AMERICAN ASSOCIATION of CRITICAL-CARE NURSES

AACN

Essentials of Critical Care Nursing

POCKET HANDBOOK

Marianne Chulay
Suzanne M. Burns

SECOND EDITION

AACN Essentials of Critical Care Nursing—Pocket Handbook

Notice

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Second Edition

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New York Chicago San Francisco Lisbon London Madrid Mexico City Milan
New Delhi San Juan Seoul Singapore Sydney Toronto

ISBN: 978-0-07-170273-7

MHID: 0-07-170273-3

The material in this eBook also appears in the print version of this title: ISBN: 978-0-07-166408-0, MHID: 0-07-166408-4.

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Preface

Given the complexity of critical care practice today, it's impossible for even experienced clinicians to remember all the information required to give safe and effective care to critically ill patients. Clinicians frequently need to use a variety of clinical resources to verify drug information, normal laboratory and physiologic values, ECG and hemodynamic monitoring information, emergency algorithms, and other essential facts of patient management.

To save time and avoid frustration, clinicians often create their own "pocket guides" by cutting and pasting together information from a variety of sources so they always have a quick reference source available. The *AACN Essentials of Critical Care Nursing Pocket Handbook* is designed to provide busy clinicians with an easy to use resource that can, literally, be kept in their pockets. The pocket handbook contains selected tables and figures from the textbook, *AACN Essentials of Critical Care Nursing,* and includes items that clinicians are most likely to need at their fingertips:

- Critical care drug tables (common vasoactive drugs, neuromuscular blocking agents, antiarrhythmics, IV medication guidelines)
- Normal values table for laboratory tests and physiologic parameters
- Lists of assessment components
- Cardiac rhythms: ECG characteristics and treatment guides including sample rhythm strips
- 12-lead ECG changes in acute myocardial ischemia and infarct
- Troubleshooting guides for hemodynamic monitoring equipment
- Indications for mechanical ventilation
- Weaning assessment tool
- Chest x-ray interpretation

We hope this pocket book will, indeed, be placed in your pocket and assist you in making a difference in the lives of the patients and families you encounter.

Marianne Chulay
Suzi Burns

To our critical care nursing colleagues around the world whose wonderful work and efforts ensure the safe passage of patients through the critical care environment.

Normal Values

Section 1

1.1 ► Normal Values Table

Abbreviation	Definition	Normal Value	Formula
BSA	Body surface area	Meters squared (m^2)	Value obtained from a nomogram based on height and weight
$C(a-v)O_2$	Arteriovenous oxygen content difference	4-6 mL/100 mL	$C(a-v)O_2$ (mL/100 mL or vol %) = $CaO_2 - CvO_2$
CaO_2	Arterial oxygen content	Will vary with hemoglobin concentration and Pa_{O_2} on air from 19-20 mL/100 mL	CaO_2 (mL O_2/100 mL blood or vol %) = (Hb × 1.39) SaO_2 + (Pa_{O_2} × 0.0031)
CI	Cardiac index	2.5-3.0 L/min/m^2	$CI\ (L/min/m^2) = \frac{\text{cardiac output (L/min)}}{\text{body surface area } (m^2)}$
CK	Creatinine kinase	<150 mcg/L	
CK-MB	Creatinine kinase MB band	<10 ng/mL or <3% of total	
CO	Cardiac output	4-6 L/min	CO = Stroke volume × heart rate
CvO_2	Mixed venous oxygen content	Will vary with CaO_2, cardiac output, and O_2 consumption from 14-15 mL/100 mL	
CVP	Central venous pressure	2-8 mm Hg	
dp/dt	First time derivative of left ventricular pressure	13-14 seconds	
EDC	Effective dynamic compliance	35-45 mL/cm H_2O women 40-50 mL/cm H_2O men	$EDC\ (mL/cm\ H_2O) = \frac{\text{tidal volume (mL)}}{\text{peak airway pressure (cm } H_2O)}$
EDV	End-diastolic volume	50-90 mL	
EF	Ejection fraction	70%	$\text{Ejection fraction} = \frac{SV}{EDV}$

1.1 ► Normal Values Table (*continued*)

Abbreviation	Definition	Normal Value	Formula
FRC	Functional residual capacity	2400 mL	
HR	Heart rate	60-90 beats/min	
IF	*Inspiratory force*	75-100 cm H_2O	
LVSW	Left ventricular stroke work	8-10 g/m/m^2	$LVSW = SI \times MAP \times 0.0144$
MAP	Mean systemic arterial pressure	$>$ 70 mm Hg	$\text{Map estimate} = \dfrac{(\text{Systolic} + 2\ \text{Diastolic})}{3}$
O_2 availability	Oxygen availability	550-650 mL/min/m^2	$O_2\ \text{availability (mL/min/m}^2) = CI \times CaO_2 \times 10$
O_2 extraction ratio	Oxygen extraction ratio	0.25	$O_2\ \text{extraction ratio} = \dfrac{C(a-v)O_2}{CaO_2}$
$P(A-a)o_2$	Alveolar-arterial oxygen gradient	25-65 mm Hg at $Fio_2 = 1.0$	$P(A-a)o_2\ (\text{mm Hg}) = PAo_2 - Pao_2$
$P(A-a)o_2$	Mean partial pressure of oxygen in alveolus	104 mm Hg	
$P(A-a)co_2$	Partial pressure of carbon dioxide in alveolus	40 mm Hg	
$Paco_2$	Partial pressure of carbon dioxide in arterial blood	35-45 mm Hg	
PAD	Pulmonary artery diastolic	5-12 mm Hg	

1.1 ► Normal Values Table (*continued*)

Abbreviation	Definition	Normal Value	Formula
Pa_{O_2}	Partial pressure of oxygen in arterial blood	Will vary with patient's age and the Fi_{O_2}. On room air: 80-95 mm Hg. On 100% O_2: 640 mm Hg	
PAS	Pulmonary artery 54 systolic pressure	16-24 mm Hg	
PCWP	Mean pulmonary capillary wedge pressure	5-12 mm Hg	
Pv_{CO_2}	Partial pressure of carbon dioxide in mixed venous blood	41-51 mm Hg	
Pv_{O_2}	Partial pressure of oxygen in mixed venous blood	Will vary with the Fi_{O_2}, cardiac output, and oxygen consumption from 35-40 mm Hg	
PVR	Pulmonary vascular resistance	120-200 dynes/s/cm^5 1.5-2.5 mm Hg	$\text{PVR } 5 = (\text{dynes/s/cm}^5) = \dfrac{(\text{PA [mm Hg]} - \text{PCWP [mm Hg]}) \times 79.9}{\text{cardiac output (L/min)}}$
Q_S/Q_T	Right-to-left shunt (percentage of cardiac output flowing past nonventilated alveoli or the equivalent	5%-8%	$Q_S/Q_T(\%) = \dfrac{0.0031 \times P(A-a)O_2}{C(a-v)O_2 + (0.0031 \times P[A-a]O_2)} \times 100$ Valid only when arterial blood is 100% saturated

1.1 ▶ Normal Values Table (*continued*)

