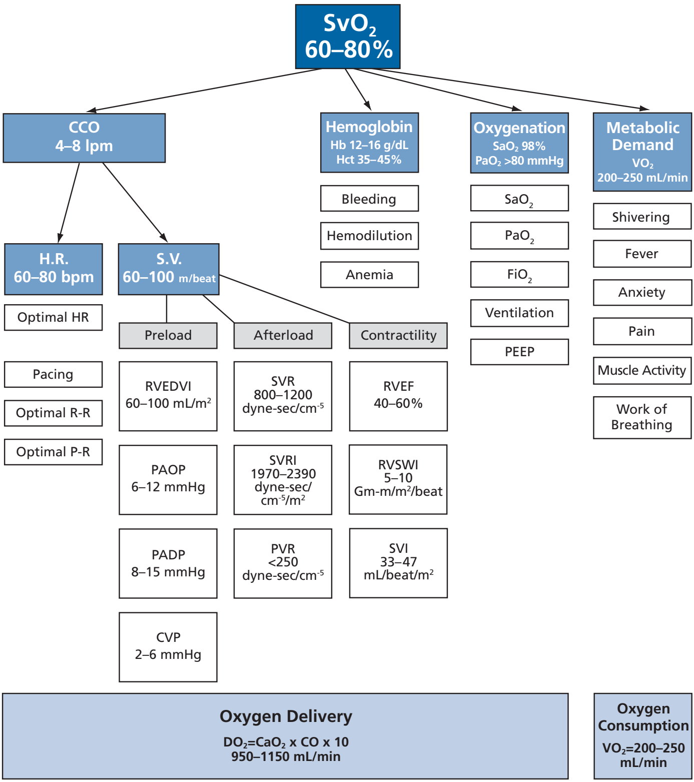
Quick Reference

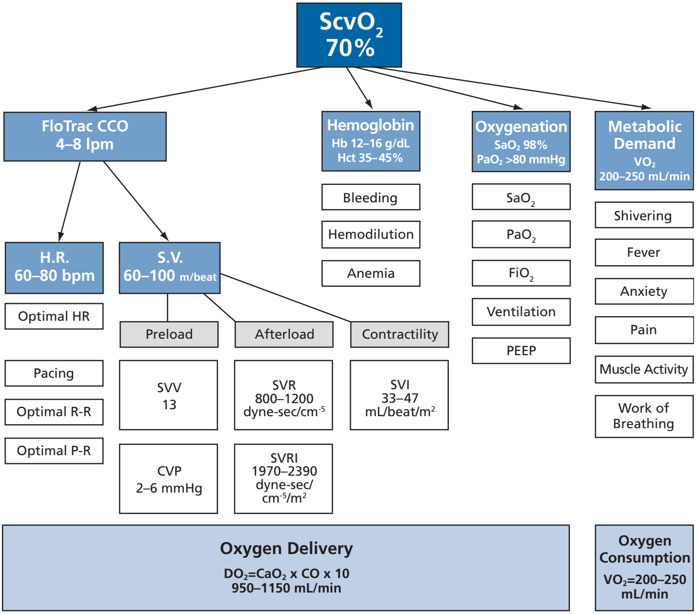
ADVANCING CRITICAL CARE
THROUGH SCIENCE-BASED EDUCATION

SINCE 1972

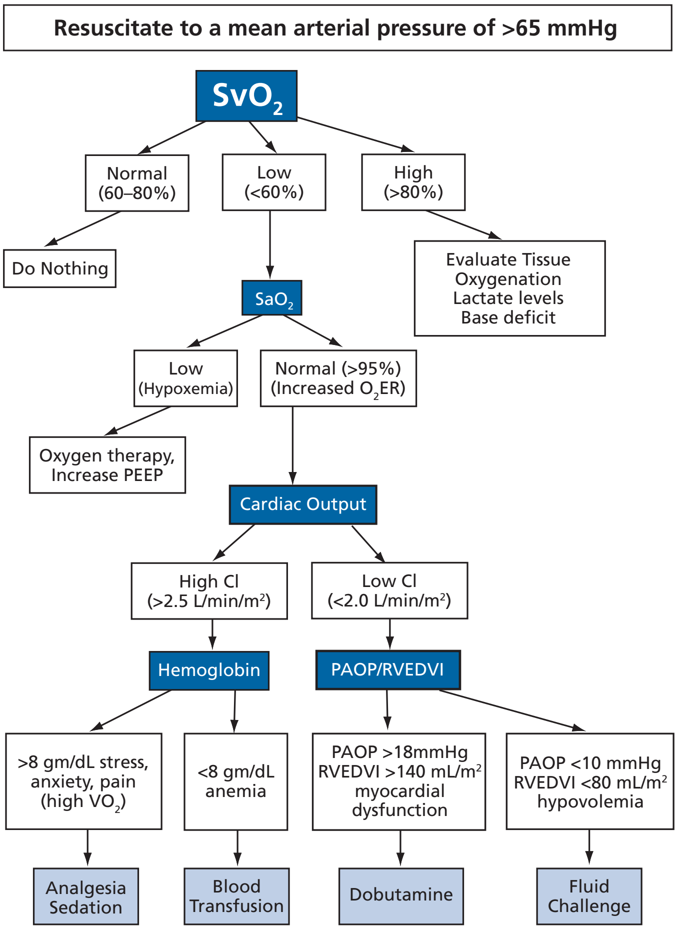
Advanced Technology Swan-Ganz Catheter Algorithm



Advanced Minimally Invasive Algorithm

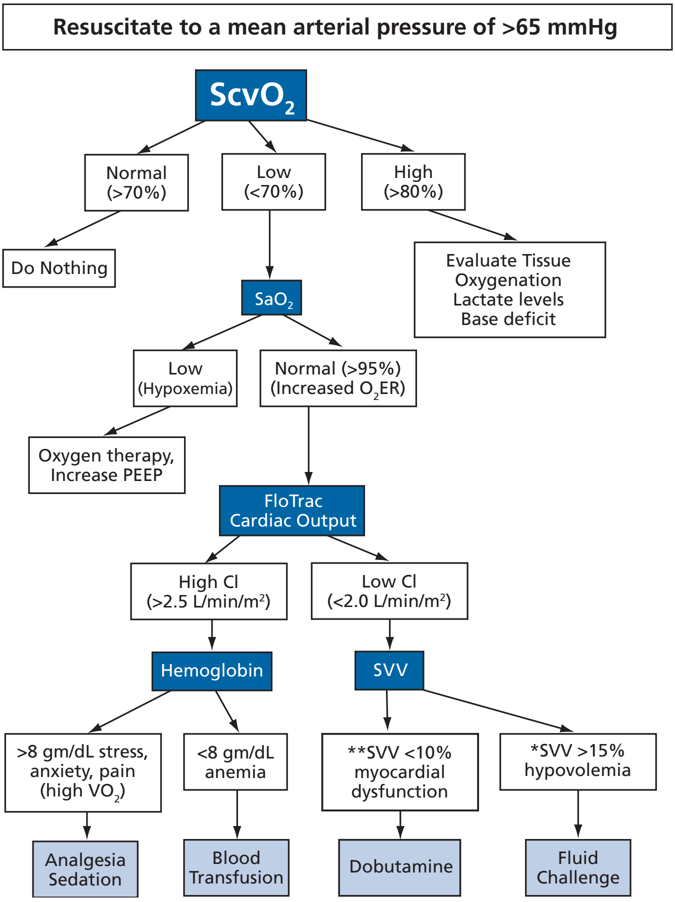


Advanced Swan-Ganz Catheter Goal-Directed Protocol



Modified from Pinsky & Vincent. Critical Care Med. 2005;33:1119-22.

