 mmol/L)
iCa^{2+}	2.24–2.60 meq/L (1.12–1.30 mmol/L)

Calculated osmolality (Osm) =

$$2 \times [Na^+] + \frac{[\text{Glucose}]}{18} + \frac{[\text{BUN}]}{2.8}$$

Normal = 285–295 mOsm/L

Fractional excretion of sodium

$$FE_{Na} = \frac{[Na^+]\text{urine} \times [Cr]\text{serum}}{[Na^+]\text{serum} \times [Cr]\text{urine}}$$

$<1 \rightarrow$ Prerenal

$>1 \rightarrow$ Renal

Anion gap = $[Na^+] - [Cl^-] - [HCO_3^-]$

Normal = 8–12 meq/L

VI. THE CENTRAL NERVOUS SYSTEM

Glasgow Coma Score

Eye Opening	Spontaneous	4
	To sound	3
	To pain	2
	Never	1
Best motor response	Obeys command	6
	Localizes pain	5
	Flexion (withdraw)	4
	Flexion (abnormal)	3
	Extension	2
	None	1
Best verbal response	Oriented	5
	Confused conversation	4
	Inappropriate words	3
	Incomprehensible sounds	2
	None	1
	Total ranges from	3–15

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