Abbreviation	Definition	Normal Value	Formula
R or RQ	Respiratory quotient	0.8	$RQ = \frac{Vco_2}{VO_2}$
RVSW	Right ventricular stroke work	51-61 g/m/m^2	$RVSW = SI \times MPAP \times 0.0144$
SaO_2	Percentage of oxyhemoglobin saturation of arterial blood	96%-100% (air)	
SI	Stroke index	35-50 mL/m^2	$SI\ (mL/min/m^2) = \frac{\text{stroke volume}}{\text{body surface area}}$
SV	Stroke volume	50-100 mL/beat	$SV\ (mL/beat) = \frac{\text{cardiac output (mL)}}{\text{heart rate}}$
SvO_2	Percentage of oxyhemoglobin saturation of mixed venous blood	70-80% (air)	
SVR	Systemic vascular resistance	900-1200 dynes/s/cm^5 10-15 mm Hg (mm Hg $\times$ 80 = dynes/s/cm^5)	$SVR\ (TPR)\ (dynes/s/cm^5) = \frac{(MAP\ [mm\ Hg] - CVP\ [mm\ Hg]) \times 79.9}{\text{cardiac output (L/min)}}$
Troponin I	Troponin I	$<$0.4 ng/mL	
Troponin T	Troponin T	$<$0.1 ng/mL	

1.1 ► Normal Values Table (*continued*)

Abbreviation	Definition	Normal Value	Formula
VC	Vital capacity	65-75 mL/kg	
V_{CO_2}	Carbon dioxide production	192 mL/min	
V_D	Dead space	150 mL	$V_D/V_T = \frac{Paco_2 - Peco_2}{Paco_2}$
V_D/V_T	Dead space to tidal volume ratio	0.25-0.40	
VO_2	Oxygen consumption	115-165 mL/min/m^2	O_2 extraction ratio $= \frac{C(a-v)O_2}{CaO_2}$
V_T	Tidal volume	6-8 mL/kg	

Adapted from: Hall J, Schmidt G, Wood L. Principles of critical care. 3rd ed. *New York: McGraw Hill, 2005; cover tables I-IV.*

Assessment

Section 2

2.1 ► Summary of Prearrival and Admission Quick Check Assessments

Prearrival Assessment

- Abbreviated report on patient (age, gender, chief complaint, diagnosis, pertinent history, physiologic status, invasive devices, equipment, and status of laboratory/diagnostic tests)
- Complete room setup, including verification of proper equipment functioning

Admission Quick Check Assessment

- General appearance (consciousness)
- *A*irway:
  Patency
  Position of artificial airway (if present)
- *B*reathing:
  Quantity and quality of respirations (rate, depth, pattern, symmetry, effort, use of accessory muscles)
  Breath sounds
  Presence of spontaneous breathing
- *C*irculation and *C*erebral Perfusion:
  ECG (rate, rhythm, and presence of ectopy)
  Blood pressure
  Peripheral pulses and capillary refill
  Skin, color, temperature, moisture
  Presence of bleeding
  Level of consciousness, responsiveness
- *C*hief Complaint:
  Primary body system
  Associated symptoms
- *D*rugs and *D*iagnostic Tests:
  Drugs prior to admission (prescribed, over-the-counter, illicit)
  Current medications
  Review diagnostic test results
- *E*quipment:
  Patency of vascular and drainage systems
  Appropriate functioning and labeling of all equipment connected to patient
- Allergies

2.2 ► Summary of Comprehensive Admission Assessment Requirements

Past Medical History
- Medical conditions, surgical procedures
- Psychiatric/emotional problems
- Hospitalizations
- Medications (prescription, over-the-counter, illicit drugs) and time of last medication dose
- Allergies
- Review of body systems (see Table 1-7)

Social History
- Age, gender
- Ethnic origin
- Height, weight
- Highest educational level completed
- Occupation
- Marital status
- Primary family members/significant others
- Religious affiliation
- Advance Directive and Durable Power of Attorney for Health Care
- Substance use (alcohol, drugs, caffeine, tobacco)
- Domestic Abuse or Vulnerable Adult Screen

Psychosocial Assessment
- General communication
- Coping styles
- Anxiety and stress
- Expectations of critical care unit
- Current stresses
- Family needs

Spirituality
- Faith/spiritual preference
- Healing practices

Physical Assessment
- Nervous system
- Cardiovascular system
- Respiratory system
- Renal system
- Gastrointestinal system
- Endocrine, hematologic, and immune systems
- Integumentary system

2.3 ► Suggested Questions for Review of Past History Categorized by Body System

Body System	History Questions
Nervous	• Have you ever had a seizure? • Have you ever fainted, blacked out, or had delirium tremens (DTs)? • Do you ever have numbness, tingling, or weakness in any part of your body? • Do you have any difficulty with your hearing, vision,or speech? • Has your daily activity level changed due to your present condition? • Do you require any assistive devices such as canes?
Cardiovascular	• Have you experienced any heart problems or disease such as heart attacks or strokes? • Do you have any problems with extreme fatigue? • Do you have an irregular heart rhythm? • Do you have high blood pressure? • Do you have a pacemaker or an implanted defibrillator?
Respiratory	• Do you ever experience shortness of breath? • Do you have any pain associated with breathing? • Do you have a persistent cough? Is it productive? • Have you had any exposure to environmental agents that might affect the lungs? • Do you have sleep apnea?
Renal	• Have you had any change in frequency of urination? • Do you have any burning, pain, discharge, or difficulty when you urinate? • Have you had blood in your urine?
Gastrointestinal	• Has there been any recent weight loss or gain? • Have you had any change in appetite? • Do you have any problems with nausea or vomiting? • How often do you have a bowel movement and has there been a change in the normal pattern? Do you have blood in your stools? • Do you have dentures? • Do you have any food allergies?
Integumentary	• Do you have any problems with your skin?
Endocrine	• Do you have any problems with bleeding?
Hematologic	• Do you have problems with chronic infections?
Immunologic	• Have you recently been exposed to a contagious illness?

2.3 ► Suggested Questions for Review of Past History Categorized by Body System (*continued*)

Body System	History Questions	Body System	History Questions
Psychosocial	• Do you have any physical conditions which make communication difficult (hearing loss, visual disturbances, language barriers, etc)? • How do you best learn? Do you need information repeated several times and/or require information in advance of teaching sessions? • What are the ways you cope with stress, crises, or pain? • Who are the important people in your "family" or network? Who do you want to make decisions with you, or for you? • Have you had any previous experiences with critical illness? • Have you ever been abused? • Have you ever experienced trouble with anxiety, irritability, being confused, mood swings, or suicide attempts? • What are the cultural practices, religious influences, and values that are important to the family? • What are family members' perceptions and expectations of the critical care staff and the setting?	Spiritual	• What is your faith or spiritual preference? • What practices help you heal or deal with stress? • Would you like to see a chaplain, priest, or other type of healer?