Advanced Minimally Invasive Goal-Directed Protocol

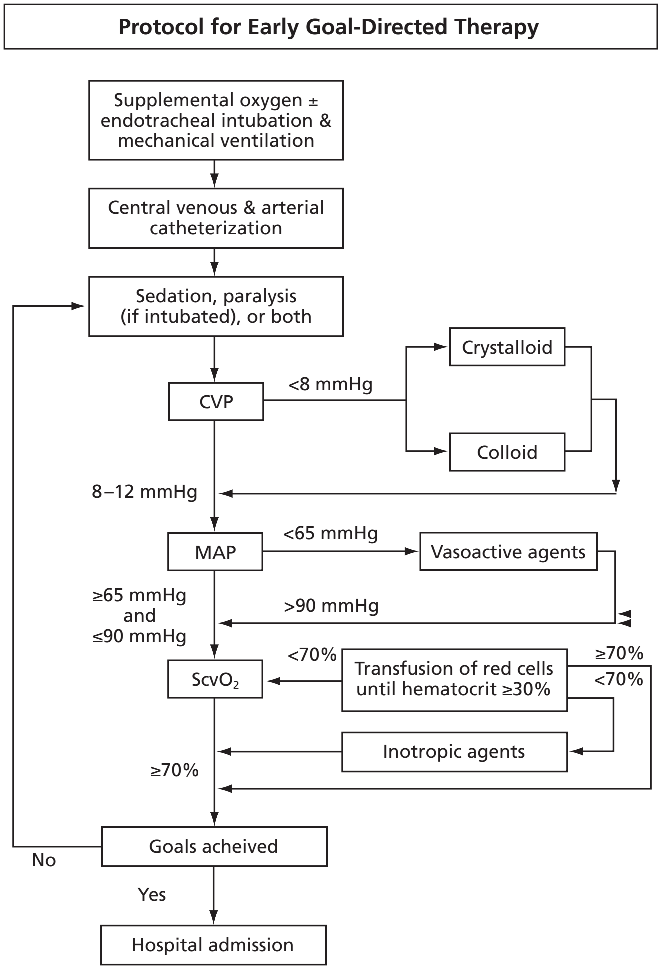


* *Used within the limitations of SVV as a guide for fluid responsiveness.*

** *Cardiac Output response to fluid challenge or passive leg raising when SVV cannot be used.*

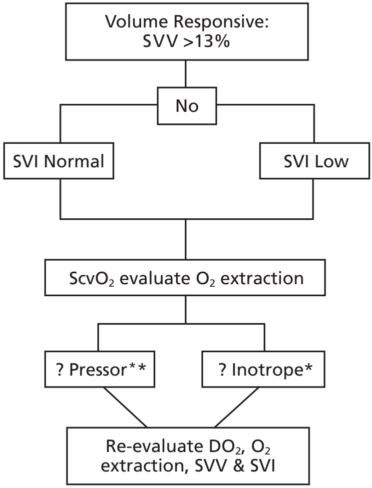
Modified from Pinsky & Vincent. Critical Care Med. 2005;33:1119-22.

EGDT In the Treatment of Sepsis or Septic Shock



Rivers, Emanuel, Nguyen, Bryant, et al; Early Goal-Directed Therapy in the Treatment of Severe Sepisis and Septic Shock: N Engl J Med, Vol. 345, No. 10, 2001.

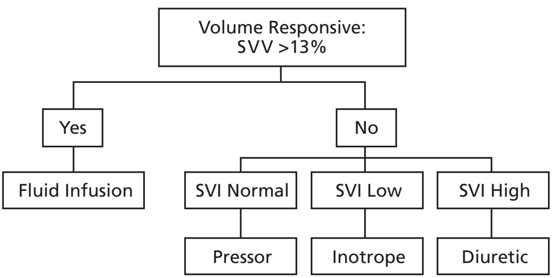
Physiologic Algorithm Using SVV, SVI and $ScvO_2$



* *If O_2 extraction is high, an inotrope may be required to provide perfusion support.*

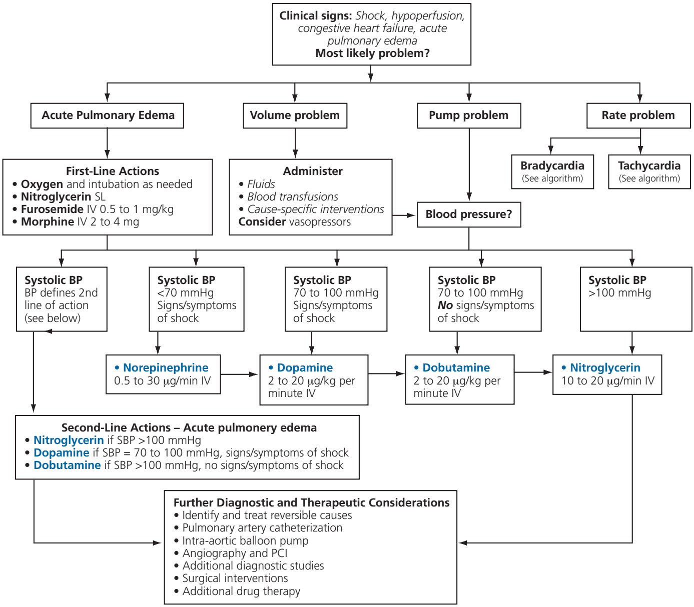
** *As individual organ perfusion may also depend on blood pressure, a MAP target > 60-65 may require a vasopressor even when O_2 extraction is normal.*

Physiologic Algorithm Using SVV and SVI



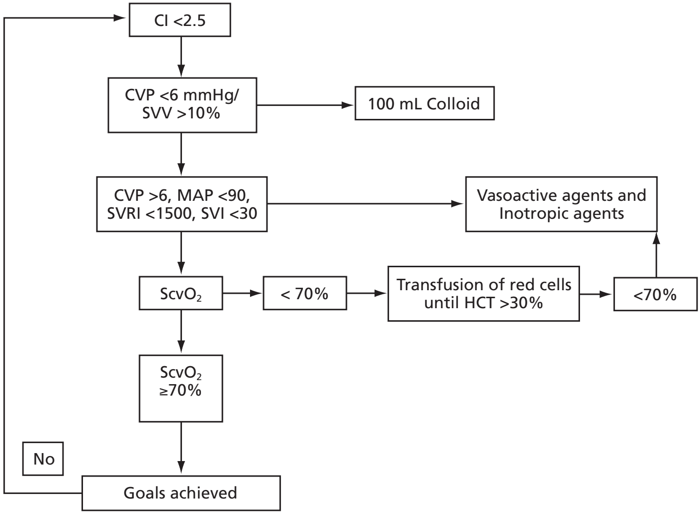
McGee, William T., Mailloux, Patrick, Jodka, Paul, Thomas, Joss: The Pulmonary Artery Catheter in Critical Care; Seminars in Dialysis—Vol. 19, No 6, November-December 2006, pp. 480-491.

Acute Pulmonary Edema, Hypotension, Shock Algorithm



This algorithm has been reviewed by the ACC/AHA STEMI Guidelines Committee but was not evaluated by the 2005 AHA Guidelines Conference for CPR and ECC.

Early Goal-Directed Therapy In Moderate to High-Risk Cardiac Surgery Patients



Malholtra PK, Kakani M, Chowdhury U, Choudhury M, Lakshmy R, Kiran U. Early goal-directed therapy in moderate to high-risk cardiac surgery patients. Ann Card Anaesth 2008;11:27-34.

Typical Hemodynamic Profiles in Various Acute Conditions

Condition	HR	MAP	CO/ CI	CVP/ RAP	PAP/PAOP	Notes
Left Ventricular Failure	↑	↓	↓	↑	↑	
Pulmonary Edema (Cardiogenic)	↑	N, ↓	↓	↑	↑PAOP >25 mmHg	
Massive Pulmonary Embolism	↑	↓	↓	↑ N	↑PAD > PAOP by >5 mmHg	↑PVR
Acute Ventricular Septal Defect	↑	↓	↓	↑	↑giant "v" waves on PAOP tracing	O_2 step up noted in SvO_2
Acute Mitral Valve Regurgitation	↑	↓	↓	↑	↑giant "v" waves on PAOP tracing	No O_2 step up noted in SvO_2
Cardiac Tamponade	↑	↓	↓	↑	↑CVP, PAD and PAOP equalized	↓RVEDVI
Right Ventricular Failure	↑,V	↓,V	↓	↑	PAP ↑, PAOP N/↓	↑RVEDVI
Hypovolemic Shock	↑	↓	↓	↓	↓	↑Oxygen extraction ↑SVR
Cardiogenic Shock	↑	↓	↓	N, ↑	↑	↑Oxygen extraction ↑SVR
Septic Shock	↑	↓	↓	↓,N	↓,N	SVR changes, ↓Oxygen extraction ↓SVR

NEW YORK HEART CLASSIFICATION OF CARDIOVASCULAR DISEASE

Class	Subjective Assessment
I	Normal cardiac output without systemic or pulmonary congestion; asymptomatic at rest and on heavy exertion
II	Normal cardiac output maintained with a moderate increase in pulmonary systemic congestion; symptomatic on exertion
III	Normal cardiac output maintained with a marked increase in pulmonary-systemic congestion; symptomatic on mild exercise
IV	Cardiac output reduced at rest with a marked increase in pulmonary-systemic congestion; symptomatic at rest

FORRESTER CLASSIFICATION HEMODYNAMIC SUBSETS OF ACUTE MYOCARDIAL INFARCTION

Subset Clinical Description	Cardiac index L/min/m²	PAOP mmHg	Therapy
I No Failure	2.7 ± 0.5	12 ± 7	Sedate
II Isolated Pulmonary Congestion	2.3 ± 0.4	23 ± 5	Normal BP: Diuretics ↑ BP: Vasodilators
III Isolated Peripheral Hypoperfusion	1.9 ± 0.4	12 ± 5	↑ HR: Add volume ↓ HR: Pacing
IV Both Pulmonary Congestion and Hypoperfusion	1.6 ± 0.6	27 ± 8	↓ BP: Inotropes Normal BP: Vasodilators

GLASGOW COMA SCALE

Neurological Function		Points
Eye Opening	Spontaneous To sound To pain Never	4 3 2 1
Best Motor Response	Obeys commands Localizes pain Flexion (withdraws) Flexion (abnormal) Extension None (flaccid)	6 5 4 3 2 1
Best Verbal Response	Oriented Confused conversation Inappropriate words Incomprehensible sounds None	5 4 3 2 1

ATLS CHART

Estimated Fluid and Blood Requirements in a 70kg Male INITIAL PRESENTATIONS				
	Class I	Class II	Class III	Class IV
Blood loss (mL)	<750	750–1500	1500–2000	>2000
Blood loss (% blood volume)	<15%	15%–30%	30%–40%	>40%
Pulse rate (bpm)	<100	>100	>120	>140
Blood pressure	Normal	Normal	Decreased	Decreased
Pulse pressure (mmHg)	Normal or increased	Decreased	Decreased	Decreased
Respiratory rate	14–20	20–30	30–40	>35
Urine output (mL/hr)	30 or more	20–30	5–15	Negligible
CNS-Mental status	Slightly anxious	Mildly anxious	Anxious and confused	Confused and lethargic
Fluid replacement	Crystalloid	Crystalloid	Crystalloid + blood	Crystalloid + blood

FLUID CHALLENGE GUIDELINE CHART

BASELINE VALUES		
PAOP* mmHg	**Challenge Volume Amount/10 Minutes**	**CVP* mmHg**
<12 mmHg	200 mL or 20 cc/minute	<6 mmHg
12–16–18 mmHg	100 mL or 10 cc/minute	6–10 mmHg
>16–18 mmHg	50 mL or 5 cc/minute	>10 mmHg

- Re-profile at the end of 10 minutes or fluid challenge
- Discontinue challenge if PAOP increased >7 mmHg or CVP increased >4 mmHg
- Repeat challenge if PAOP increased <3 mmHg or CVP increased <2 mmHg
- Observe patient for 10 minutes and re-profile if PAOP increased >3 mmHg, but <7 mmHg or CVP increased >2 mmHg or <4 mmHg
- Observe SVI and RVEDVI if RV volume values are available
- Discontinue challenge if: SVI fails to increase by at least 10% and RVEDVI increases by 25% or RVEDVI is >140 mL/m^2 and PAOP increases >7 mmHg

Optional Baseline RVEDVI Value Guidelines:

- If RVEDVI <90 mL/m^2 or mid-range 90-140 mL/m^2, administer fluid challenge
- If RVEDVI >140 mL/m^2, do not administer fluid challenge