2.4 ► Ongoing Assessment Template

Body System	Assessment Parameters
Nervous	• LOC • Pupils • Motor strength of extremities
Cardiovascular	• Blood pressure • Heart rate and rhythm • Heart sounds • Capillary refill • Peripheral pulses • Patency of IVs • Verification of IV solutions and medications • Hemodynamic pressures and waveforms • Cardiac output data
Respiratory	• Respiratory rate and rhythm • Breath sounds • Color and amount of secretions • Noninvasive technology information (eg, pulse oximetry, end-tidal CO_2) • Mechanical ventilatory parameters • Arterial and venous blood gases
Renal	• Intake and output • Color and amount of urinary output • BUN/creatinine values
Gastrointestinal	• Bowel sounds • Contour of abdomen • Position of drainage tubes • Color and amount of secretions • Bilirubin and albumin values
Endocrine, hematologic, and immunologic	• Fluid balance • Electrolyte and glucose values • CBC and coagulation values • Temperature • WBC with differential count
Integumentary	• Color and temperature of skin • Intactness of skin • Areas of redness
Pain/discomfort	• Assessed in each system • Response to interventions
Psychosocial	• Mental status and behavioral responses • Reaction to critical illness experience (eg, stress, anxiety, coping, mood) • Presence of cognitive impairments (dementia, delirium), depression, or demoralization • Family functioning and needs • Ability to communicate needs and participate in care • Sleep patterns

2.5 ► Identification of Symptom Characteristics

Characteristic	Sample Questions
Onset	How and under what circumstances did it begin? Was the onset sudden or gradual? Did it progress?
Location	Where is it? Does it stay in the same place or does it radiate or move around?
Frequency	How often does it occur?
Quality	Is it dull, sharp, burning, throbbing, etc?
Intensity	Rank pain on a scale (numeric, word description, FACES, FLACC)
Quantity	How long does it last?
Setting	What are you doing when it happens?
Associated findings	Are there other signs and symptoms that occur when this happens?
Aggravating and alleviating factors	What things make it worse? What things make it better

2.6 ► Chest Pain Assessment

	Ask the Question	Examples
P (Provoke)	What *provokes* the pain or what precipitates the pain?	Climbing the stairs, walking; or may be unpredictable—comes on at rest
Q (Quality)	What is the *quality* of the pain?	Pressure, tightness; may have associated symptoms such as nausea, vomiting, diaphoresis
R (Radiation)	Does the pain *radiate* to locations other than the chest?	Jaw, neck, scapular area, or left arm
S (Severity)	What is the *severity* of the pain (on a scale of 1-10)?	On a scale of 1-10, with 10 being the worst, how bad is your pain?
T (Timing)	What is the *time of onset* of this episode of pain that caused you to come to the hospital?	When did this episode of pain that brought you to the hospital start? Did this episode wax and wane or was it constant? For how many days, months, or years have you had similar pain?

2.7 ► Pain Assessment Tools Commonly Used in Critically Ill Patients

Numeric Rating Scales (NRS)

NRS Verbal (*0 to 10 scale*)	NRS-101 (*0 to 100 scale*)
0 = No pain	0 = No pain
10 = Worst pain imaginable	100 = Worst pain imaginable

Verbal Descriptive Scale

None Mild Moderate Severe

Visual Analog Scale

No pain _____ Worst pain imaginable

2.8 ► CAM-ICU Worksheet

CAM-ICU Worksheet

Feature 1: Acute Onset or Fluctuating Course Positive if you answer 'yes' to either 1A or 1B.	**Positive**	**Negative**
1A: Is the patient different than his/her baseline mental status? Or **1B:** Has the patient had any fluctuation in mental status in the past 24 hours as evidenced by fluctuation on a sedation scale (eg, RASS), GCS, or previous delirium assessment?	**Yes**	**No**
Feature 2: Inattention Positive if either score for 2A or 2B is less than 8. Attempt the ASE letters first. If patient is able to perform this test and the score is clear, record this score and move to Feature 3. If patient is unable to perform this test or the score is unclear, then perform the ASE Pictures. If you perform both tests, use the ASE Pictures' results to score the Feature.	**Positive**	**Negative**
2A: ASE Letters: record score (enter NT for not tested) Directions: Say to the patient, *"I am going to read you a series of 10 letters. Whenever you hear the letter "A," indicate by squeezing my hand."* Read letters from the following letter list in a normal tone. **S A V E A H A A R T** Scoring: Errors are counted when patient fails to squeeze on the letter "A" and when the patient squeezes on any letter other than "A."	**Score (out of 10): _____**	
2B: ASE Pictures: record score (enter NT for not tested) Directions are included on the picture packets.	**Score (out of 10): _____**	

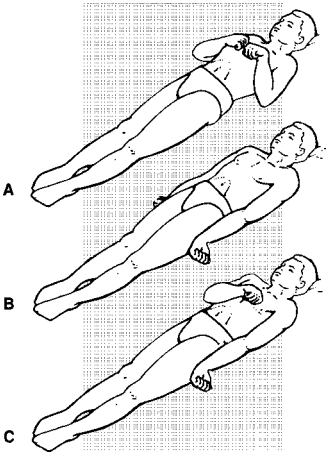
Feature 3:Disorganized Thinking Positive if the combined score is less than 4	**Positive**	**Negative**
3A: Yes/No Questions (Use either Set A or Set B, alternate on consecutive days if necessary)**:** **Set A** 1. Will a stone float on water? 2. Are there fish in the sea? 3. Does one pound weigh more than two pounds? 4. Can you use a hammer to pound a nail? **Set B** 1. Will a leaf float on water? 2. Are there elephants in the sea? 3. Do two pounds weigh more than one pound? 4. Can you use a hammer to cut wood? **Score** ___(Patient earns 1 point for each correct answer out of 4) **3B:Command** Say to patient: "Hold up this many fingers" (Examiner holds two fingers in front of patient) "Now do the same thing with the other hand" (Not repeating the number of fingers). *If patient is unable to move both arms, for the second part of the command ask patient "Add one more finger." **Score**___(Patient earns 1 point if able to successfully complete the entire command)	**Combined Score (3A+3B):** **_____ (out of 5)**	
Feature 4: Altered Level of Consciousness Positive if the Actual RASS score is anything other than "0" (zero)	**Positive**	**Negative**
Overall CAM-ICU (Features 1 and 2 and either Feature 3 or 4):	**Positive**	**Negative**

Confusion Assessment Method for the intensive care unit (CAM-ICU) worksheet. Delirium is diagnosed when both I and II are positive, along with either III or IV. (*With permission from: E. Wesley Ely, MD, MPH, Vanderbilt University, Nashville, TN, 2002; complete training manual is available at www.ICUdelirium.org*).

2.9 ► Glasgow Coma Scale

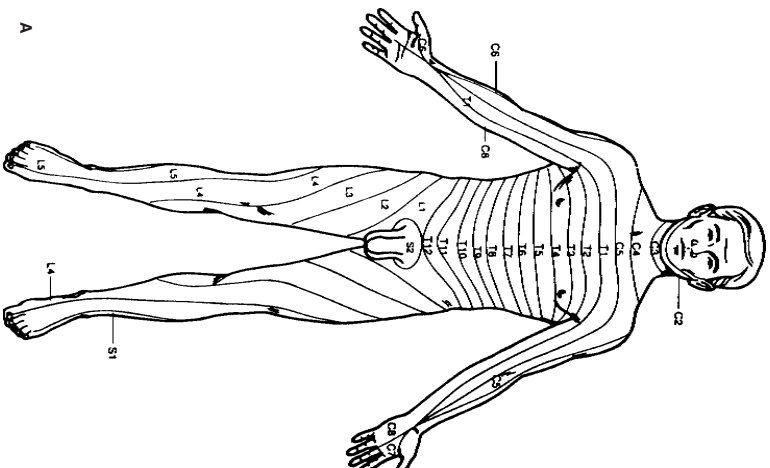
Behavior	Score[a]
Eye Opening (E)	
Spontaneous	4
To verbal stimuli	3
To pain	2
None	1
Motor Response (M)	
Obeys commands	6
Localizes pain	5
Withdraws to pain	4
Abnormal flexion	3
Extensor response	2
None	1
Verbal Response (V)	
Oriented	5
Confused	4
Inappropriate words	3
Incomprehensible sounds	2
None	1

[a]Coma score = E + M + V (scores range 3-15).