** References differ on PAOP and CVP ranges*

APACHE II SEVERITY OF DISEASE CLASSIFICATION SYSTEM

	High Abnormal Range					Low Abnormal Range			
	+4	**+3**	**+2**	**+1**	**0**	**+1**	**+2**	**+3**	**+4**
Temperature- rectal (°C)	≥41°	39–40.9°		38.5°–38.9°	36°–38.4°	34°–35.9°	32°–33.9°	30°–31.9°	≤29.9°
Mean Arterial Pressure - mmHg	≥160	130–159	110–129		70–109		50–69		≤49
Heart Rate (ventricular response)	≥180	140–179	110–139		70–109		55–69	40–54	≤39
Respiratory Rate (non-ventilated or ventilated)	≥50	35–49		25–34	12–24	10–11	6–9		≤5
Oxygenation A-aDO_2 or PaO_2 (mmHg) a. FIO_2 ≥0.5 record A-aDO_2 b. FIO_2 ≤0.5 record only PaO_2	≥500	350-499	200-349		<200 PO_2>7	PO_2 61-70		PO_2 55-60	PO_2 <55
Arterial pH	≥7.7	7.6–7.69		7.5–7.59	7.33–7.49		7.25–7.32	7.15–7.24	<7.15
Serum Sodium (mMol/L)	≥180	160–179	155–159	150–154	130–149		120–129	111–119	≤110
Serum Potassium (mMol/L)	≥7	6–6.9		5.5–5.9	3.5–5.4	3–3.4	2.5–2.9		<2.5
Serum Creatinine (mg/100 mL) (Double point score for acute renal failure)	≥3.5	2–3.4	1.5–1.9		0.6–1.4		<0.6		
Hematocrit (%)	≥60		50–59.9	46–49.9	30–45.9		20–29.9		<20
White Blood Count (total/ mm3) (in 1,000s)	≥40		20–39.9	15–19.9	3–14.9		1–2.9		<1
Glasgow Coma Scale (GCS) Score = 15 minus actual GCS									
A. Acute Physiology Score (APS): Sum of the 12 individual variable points from the chart above.									
Serum HCO_3 (venous-mMol/L) [Not preferred, use if no ABGs]	≥52	41–51.9		32–40.9	22–31.9		18–21.9	15–17.9	<15

B. Age Points:

Assign points to age as shown in chart at right:

Age (years)	Points
≤44	0
45–54	2
55–64	3
65–74	5
≥75	6

C. Chronic Health Points:

If the patient has a history of severe organ system insufficiency or is immunocompromised, assign points as follows:

a. for nonoperative or emergency postoperative patients - 5 points or
b. for elective postoperative patient - 2 points

Definitions

Organ insufficiency or immunocompromised state must have been evident prior to this hospital admission and conform to the following criteria:

Liver: Biopsy-proven cirrhosis and documented portal hypertension; episodes of past upper GI bleeding attributed to portal hypertension; or prior episodes of hepatic failure/encephalopathy/coma.

Cardiovascular: New York Heart Association Class IV.

Respiratory: Chronic restrictive, obstructive, or vascular disease resulting in severe exercise restriction, i.e., unable to climb stairs or perform household duties; or documented chronic hypoxia, hypercapnia, secondary polycythemia, severe pulmonary hypertension (>40 mm Hg), or respiratory dependency.

Renal: Receiving chronic dialysis.

Immunocompromised: Immunosuppression, chemotherapy, radiation, long-term or recent high-dose steroids, or has a disease that is sufficiently advanced to suppress resistance to infection, e.g., leukemia, lymphoma, AIDS.

APACHE II Score

Sum of A + B + C

A. APS points
B. Age points
C. Chronic health points

Total Apache II

ACC/AHA 2004 Guidelines Pulmonary Artery Catheter and Arterial Pressure Monitoring

Recommendations for Pulmonary Artery Catheter Monitoring:

Class I

1. Pulmonary artery catheter monitoring should be performed for the following:
   a. Progressive hypotension, when unresponsive to fluid administration or when fluid administration may be contraindicated
   b. Suspected mechanical complications of STEMI, (i.e., VSR, papillary muscle rupture, or free wall rupture with pericardial tamponade) if an echocardiogram has not been performed

Class IIa

1. Pulmonary artery catheter monitoring can be useful for the following:
   a. Hypotension in a patient without pulmonary congestion who has not responded to an initial trial of fluid administration
   b. Cardiogenic shock
   c. Severe or progressive CHF or pulmonary edema that does not respond rapidly to therapy
   d. Persistent signs of hypoperfusion without hypotension or pulmonary congestion
   e. Patients receiving vasopressor/inotripic agents

Class III

1. Pulmonary artery catheter monitoring is not recommended in patients with STEMI without evidence of hemodynamic instability or respiratory compromise.

Recommendations for Intra-arterial Pressure Monitoring:

Class I

1. Intra-arterial pressure monitoring should be performed for the following:
   a. Patients with severe hypotension (systolic arterial pressure less than 80 mmHg)
   b. Patients receiving vasopressor/inotropic agents
   c. Cardiogenic shock

Class II

1. Intra-arterial pressure monitoring can be useful for patients receiving intravenous sodium nitroprusside or other potent vasodilators.

Class IIb

1. Intra-arterial pressure monitoring might be considered in patients receiving intravenous inotropic agents.

Class III

1. Intra-arterial pressure monitoring is not recommended for patients with STEMI who have no pulmonary congestion and have adequate tissue perfusion without use of circulatory support measures.

Normal Hemodynamic Parameters and Laboratory Values

NORMAL HEMODYNAMIC PARAMETERS – ADULT

Parameter	Equation	Normal Range
Arterial Blood Pressure (BP)	Systolic (SBP) Diastolic (DBP)	100–140 mmHg 60–90 mmHg
Mean Arterial Pressure (MAP)	SBP + (2 x DPB)/3	70–105 mmHg
Right Arterial Pressure (RAP)		2–6 mmHg
Right Ventricular Pressure (RVP)	Systolic (RVSP) Diastolic (RVDP)	15–30 mmHg 2–8 mmHg
Pulmonary Artery Pressure (PAP)	Systolic (PASP) Diastolic (PADP)	15–30 mmHg 8–15 mmHg
Mean Pulmonary Artery Pressure (MPAP)	PASP + (2 x PADP)/3	9–18 mmHg
Pulmonary Artery Occlusion Pressure (PAOP)		6–12 mmHg
Left Atrial Pressure (LAP)		4–12 mmHg
Cardiac Output (CO)	HR x SV/1000	4.0–8.0 L/min
Cardiac Index (CI)	CO/BSA	2.5–4.0 L/min/m^2
Stroke Volume (SV)	CO/HR x 1000	60–100 mL/beat
Stroke Volume Index (SVI)	CI/HR x 1000	33–47 mL/m^2/beat
Systemic Vascular Resistance (SVR)	80 x (MAP–RAP)/CO	800–1200 dynes- sec/cm^{-5}
Systemic Vascular Resistance Index (SVRI)	80 x (MAP–RAP)/CI	1970–2390 dynes- sec/cm^{-5}/m^2
Pulmonary Vascular Resistance (PVR)	80 x (MPAP–PAOP)/CO	<250 dynes-sec/cm^{-5}
Pulmonary Vascular Resistance Index (PVRI)	80 x (MPAP–PAOP)/CI	255–285 dynes-sec/cm^{-5}/m^2
Left Ventricular Stroke Work (LVSW)	SI x MAP x 0.0144	8–10 g/m/m^2
Left Ventricular Stroke Work Index (LVSWI)	SVI x (MAP–PAOP) x 0.0136	50–62 g/m^2/beat
Right Ventricular Stroke Work (RVSW)	SI x MAP x 0.0144	51–61 g/m/m^2
Right Ventricular Stroke Work Index (RVSWI)	SVI x (MPAP–CVP) x 0.0136	5–10 g/m^2/beat
Coronary Artery Perfusion Pressure (CPP)	Diastolic BP–PAOP	60–80 mmHg
Right Ventricular End-Diastolic Volume (RVEDV)	SV/EF	100–160 mL
Right Ventricular End-Diastolic Volume Index (RVEDVI)	RVEDV/BSA	60–100 mL/m^2
Right Ventricular End-Systolic Volume (RVESV)	EDV–SV	50–100 mL
Right Ventricular Ejection Fraction (RVEF)	SV/EDV x 100	40–60%

OXYGEN PARAMETERS – ADULT

Parameter	Equation	Normal Range
Partial Pressure of Arterial Oxygen (PaO_2)		75–100 mmHg
Partial Pressure of Arterial CO_2 ($PaCO_2$)		35–45 mmHg
Bicarbonate (HCO_3)		22–26 mEq/L
pH		7.34–7.44
Arterial Oxygen Saturation (SaO_2)		95–100%
Mixed Venous Saturation (SvO_2)		60–80%
Arterial Oxygen Content (CaO_2)	$(0.0138 \times Hgb \times SaO_2) + 0.0031 \times PaO_2$	16–22 mL/dL
Venous Oxygen Content (CvO_2)	$(0.0138 \times Hgb \times SvO_2) + 0.0031 \times PvO_2$	15 mL/dL
A-V Oxygen Content Difference ($C(a\text{-}v)O_2$)	$CaO_2 – CvO_2$	4–6 mL/dL
Oxygen Delivery (DO_2)	$CaO_2 \times CO \times 10$	950–1150 mL/min
Oxygen Delivery Index (DO_2I)	$CaO_2 \times CI \times 10$	500–600 mL/min/m^2
Oxygen Consumption (VO_2)	$C(a\text{-}v)O_2 \times CO \times 10$	200–250 mL/min
Oxygen Consumption Index (VO_2I)	$C(a\text{-}v)O_2 \times CI \times 10$	120–160 mL/min/m^2
Oxygen Extraction Ratio (O_2ER)	$(CaO_2 – CvO_2)/CaO_2 \times 100$	22–30%
Oxygen Extraction Index (O_2EI)	$(SaO_2 – SvO_2)/SaO_2 \times 100$	20–25%

NORMAL BLOOD LABORATORY VALUES

Test	Conventional Units (Reference Values*)	SI Units
Chemistry Studies		
Sodium (Na)	135–145 mEq/L	135–145 mmol/L
Potassium (K)	3.5–5.0 mEq/L	3.5–5.0 mmol/L
Chloride (Cl)	100–108 mEq/L	100–108 mmol/L
Carbon Dioxide (CO_2)	22–26 mEq/L	22–26 mmol/L
Glucose (BS)	70–100 mg/dL	3.9–6.1 mmol/L
Blood Urea Nitrogen (BUN)	8–20 mg/dL	2.9–7.5 mmol/L
Creatine kinase (CK)	Males: 55–170 U/L Females: 30–135 U/L	Males: 0.94–2.89 μkat/L Females: 0.51–2.3 μkat/L
Creatinine	0.6–1.2 mg/dL	53–115 μmol/L
Calcium (Ca)	8.2–10.2 mEq/l	2.05–2.54 mmol/L
Magnesium (Mg)	1.3–2.1 mg/dL	0.65–1.05 mmol/L
Bilirubin (direct/indirect)	<0.5–1.1 mg/dL	<6.8–19 μmol/L
Amylase	25–85 U/L	0.39–1.45 μkat/L
Lipase	<160 U/L	<2.72 μkat
Anion Gap	8–14 mEq/L	8–14 mmol/L
Lactate	0.93–1.65 mEql/L	0.93–1.65 mmol/L
Alanine Aminotransferase (ALT, GPT)	8–50 IU/L	0.14–0.85 μkat/L
Aspartate Aminotransferase (AST, GOT)	7–46 U/L	0.12–0.78 μkat/L
Hemotologic Studies		
Red Blood Cells	Males: 4.5–5.5 million/μL Females: 4–5 million/μL	4.5–5.5 x 10^{12}/L 4–5 x 10^{12}/L
White Blood Cells (WBC)	4,000–10,000/μL	4–10 x 10^{9}/L
Hemoglobin (Hgb)	Males: 12.4–17.4 g/dL Females: 11.7–16 g/dL	124–174 g/L 117–160 g/L
Hematocrit (Hct)	Males: 42%–52% Females: 36%–48%	0.42–0.52 0.36–0.48

Test	Conventional Units (Reference Values*)	SI Units
Lipids/Lipoproteins Studies		
Total Cholesterol: Desirable Range	Males: <205 mg/dL Females: <190 mg/dL	<5.3 mmol/L <4.9 mmol/L
LDL Cholesterol: Desirable Range	<130 mg/dL	<3.36 mmol/L
HDL Cholesterol: Desirable Range	Males: 37–70 mg/dL Females: 40–85 mg/dL	0.96–1.8 mmol/L 1.03–2.2 mmol/L
Triglycerides	Males: 44–180 mg/dL Females: 11–190 mg/dL	0.44–2.01 mmol/L 0.11–2.21 mmol/L
Coagulation Studies		
Platelet Count	150,000–400,000/mm^3	
Prothrombin Time (PT)	10–13 sec	
International Normalized Ratio (INR)	2.0–3.0 for pts. on warfarin therapy; 2.5–3.5 for pts. with mech. prosthetic heart valves	
Plasma Thrombin Time (PTT)	60–70 sec	
Activated Partial Thromboplastin Time (APTT)	35–45 sec	
Activated Clotting Time (ACT)	107 ± 13 sec	
Fibrin Split Product (FSP)	<10 μg/mL	<10 mg/L
D-dimer	Neg. or <250 μg/L	
Fibrinogen	200–400 mg/dL	2–4 g/L

SI Units = International Units

Reference Values vary by regional laboratory techniques and methods.

Test	Conventional Units (Reference Values*)	SI Units
Cardiac Biomarkers		
Creatine kinase (CK)	Males: 55–170 U/L Females: 30–135 U/L	0.94–2.89 μkat/L 0.51–2.3 μkat/L
CK isoenzymes: CK-MM (muscle) CK-MB (myocardial) With AMI CK-MB: Onset: 4–6 hours Peak: 12–24 hours Duration: 2 days	 95–100% 0–5%	
Troponin I With AMI: Onset: 4–6 hours Peak: 10–24 hours Duration: 7–10 days	0–0.2 ng/mL	
Myoglobin With AMI: Onset: 2–4 hours Peak: 8–12 hours Duration: 24–30 days	Males: 20–90 ng/mL Females: 10–75 ng/mL	
Other Cardiac Tests		
High sensitivity C-reactive Protein (hs-CRP)	Low: <1.0 mg/L Average: 1.0–3.0 mg/L High: >3.0 mg/L	
B-type natiuretic peptide (BNP)	<100 pg/mL	

SI Units = International Units

**Reference Values vary by regional laboratory techniques and methods.*

References

ADVANCING CRITICAL CARE
THROUGH SCIENCE-BASED EDUCATION

SINCE 1972

References

ANATOMY AND PHYSIOLOGY

Alspach JG. Core curriculum for critical care nursing. 6th ed. St. Louis: Saunders Elsevier; 2006.