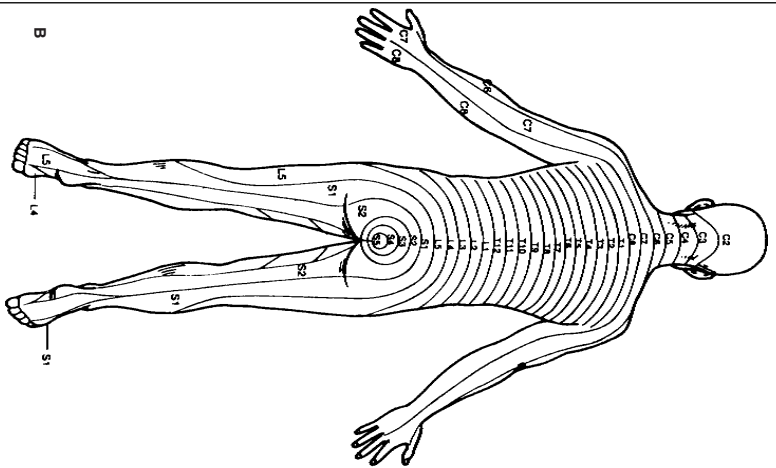
► Abnormal motor responses. **(A)** Decorticate posturing. **(B)** Decerebrate posturing. **(C)** Decorticate posturing on right side and decerebrate posturing on left side of body. (*Reprinted from: Carlson BA. Neurologic clinical assessment. In: Urden LD, Stacy KM, Lough ME, eds.* Thelan's Critical Care Nursing: Diagnosis and Management. *St Louis, MO: Mosby; 2002:649.*)

2.10 ► Sensory Dermatomes.



(A) Anterior view.

2.10 ► Sensory Dermatomes (*continued*)



(B) Posterior view. (*Reprinted from: Carlson BA. Neurologic anatomy and physiology. In: Urden LD, Stacy KM, Lough ME, eds.* Thelan's Critical Care Nursing: Diagnosis and Management. *St Louis, MO: Mosby; 2002: 641.*)

2.11 ► Edema Rating Scale

Following the application and removal of firm digital pressure against the tissue, the edema is evaluated for one of the following responses:

- 0 No depression in tissue
- +1 Small depression in tissue, disappearing in <1 second
- +2 Depression in tissue disappears in <1-2 second
- +3 Depression in tissue disappears in <2-3 second
- +4 Depression in tissue disappears in ≥4 second

2.12 ► Peripheral Pulse Rating Scale

- 0 Absent pulse
- +1 Palpable but thready; easily obliterated with light pressure
- +2 Normal; cannot obliterate with light pressure
- +3 Full
- +4 Full and bounding

2.13 ► Physiologic Effects of Aging

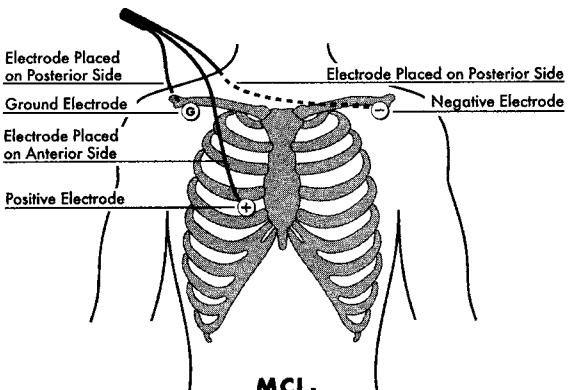
Body System	Effects
Nervous	Diminished hearing and vision, short-term memory loss, altered motor coordination, decreased muscle tone and strength, slower response to verbal and motor stimuli, decreased ability to synthesize new information, increased sensitivity to altered temperature states, increased sensitivity to sedation (confusion or agitation), decreased alertness levels
Cardiovascular	Increased effects of atherosclerosis of vessels and heart valves, decreased stroke volume with resulting decreased cardiac output, decreased myocardial compliance, increased workload of heart, diminished peripheral pulses
Respiratory	Decreased compliance and elasticity, decreased vital capacity, increased residual volume, less effective cough, decreased response to hypercapnia
Renal	Decreased glomerular filtration rate, increased risk of fluid and electrolyte imbalances
Gastrointestinal	Increased presence of dentition problems, decreased intestinal mobility, decreased hepatic metabolism, increased risk of altered nutritional states
Endocrine, hematologic, and immunologic	Increased incidence of diabetes, thyroid disorders, and anemia; decreased antibody response and cellular immunity
Integumentary	Decreased skin turgor, increased capillary fragility and bruising, decreased elasticity
Miscellaneous	Altered pharmacokinetics and pharmacodynamics, decreased range of motion of joints and extremities
Psychosocial	Difficulty falling asleep and fragmented sleep patterns, increased incidence of depression and anxiety, cognitive impairment disorders, difficulty with change

ECG Concepts

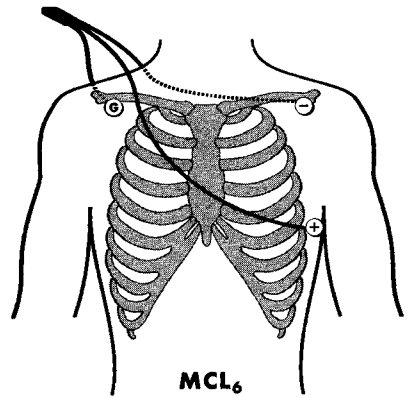
Section 3

NORMAL VALUES

3.1 ► ECG Lead Placement for a Three-Wire System

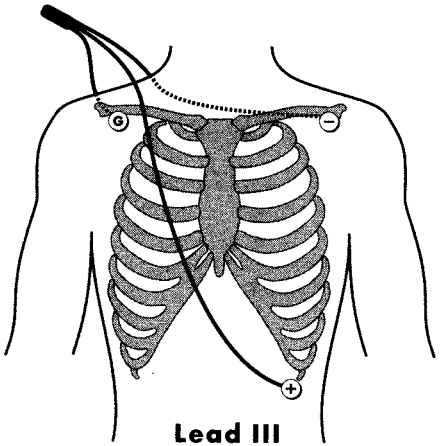


Lead MCL_1: ground electrode on the posterior right shoulder, negative electrode on the posterior left shoulder, and positive electrode in the V_1 position (fourth intercostal space, right of the sternum).

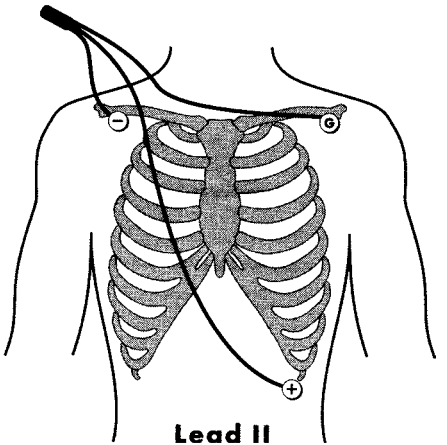


Lead MCL_6: ground electrode on the posterior right shoulder, negative electrode on the posterior left shoulder, and positive electrode in the V_6 position (horizontal from V_4 in the midaxillary line).