Braunwald E. Heart disease: a textbook of cardiovascular medicine. 7th ed. Philadelphia: Elsevier Saunders; 2005.

Dantzker DR, Scharf SM. Cardiopulmonary critical care. 3rd ed. Philadelphia: WB Saunders Company; 1998.

Darovic GO. Hemodynamic monitoring: invasive and noninvasive clinical application. 3rd ed. Philadelphia: Saunders; 2002.

Fink MP, Abraham E, Vincent JL, Kochanek PM. Textbook of critical care. 5th ed. Philadelphia: Elsevier Saunders; 2005.

Guyton AC, Hall JE. Textbook of medical physiology. 11th ed. Philadelphia: Elsevier Inc.; 2006.

Headley JM. Strategies to optimize the cardiorespiratory status of the critically ill. AACN Clinical Issues in Critical Care Nursing. 1995;6(1):121-134.

Headley JM, Diethorn ML. Right ventricular volumetric monitoring. AACN Clinical Issue. 1993;4(1):120-133.

McGee WT, Jodka P: Oxygen transport and tissue oxygenation. In: Higgins TL, Steingrub JS, Kacmarek RM, Stoller JK. Cardiopulmonary Critical Care. BIOS Scientific Publishers, Ltd. Oxford UK; 2002. pp. 35-46.

McGee WT, Veremakis C, Wilson GL. Clinical importance of tissue oxygenation and use of the mixed venous blood gas. Res Medica. 1988;4(2):15-24.

Perret C, Tagan D, Feihl F, Marini JJ. The pulmonary artery catheter in critical care. Cambridge: Blackwell Science Inc.; 1996.

Thelan LA, Davie JK, Urden LD, Lough ME. Critical care nursing: diagnosis and management. 2nd ed. St. Louis: Mosby; 1994.

Woods SL, Froelicher ESS, Motzer SU, Bridges EJ. Cardiac nursing. 5th ed. Philadelphia: Lippincott Williams & Wilkins; 2005.

BASIC MONITORING

Pressure Monitoring

Civetta JM, Taylor RW, Kirby RR. Critical care. 2nd ed. Philadelphia: J.B. Lippincott; 2002.

Daily EK, Schroeder JS. Techniques in bedside hemodynamic monitoring. 5th ed. St. Louis: Mosby; 1994.

Darovic, GO. Hemodynamic monitoring: invasive and noninvasive clinical application. 3rd ed. Philadelphia: Saunders; 2002.

Fawcett J. Hemodynamic Monitoring Made Easy. 1st ed. Baillere Tindall; 2005. 240p.

Headley, JM. Advanced Monitoring of Critical Functions. Springhouse Corporation; 1994. Chapter 3, Techniques of Pressure Monitoring.

Headley, JM. Advanced Monitoring of Critical Functions. Springhouse Corporation; 1994. Chapter 5, Monitoring Pulmonary Artery and Central Venous Pressures.

Imperial-Perez F, McRae M, Gawlinski A, Keckeisen M, Jesurum J. AACN protocols for practice: Hemodynamic Monitoring. 1998.

Mims BC, Toto KH, Luecke LE, Roberts MK, Brock JD, Tyner TE. Critical care skills: a clinical handbook. 2nd ed. St. Louis: Saunders; 2004.

Woods SL, Froelicher ESS, Motzer SU, Bridges EJ. Cardiac nursing. 5th ed. Philadelphia: Lippincott Williams & Wilkins; 2005.

Central Venous Access

Ayres SM, Grenvik A, Holbrook PR, Shoemaker WC. Textbook of critical care. 3rd ed. Philadelphia: WB Saunders; 1995.

Baranowski L. Central venous access devices: current technologies, uses and management strategies. J Intravenous Nurs. 1993;16:167-194.

Calkins DR, et al. 5 million lives campaign. Getting started kit: prevent central line infections how-to guide. Cambridge, MA: Institute for Healthcare Improvement; 2008.

Darouiche RO, Raad I, Heard J, Thornby JI, Wenker OC, Gabrielli A, et al. A comparison of two antimicrobial-impregnated central venous catheters. Catheter Study Group. N Engl J Med. 1999;340(1):1-8.

Hanna H, Bahna P, Reitzel R, Dvorak T, et al. Comparative *in vitro* efficacies and antimicrobial durabilities of novel antimicrobial central venous catheters. Amer Society Microbiology. 2006;50(10):3283-3288.

Haxhe JJ, D'Hoore W. A meta-analysis dealing with the effectivensss of chlorhexidine and silver sulfadiazine impregnated central venous catheters. J Hosp Infect. 1998;40(2):166-168.

Kaplan JA. Cardiac anesthesia. 3rd ed. Philadelphia: WB Saunders; 1993.

Laster J, Silver D. Heparin-coated catheters and heparin-induced thrombocytopenia. J Vasc Surg. 1988;7(5):667-672.

Maki DG, Stolz SM, Wheeler S. Prevention of central venous catheter-related bloodstream infection by use of an antiseptic-impregnated catheter. A randomized, controlled trial. Ann Intern Med. 1997;127(4):3257-266.

Maschke SP, Rogove HJ. Cardiac tamponade associated with a multi-lumen central venous catheter. Crit Care Med. 1984;12(7):611-613.

McGee WT, Mallory DL. Cannulation of the internal and external jugular veins. In: Kirby RR, Taylor RW. Problems in Critical Care. Philadelphia: JP Lippincott Co; 1988. pp. 217-241.

McGee WT, Steingrub JS, Higgins TL. Techniques of vascular access for invasive hemodynamic monitoring. In: Higgins TL, Steingrub JS, Kacmarek RM, Stoller JK. Cardiopulmonary Critical Care. Oxford UK: BIOS Scientific Publishers; 2002. pp. 381-399.

Mermel L, Stolz S, Maki D. Surface antimicrobial activity of heparin-bonded and antiseptic-impregnated vascular catheters. J Infect Dis. 1993;167:920-924.

NICE: Guidance on the use of ultrasound locating devices for placing central venous catheters. National Institute for Clinical Excellence. Tech Appraisal No. 49.

O'Grady NP, Alexander M, Dellinger EP, et al. Guidelines for the prevention of intravascular catheter-related infections. MMWR. 2002;51(RR-10):1-29.

Pemberton LB, Ross V, Cuddy P, et al. No difference in catheter sepsis between standard and antiseptic central venous catheters. A prospective randomized trial. Arch Surg. 1996;131(9):986-989.

Raad II. Vascular catheters impregnated with antimicrobial agents: present knowledge and future direction. Infect Control Hosp Epidemiol. 1997;18(4):227-229.

Randolph AG, Cook DJ, Gonzales CA, Andrew M. Benefit of heparin in central venous and pulmonary artery catheters. CHEST. 1998;113:165-71.

Russell LM, Weinstein RA. Antimicrobial-coated central venous catheters–icing on the cake or the staff of life? Crit Care Med. 1998;26(2):195-196.