3.1 ► ECG Lead Placement for a Three-Wire System (*continued*)

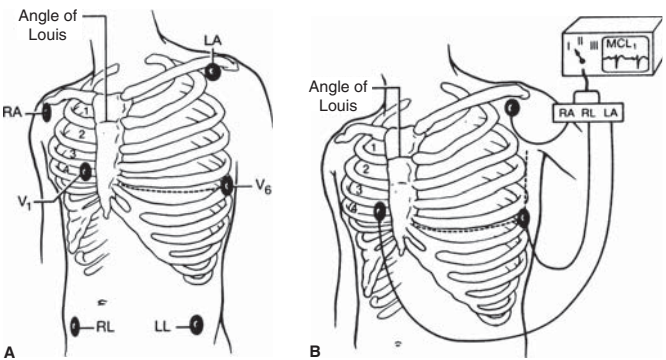


Lead III: the positive electrode is placed on the upper left abdomen.



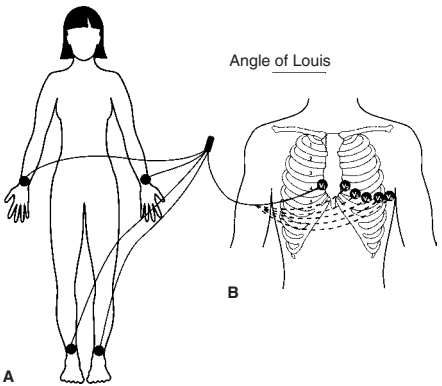
Lead II: ground electrode on the left shoulder, negative electrode on right shoulder, and positive electrode on the left lower rib cage.

3.2 ► ECG Lead Placement for a Five-Wire System



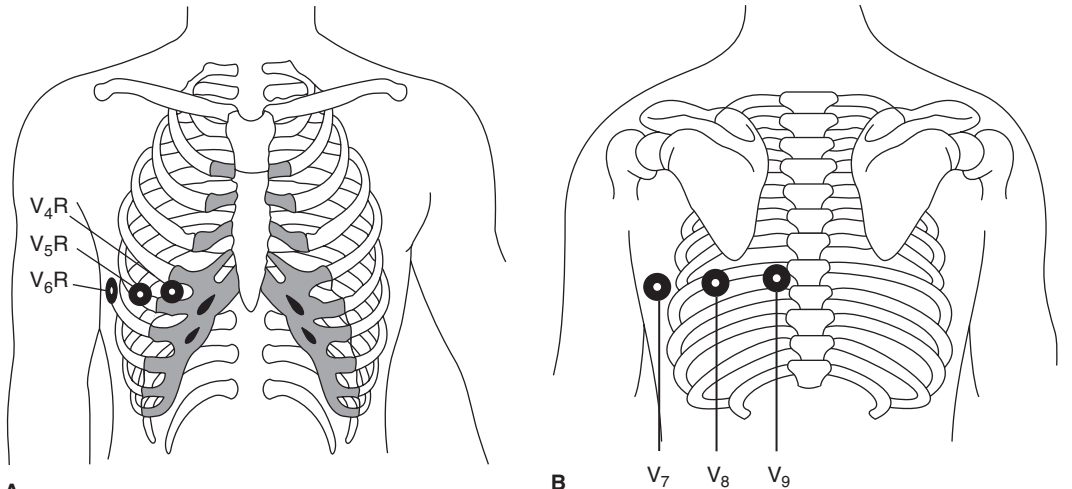
(A) Correct electrode placement for using a 5-wire monitoring cable. Right and left arm electrodes are placed on the shoulders and right and left leg electrodes are placed low on the thorax or on the hips. With the arm and leg electrodes placed as illustrated, leads I, II, III, aVR, aVL, and aVF can be obtained by selecting the desired lead on the bedside monitor. To obtain lead V_1 place the chest lead in the fourth intercostal space at the right sternal border and select "V" on the bedside monitor. To obtain lead V_6, place the chest lead in the fifth intercostal space at the left midaxillary line and select "V" on the bedside monitor. **(B)** Correct lead placement for obtaining MCL_1 and MCL_6 using a 3-wire lead system. Place the right arm electrode on the left shoulder; the left arm electrode in the fourth intercostal space at the right sternal border; and the left leg electrode in the fifth intercostal space at the left midaxillary line. To monitor in MCL_1, select lead I on the bedside monitor. To monitor in MCL_6, select lead II on the bedside monitor. (*Adapted from Drew BJ. Bedside electrocardiogram monitoring.* AACN Clin Issues Crit Care Nurs. *1993;4:26, 28.*)

3.3 ► Twelve-Lead ECG Placement



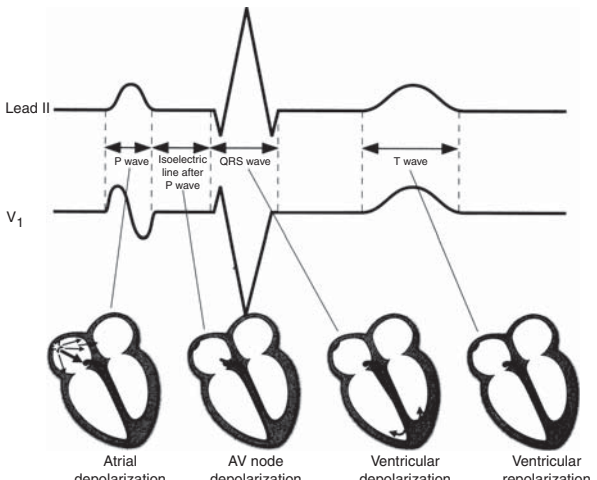
(A) Limb electrodes can be placed anywhere on arms and legs. Standard placement is shown here on wrists and ankles. **(B)** Chest electrode placement. V_1 = fourth intercostal space to right of sternum; V_2 = fourth intercostal space to left of sternum; V_3 = halfway between V_2 and V_4 in a straight line; V_4 = fifth intercostal space at midclavicular line; V_5 = same level as V_4 at anterior axillary line; V_6 = same level as V_4 at midaxillary line.

3.4 ► Right Side ECG Chest Lead Placement



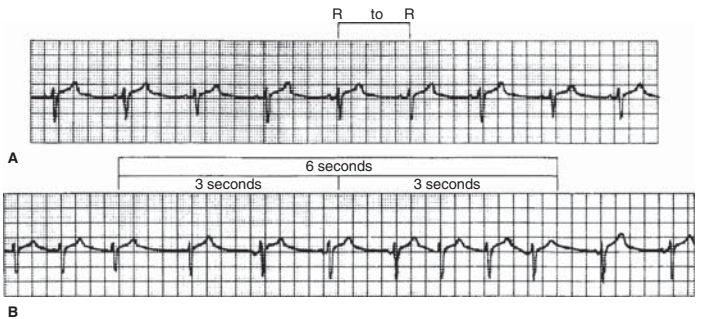
(A) Right side chest leads. V_4R at right fifth intercostal space, midclavicular line; V_5R at right fifth intercostal space, anterior axillary line; V_6R at right fifth intercostal space, midaxillary line. **(B)** Posterior leads: V_6 is shown at its normal location at the left fifth intercostal space, midaxillary line; V_7 at posterior axillary line; V_8 at tip of scapula; V_9 next to spine.

3.5 ► Waves, Complexes, and Intervals



Electrocardiographic waves, complexes, and intervals in leads II and V_1.