Veenstra DL, Saint S, Saha S, et al. Efficacy of antiseptic-impregnated central venous catheters in preventing catheter-related bloodstream infection: a meta-analysis. JAMA. 1999;281(3):261-267.

ADVANCED MINIMALLY INVASIVE MONITORING

FloTrac

Biais M, Nouette-Gaulain K, Cottenceau V, Revel P, Sztark F. Uncalibrated pulse contour-derived stroke volume variation predicts fluid responsiveness in mechanically ventilated patients undergoing liver transplantation. Br J Anaesth. 2008 Dec; 101(6):761-8. Epub 2008 Oct 12.

Button D, Weibel L, Reuthebuch O, Genoni M, Zollinger A, Hofer CK. Clinical evaluation of the FloTrac/Vigileo system and two established continuous cardiac output monitoring devices in patients undergoing cardiac surgery. Br J Anaesth. 2007 Sep; 99(3):329-36. Epub 2007 Jul 12.

Collange O, Xavier L, Kuntzman H, Calon B, Schaeffer R, Pottecher T, Diemunsch P, Pessaux P. FloTrac for monitoring arterial pressure and cardiac output during phaeochromocytoma surgery. Eur J Anaesthesiol. 2008 Sep; 25(9):779-80. Epub 2008 May 14.

Headley, JM. Arterial Pressure Based Technologies: A New Trend in Cardiac Output Monitoring. Critical Care Nursing Clinics of North America. Elsevier Saunders; 2006.

Hofer CK, Senn A, Weibel L, Zollinger A. Assessment of stroke volume variation for prediction of fluid responsiveness using the modified FloTrac and PiCCOplus system. Crit Care. 2008; 12(3):R82. Epub 2008 Jun 20.

Kobayashi M, Ko M, Kimura T, Meguro E, Hayakawa Y, Irinoda T, Takagane A. Perioperative monitoring of fluid responsiveness after esophageal surgery using stroke volume variation. Expert Rev Med Devices. 2008 May; 5(3):311-6.

Manecke GR. Edwards FloTrac sensor and Vigileo monitor: easy, accurate, reliable cardiac output assessment using the arterial pulse wave. Expert Rev Med Devices. 2005 Sep; 2(5):523-7.

Mayer J, Boldt J, Wolf MW, Lang J, Suttner S. Cardiac output derived from arterial pressure waveform analysis in patients undergoing cardiac surgery: validity of a second generation device. Anesth Analg. 2008 Mar; 106(3):867-72.

McGee W, Horswell J, Calderon J, et al. Validation of a continuous, arterial pressure-based cardiac output measurement: a multicenter, prospective clinical trial. Critical Care. 2007; 11(5):R105.

Mehta Y, Chand RK, Sawhney R, Bhise M, Singh A, Trehan N. Cardiac output monitoring: comparison of a new arterial pressure waveform analysis to the bolus thermodilution technique in patients undergoing off-pump coronary artery bypass surgery. J Cardiothorac Vasc Anesth. 2008 Jun; 22(3):394-9.

Pratt B, Roteliuk L, Hatib F, Frazier J, Wallen RD. Calculating arterial pressure-based cardiac output using a novel measurement and analysis method. Biomed Instrum Technol. 2007 Sep-Oct; 41(5):403-11.

Zimmermann A, Kufner C, Hofbauer S, Steinwendner J, Hitzl W, Fritsch G, Schistek R, Kirnbauer M, Pauser G. The accuracy of the Vigileo/FloTrac continuous cardiac output monitor. J Cardiothorac Vasc Anesth. 2008 Jun; 22(3):388-93. Epub 2008 Jan 22.

Passive Leg Raising

Biais M, Nouette-Gaulain K, Cottenceau V, Revel P, Sztark F. Uncalibrated pulse contour-derived stroke volume variation predicts fluid responsiveness in mechanically ventilated patients undergoing liver transplantation. Br J Anaesth. 2008 Dec 101(6):761-8.

Edwards Lifesciences, Critical Care Division. Vigileo manual software 1.14. Irvine, CA: Edwards Lifesciences; 2008; 186p.

Grier L. Utilization of stroke volume variation (SVV) in spontaneously breathing critically ill patients to predict fluid responsiveness. Critical Care Medicine. 2006 Dec Suppl; 34(12): A56.

Heenen S, De Backer D, Vincent JL. How can the response to volume expansion in patients with spontaneous respiratory movements be predicted? Critical Care. 2006 Jul 17; 10:R102.

Hofer CK, Senn A, Weibel L, Zollinger A. Assessment of stroke volume variation for prediction of fluid responsiveness using the modified FloTrac and PiCCOplus system. Critical Care 2008 Jun 20; 12:R82.

Jabot J, Teboul JL, Richard C, Monnet X. Passive leg raising for predicting fluid responsiveness: importance of the postural change. Intensive Care Med. Epub 2008 Sep 16.

Kobayashi M, Ko M, Kimura T, Meguro E, Hayakawa Y, Irinoda T, Takagane A. Perioperative monitoring of fluid responsiveness after esphogeal surgery using stroke volume variation. Expert Rev Med Devices. 2008 May;5(3):311-6.

Michard F. Changes in arterial pressure during mechanical ventilation. Anesthesiology. 2005 Aug; 103(2):419-28.

Michard F. Volume Management Using Dynamic Parameters. Chest. 2005; 128:1902-1903.

Monnet X, Teboul JL. Passive Leg Raising. Intensive Care Med. 2008 Apr; 34(4):659-63.

Venous Oximetry

Berkenstadt H, Margalit N, Hadani M, et al. "Stroke Volume Variation as a Predictor of Fluid Responsiveness in Patients Undergoing Brain Surgery." Anesthesia and Analgesia 2001;92:984-9.

Echiadis AS, et al. Non-invasive measurement of peripheral venous oxygen saturation using a new venous oximetry method: evaluation during bypass in heart surgery. Physio. Meas. 2007;28:897-911.

Goodrich C. Continuous Central Venous Oximetry Monitoring. Critical Care Nursing Clinics of North America; 18(2):203-9.

Headley, JM, Giuliano K. Special Pulmonary Procedures; Continuous Mixed Venous Oxygen Saturation Monitoring. In: Lynn-McHale DJ, Carlson KK. AACN Procedure Manual for Critical Care. 6th Edition. Philadelphia: W.B. Saunders Company 2009.

Huber D, Osthaus WA, Optenhofel J, et al. Continuous monitoring of central venous oxygen saturation in neonates and small infants: *in vitro* evaluation of two different oximetry catheters. Pediatric Anesthesia. 2006;16:1257-63.

Kumon K, et al. Continuous measurement of coronary sinus oxygen saturation after cardiac surgery. Crit Care Med. 1987 June; 15(6):595-7.

Ladakis C, Myrianthefs P, Karabinis A, et al. Central venous and mixed venous oxygen saturation in critically ill patients. Respiration 2001;68:279-85.