3.6 ► Heart Rate Determination



(A) Heart rate determination for a regular rhythm using little boxes between two R waves. One RR interval is marked at the top of the ECG paper. There are 25 little boxes between these two R waves. There are 1500 little boxes in a 60-second strip. By dividing 1500 by 25, one calculates a heart rate of 60 beats/min. Heart rate can also be determined for a regular rhythm counting large boxes between R waves. There are five large boxes between R waves. There are 300 large boxes in a 60-second strip. By dividing 300 by 5, one calculates a heart rate of 60 beats/min. **(B)** Heart rate determination for a regular or irregular rhythm using the number of RR intervals in a 6-second strip and multiplying by 10. There are seven RR intervals in this example. Multiplying by 10 gives a heart rate of 70 beats/min. (*Gilmore SB, Woods SL. Electrocardiography and vectorcardiography. In: Woods SL, Froelicher ES, Motzer SU, eds.* Cardiac Nursing *3rd ed. Philadelphia, PA: JB Lippincott; 1995:295.*)

3.7 ► Heart Rate Determination Using the Electrocardiogram Large Boxes

Number of Large Boxes Between R Waves	Heart Rate (Beats/Min)
1	300
2	150
3	100
4	75
5	60
6	50
7	40
8	38
9	33
10	30

3.8 ► Recommended Leads for Continuous ECG Monitoring

Purpose	Best Leads
Arrhythmia detection	V_1 (V_6 next best)
RCA ischemia, inferior MI	III, aVF
LAD ischemia, anterior MI	V_3
Circumflex ischemia, lateral MI	I, aVL (III, aVF best limb leads)
RV infarction	V_4R
Axis shifts	I and aVF together

3.9 ► Advantages of Common Monitoring Leads

Lead	Advantages
Preferred Monitoring Leads	
V_1 and V_6 (or MCL_1 and MCL_6 if using a 3-wire system)	Differentiate between right and left bundle branch block Morphology clues to differentiate between ventricular beats and supraventricular beats with aberrant conduction Differentiate between right and left ventricular ectopy Differentiate between right and left ventricular pacing Usually shows well-formed P waves Placement of electrodes keeps apex clear for auscultation or defibrillation
Other Monitoring Leads	
Lead II	Usually shows well-formed P waves Often best lead for identification of atrial flutter waves Usually has tall, upright QRS complex on which to synchronize machine for cardioversion Allows identification of retrograde P waves
Lead III or aVF	Assists in diagnosis of hemiblock Allows identification of retrograde P waves Allows Identification of atrial flutter waves Best limb leads for ST-segment monitoring
Lewis Lead (negative electrode at second right intercostal space, positive electrode at fourth right intercostal space)	Often best lead to identify P waves

3.10 ► Evidence-Based Practice: Bedside Cardiac Monitoring for Arrhythmia Detection

Electrode Application
- Make sure skin is clean and dry before applying monitoring electrodes.
- Place arm electrodes on shoulder (front, top, or back) as close as possible to where arm joins torso.
- Place leg electrodes below the rib cage or on hips.
- Place V_1 electrode at the fourth intercostal space at right sternal border.
- Place V_6 electrode at the fifth intercostal space at left midaxillary line.
- Replace electrodes every 48 hours or more often if skin irritation occurs.
- Mark electrode position with indelible ink to ensure consistent lead placement.

Lead Selection
- Use lead V_1 as the primary arrhythmia monitoring lead whenever possible.
- Use lead V_6 if lead V_1 is not available.
- If using a 3-wire system, use MCL_1 as the primary lead and MCL_6 as the second choice lead.

Alarm Limits
- Set heart rate alarms as appropriate for patient's current heart rate and clinical condition.
- *Never* turn heart rate alarms off while patient's rhythm is being monitored.
- Set alarm limits on other parameters if using a computerized arrhythmia monitoring system.

Documentation
- Document the monitoring lead on every rhythm strip.
- Document heart rate, PR interval, QRS width, QT interval with every shift and with any significant rhythm change.
- Document rhythm strip with every significant rhythm change:
  - Onset and termination of tachycardias.
  - Symptomatic bradycardias or tachycardias.
  - Conversion into or out of atrial flutter or atrial fibrillation.
  - All rhythms requiring immediate treatment.
- Place rhythm strips flat on page (avoid folding or winding strips into chart).

Transporting Monitored Patients
- Continue cardiac monitoring using a portable, battery-operated monitor-defibrillator if patient is required to leave a monitored unit for diagnostic or therapeutic procedures.
- Monitored patients must be accompanied by a health-care provider skilled in ECG interpretation and defibrillation during transport.

Compiled from Jacobson (2010); Drew, Califf, Funk, et al (2004); and the American Association of Critical-Care Nurse (2004).

3.11 ► Evidence-Based Practice: ST-Segment Monitoring

Patient Selection

Class I: ST-segment monitoring recommended for the following types of patients:

- Patients in the early phase of acute coronary syndromes (unstable angina, "rule-out MI, ST elevation MI, non–ST-elevation MI).[a,c]
- Patients presenting to emergency department with chest pain or anginal equivalent symptoms.[a,c]
- Patients and who have undergone nonurgent percutaneous coronary intervention who have suboptimal angiographic results.[a,c]
- Patients with possible variant angina due to coronary vasospasm.[a,c]

Class II: ST-segment monitoring may be of benefit in some patients but is not considered essential for all:

- Patients with post-acute MI (after 24–48 h).[a]
- Patients who have undergone nonurgent, uncomplicated percutaneous coronary intervention 1.
- Patients at high risk for ischemia after cardiac or noncardiac surgery.[a]
- Pediatric patients at risk of ischemia or infarction due to congenital or acquired conditions.[a]

Electrode Application

- Make sure skin is clean and dry before applying monitoring electrodes.[a,b,c]
- Place electrodes according to manufacturer recommendations when using a derived 12-lead ECG system.[a]
- When using a 3- or 5-wire-monitoring system, place electrodes as follows:
  - Place arm electrodes in infraclavicular fossa close to shoulder[a] or on top or back of shoulder as close to where arm joins torso as possible.
  - Place leg electrodes at lowest point on rib cage or on hips.[a,b]
  - Place V_1 electrode at the fourth intercostal space at right sternal border.[b]
  - Place V_6 electrode at the fifth intercostal space at left midaxillary line.[b]
- Mark electrode placement with indelible ink.[a,c]
- Replace electrodes every 48 hours or more often if skin irritation occurs.[b]

Lead Selection

- Monitor all 12 leads continuously if using a 12-lead monitoring system.[b]
- Use V_1 (or V_6 if V_1 is not possible due to dressings, etc.) for arrhythmia monitoring in all multilead combinations.[b]
- Choose the ST-segment monitoring lead according to the patient's "ischemic fingerprint" obtained during an ischemic event whenever possible.[b,c] Use the lead with the largest ST-segment deviation (elevation or depression).[b]
- If no ischemic fingerprint is available, use either lead III[b,c] or aVF (whichever has tallest QRS complex)[b] for ST-segment monitoring.
- Lead V_3 is the best lead for detecting anterior wall ST-segment deviation,[c] but can only be used if the chest lead is not being used for arrhythmia monitoring in lead V_1.

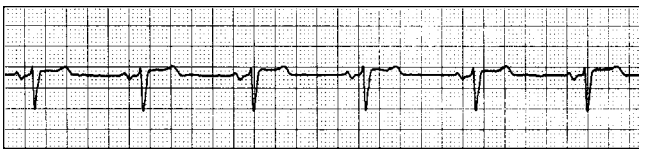
Alarm Limits

- Establish baseline ST level with patient in the supine position.[a,c]
- Set ST alarm parameters at 1 mm above and below the patient's baseline ST level in patients at high risk for ischemia.[a]
- Set ST alarm parameters at 2 mm above and below the patient's baseline ST level in more stable patients.[a]

Data compiled from [a]Drew (2004); [b]Jacobson (2007); and [c]AACN (2004).

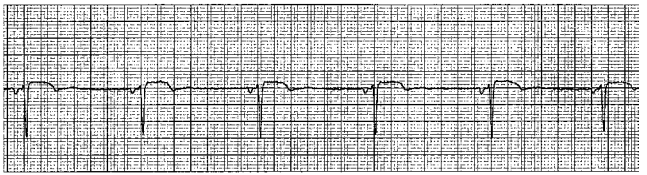
3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide

Rhythm	ECG Characteristics	Treatment
Normal sinus rhythm (NSR)	• Rate: 60-100 beats/min. • Rhythm: Regular. • P waves: Precede every QRS; consistent shape. • PR interval: 0.12-0.20 second. • QRS complex: 0.04-0.10 second.	• None.



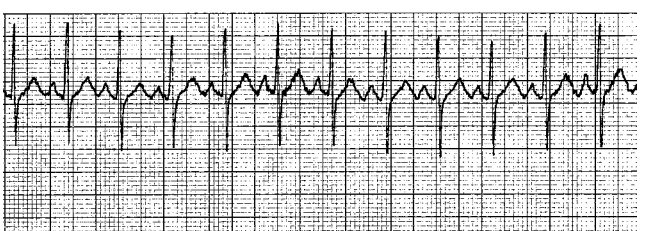
3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

Rhythm	ECG Characteristics	Treatment
Sinus bradycardia	• Rate: <60 beats/min. • Rhythm: Regular. • P waves: Precede every QRS; consistent shape. • PR interval: Usually normal (0.12-0.20 second). • QRS complex: Usually normal (0.04-0.10 second). • Conduction: Normal through atria, AV node, bundle branches, and ventricles.	• Treat only if symptomatic. • Atropine 0.5 mg IV.



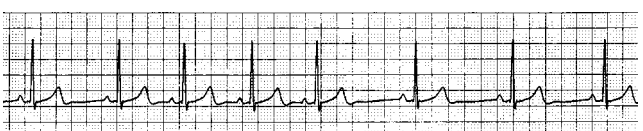
3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

Rhythm	ECG Characteristics	Treatment
Sinus tachycardia	• Rate: >100 beats/min. • Rhythm: Regular. • P waves: Precede every QRS; consistent shape. • PR interval: Usually normal (0.12-0.20 second); may be difficult to measure if P waves are buried in T waves. • QRS complex: Usually normal (0.04-0.10 second). • Conduction: Normal through atria, AV node, bundle branches, and ventricles.	• Treat underlying cause.



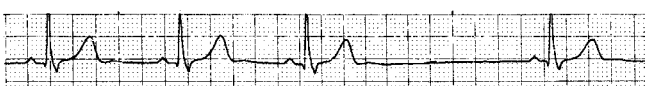
3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

Rhythm	ECG Characteristics	Treatment
Sinus arrhythmia	• Rate: 60-100 beats/min. • Rhythm: Irregular; phasic increase and decrease in rate, which may or may not be related to respiration. • P waves: Precede every QRS; consistent shape. • PR interval: Usually normal. • QRS complex: Usually normal. • Conduction: Normal through atria, AV node, bundle branches, and ventricles.	• Treatment is usually not required. • Hold digoxin if due to digitalis toxicity.



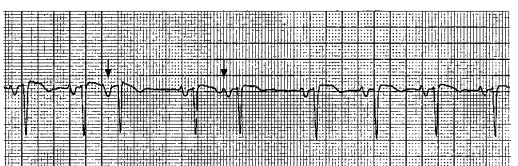
3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

Rhythm	ECG Characteristics	Treatment
Sinus arrest	• Rate: Usually within normal range, but may be in the bradycardia range. • Rhythm: Irregular due to absence of sinus node discharge. • P waves: Present when sinus node is firing and absent during periods of sinus arrest. When present, they precede every QRS complex and are consistent in shape. • PR interval: Usually normal when P waves are present. • QRS complex: Usually normal when sinus node is functioning and absent during periods of sinus arrest, unless escape beats occur. • Conduction: Normal through atria, AV node, bundle branches, and ventricles when sinus node is firing. When the sinus node fails to form impulses, there is no conduction through the atria.	• Treat underlying cause. • Discontinue drugs that may be causative. • Minimize vagal stimulation. • For frequent sinus arrest causing hemodynamic compromise, atropine 0.5 mg IV may increase heart rate. • Pacemaker may be necessary for refractory cases.

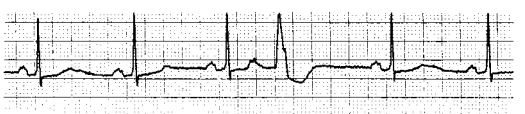


3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

Rhythm	ECG Characteristics	Treatment
Premature atrial contraction	• Rate: Usually within normal range. • Rhythm: Usually regular except when PACs occur, resulting in early beats. PACs usually have a noncompensatory pause. • P waves: Precede every QRS. The configuration of the premature P wave differs from that of the sinus P waves. • PR interval: May be normal or long depending on the prematurity of the beat. Very early PACs may find the AV junction still partially refractory and unable to conduct at a normal rate, resulting in a prolonged PR interval. • QRS complex: May be normal, aberrant (wide), or absent, depending on the prematurity of the beat. • Conduction: PACs travel through the atria differently from sinus impulses because they originate from a different spot. Conduction through the AV node, bundle branches, and ventricles is usually normal unless the PAC is very early.	• Treatment is usually not necessary. • Treat underlying cause. • Drugs (eg, beta-blockers, calcium channel blockers, procainamide) can be used if necessary.



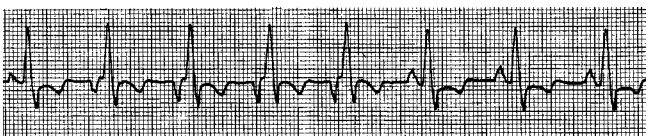
PACs conducted normally in the ventricle.



PACs conducted abnormally in the ventricle.

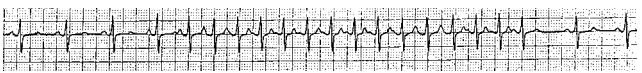
3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

Rhythm	ECG Characteristics	Treatment
Wandering atrial pacemaker	• Rate: 60-100 beats/min. If the rate is faster than 100 beats/min, it is called *multifocal atrial tachycardia* (MAT). • Rhythm: May be slightly irregular. • P waves: Varying shapes (upright, flat, inverted, notched) as impulses originate in different parts of the atria or junction. At least three different P-wave shapes should be seen. • PR interval: May vary depending on proximity of the pacemaker to the AV node. • QRS complex: Usually normal. • Conduction: Conduction through the atria varies as they are depolarized from different spots. Conduction through the bundle branches and ventricles is usually normal.	• Treatment is usually not necessary. • Treat underlying cause. • For symptoms from slow rate, use atropine. • Antiarrhythmic therapy is often ineffective, but beta-blockers, verapamil, flecainide, amiodarone, or magnesium may be successful.