Liakopoulos O, Ho J, Yezbick A, et al. An experimental and clinical evaluation of a novel central venous catheter with integrated oximetry for pediatric patients undergoing cardiac surgery. International Anesthesia Research Society. 2007;105(6).

McGee WT: A simple physiologic algorithm for managing hemodynamics in the intensive care unit utilizing stroke volume and stroke volume variation. J Inten Care Med 2008. Submitted.

Reinhart K, Kuhn HJ, Hartog C, et al. Continuous central venous and pulmonary artery oxygen saturation monitoring in the critically ill. Intensive Care Med. 2004;30:1572-8.

Rivers E, Nguyen B, Havstad S, et al. Early goal-directed therapy in the treatment of severe sepsis and septic shock. N Engl J Med. 2001;345:1368–1377.

Rivers EP, Ander DS, Powell D. Central venous oxygen saturation monitoring in the critically ill patient. Curr Opin Crit Care. 2001;7:204-11.

Schell RM, Cole DJ. Cerebral monitoring: jugular venous oximetry. Anesth Analg 2000;90:559-66.

Spenceley N. Continuous central venous saturations during pericardial tamponade: Case Report.

Takano H, et al. Hepatic venous oxygen saturation monitoring in patients with assisted circulation for severe cardiac failure. Artif. Organs. 1991 Jun;15(3):248-52.

Zaja J: Venous oximetry. Signa Vitae 2007; 2(1):6-10.

SWAN-GANZ CATHETERS ADVANCED AND STANDARD TECHNOLOGY

Alspach JG (ed.). Core Curriculum for Critical Care Nursing. 6th ed. St. Louis: Saunders Elsevier; 2006.

Daily EK, Schroeder JS. Techniques in bedside hemodynamic monitoring. 5th ed. St. Louis: Mosby; 1994.

Darovic, GO. Hemodynamic monitoring: invasive and noninvasive clinical application. 3rd ed. Philadelphia: Saunders; 2002.

Headley, JM. Invasive Hemodynamic Monitoring: Applying Advanced Technologies. Critical Care Nursing Quarterly. 1998;21:3:73-84.

Headley, JM. Puzzled by Continuous Cardiac Output Monitoring? Nursing '97. 1997; 32aa - 32dd.

Headley, JM. Special Pulmonary Procedures; Continuous Mixed Venous Oxygen Saturation Monitoring. In: Lynn-McHale DJ, Carlson KK. AACN Procedure Manual for Critical Care. 5th Edition. Philadelphia.: W.B. Saunders Company; 2005.

Imperial-Perez F, McRae M, Gawlinski A, Keckeisen M, Jesurum J. AACN protocols for practice: Hemodynamic Monitoring. 1998.

Leeper B. Monitoring right ventricular volumes: a paradigm shift. AACN Clin Issues. 2003 May; (14):208-19.

Mims BC, Toto KH, Luecke LE, Roberts MK, Brock JD, Tyner TE. Critical care skills: a clinical handbook. 2nd ed. St. Louis: Saunders; 2004.

Perret C, Tagan D, Feihl F, Marini JJ. The pulmonary artery catheter in critical care. Cambridge: Blackwell Science Inc.; 1996.

Pinsky MR, Vincent JL. Let us use the pulmonary artery catheter correctly and only when we need it. Crit Care Med. 2005 May;33(5):1119-22.

Thelan LA, Davie JK, Urden LD, Lough ME. Critical care nursing: diagnosis and management. 2nd ed. St. Louis: Mosby; 1994.

Vincent JL, Pinsky MR, Sprung CL, Levy M, Marini JJ, Payen D, Rhodes A, Takala J. The pulmonary artery catheter: in medio virtus. Crit Care Med. 2008 Nov;36(11):3093-6.

Woods SL, Froelicher ESS, Motzer SU, Bridges EJ. Cardiac nursing. 5th ed. Philadelphia: Lippincott Williams & Wilkins; 2005.

Zink W, Nöll J, Rauch H, Bauer H, Desimone R, Martin E, Böttiger BW. Continuous assessment of right ventricular ejection fraction: new pulmonary artery catheter versus transoesophageal echocardiography. Anaesthesia. 2004 Nov;59(11):1126-32.

QUICK REFERENCE SECTION

Abramo L, Alexander IV, Bastien D, Bussear EW, et al. Professional guide to diagnostic tests. Philadelphia: Lippincott Williams & Wilkins; 2005.

Alspach JG. Core curriculum for critical care nursing. 6th ed. St. Louis: Saunders Elsevier; 2006.

Antman EM, Anbe DT, Armstrong PW, et al. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction. Circulation. 2004;110:588-636.

Chulay M, Burns SM. AACN essentials of critical care nursing pocket handbook. McGraw-Hill, 2006.

Field JM, Hazinski MF, Gilmore D. Handbook of emergency cardiovascular care. American Heart Association. 2006.

Forrester JS, Diamond G, Chatterjee K, Swan HJC. Medical therapy of acute myocardial infarction by application of hemodynamic subsets. NEJM. 1976;295(24):1356-1362.

Frishman WH, Cheng-Lai A, Nawarskas J. Current cardiovascular drugs. 4th ed. Philadelphia: Current Medicine; 2005.

Headley JM. Strategies to optimize the cardiorespiratory status of the critically ill. AACN Clinical Issues in Critical Care Nursing. 1995;6(1):121-134.

Knaus WA, Draper EA, Wagner DP, Zimmerman JE. APACHE II: A severity of disease classification system. Crit Care Med. 1985;13(10):818-829.

McGee WT, Mailloux P, Jodka P, Thomas J. The pulmonary artery catheter in critical care. Seminars in Dialysis. 2006;19(6):480-491.

Malholtra PK, Kakani M, Chowdhury U, Choudhury M, Lakshmy R, Kiran U. Early goal-directed therapy in moderate to high-risk cardiac surgery patients. Ann Card Anaesth 2008;11:27-34.

Mims BC, Toto KH, Luecke LE, Roberts MK, Brock JD, Tyner TE. Critical care skills: a clinical handbook. 2nd ed. St. Louis: Saunders; 2004.

Opie LH, Gersh BJ. Drugs for the heart. 6th ed. Philadelphia: Elsevier Saunders; 2005.

Perret C, Tagan D, Feihl F, Marini JJ. The pulmonary artery catheter in critical care. Cambridge: Blackwell Science Inc.; 1996.

Pinsky MR, Vincent J. Let us use the pulmonary artery catheter correctly and only when we need it. Crit Care Med. 2005;33(5):1119-1121.

Rivers E, Nguyen B, Havstad S, et al. Early goal-directed therapy in the treatment of severe sepsis and septic shock. N Engl J Med. 2001;345(19):1368-1377.

Vallet B, Tytgat H, Lebuffe G. How to titrate vasopressors against fluid loading in septic shock. Advances in Sepsis. 2007;6(2):34-40.

Wilson RF. Critical care manual: applied physiology and principles of therapy. 2nd ed. Philadelphia: FA Davis Company; 1992.

Woods SL, Froelicher ESS, Motzer SU, Bridges EJ. Cardiac nursing. 5th ed. Philadelphia: Lippincott Williams & Wilkins; 2005.

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