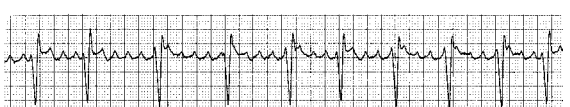
3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

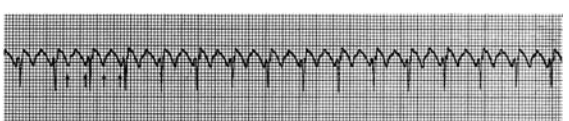
Rhythm	ECG Characteristics	Treatment
Atrial tachycardia	• Rate: Atrial rate is 120-250 beats/min. • Rhythm: Regular unless there is variable block at the AV node. • P waves: Differ in shape from sinus P waves because they are ectopic. Precede each QRS complex but may be hidden in preceding T wave. When block is present, more than one P wave appears before each QRS complex. • PR interval: May be shorter than normal but often difficult to measure because of hidden P waves. • QRS complex: Usually normal but may be wide if aberrant conduction is present. • Conduction: Usually normal through the AV node and into the ventricles. In atrial tachycardia with block some atrial impulses do not conduct into the ventricles. Aberrant ventricular conduction may occur if atrial impulses are conducted into the ventricles while the ventricles are still partially refractory.	• Eliminate underlying cause and decrease ventricular rate. • Sedation. • Vagal stimulation. • Digitalis (unless it is the cause of atrial tachycardia with block). • Propranolol, verapamil, or diltiazem can slow ventricular rate. • Procainamide, flecainide, amiodarone may be effective to prevent recurrences. • Radiofrequency ablation is often successful.



3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

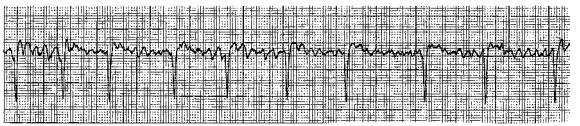
Rhythm	ECG Characteristics	Treatment
Atrial flutter	• Rate: Atrial rate varies between 250 and 350 beats/min, most commonly 300. Ventricular rate varies depending on the amount of block at the AV node. • Rhythm: Atrial rhythm is regular. Ventricular rhythm may be regular or irregular due to varying AV block. • P waves: F waves (flutter waves) are seen, characterized by a very regular, "sawtooth" pattern. One F wave is usually hidden in the QRS complex, and when 2:1 conduction occurs, F waves may not be readily apparent. • FR interval (flutter wave to the beginning of the QRS complex): May be consistent or may vary. • QRS complex: Usually normal; aberration can occur. • Conduction: Usually normal through the AV node and ventricles.	• Treatment depends on hemodynamic consequences of arrhythmia. • Cardioversion is preferred for markedly reduced cardiac output. • Beta-blockers, calcium channel blockers are used to slow ventricular rate. • Procainamide, flecainide, amiodarone, ibutilide, dofetilide, sotalol may convert to sinus. • Use drugs that slow atrial rate (procainamide, flecainide, propafenone) *only* after prior treatment to ensure AV block (eg, beta-blockers, calcium channel blockers). • Radiofrequency ablation is usually successful.

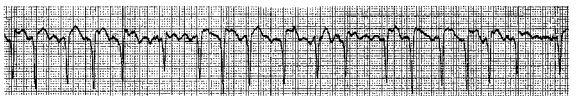




3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

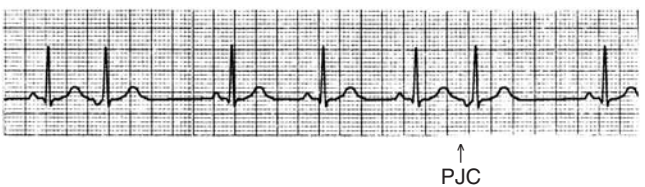
Rhythm	ECG Characteristics	Treatment
Atrial fibrillation	• Rate: Atrial rate is 400-600 beats/min or faster. Ventricular rate varies depending on the amount of block at the AV node. In new atrial fibrillation, the ventricular response is usually quite rapid, 160-200 beats/min; in treated atrial fibrillation, the ventricular rate is controlled in the normal range of 60-100 beats/min. • Rhythm: Irregular. One of the distinguishing features of atrial fibrillation is the marked irregularity of the ventricular response. • P waves: Not present. Atrial activity is chaotic with no formed atrial impulses visible. Irregular F waves are often seen and vary in size from coarse to very fine. • PR interval: Not measurable; there are no P waves. • QRS complex: Usually normal; aberration is common. • Conduction: Conduction within the atria is disorganized and follows a very irregular pattern. Most of the atrial impulses are blocked within the AV junction. Those impulses that are conducted through the AV junction are usually conducted normally through the ventricles. If an atrial impulse reaches the bundle branch system during its refractory period, aberrant intraventricular conduction can occur.	• Eliminate underlying cause. • Cardiovert if hemodynamically unstable. • Calcium channel blockers and beta-blockers are used to slow ventricular rate. Procainamide, disopyramid, flecainide, propafenone, amiodarone, sotalol, ibutilide, dofetilide are used to convert to sinus. • Radiofrequency ablation may be successful.





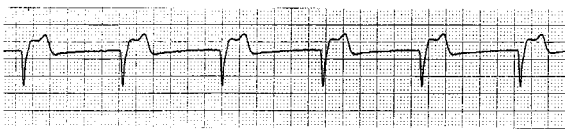
3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

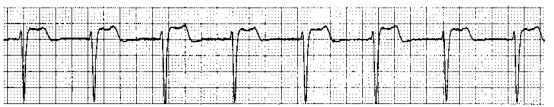
Rhythm	ECG Characteristics	Treatment
Premature junctional complexes	• Rate: 60-100 beats/min or whatever the rate of the basic rhythm. • Rhythm: Regular except for occurrence of premature beats. • P waves: May occur before, during, or after the QRS complex of the premature beat and are usually inverted. • PR interval: Short, usually 0.10 second or less, when P waves precede the QRS. • QRS complex: Usually normal but may be aberrant if the PJC occurs very early and conducts into the ventricles during the refractory period of a bundle branch. • Conduction: Retrograde through the atria; usually normal through the ventricles.	• Treatment is usually not necessary.



3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

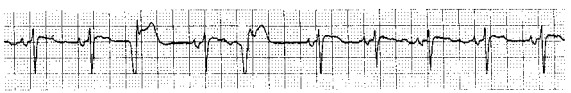
Rhythm	ECG Characteristics	Treatment
Junctional rhythm	• Rate: Junctional rhythm, 40-60 beats/min; accelerated junctional rhythm, 60-100 beats/min; junctional tachycardia, 100-250 beats/min. • Rhythm: Regular. • P waves: May precede or follow QRS. • PR interval: Short, 0.11 second or less if P waves precede QRS. • QRS complex: Usually normal. • Conduction: Retrograde through the atria; normal through the ventricles. .	• Treatment is rarely needed unless rate is too slow or too fast to maintain adequate CO. • Atropine is used to increase rate. • Verapamil, propranolol, or beta-blockers is used to decrease rate. • Withhold digitalis if digitalis toxicity is suspected.

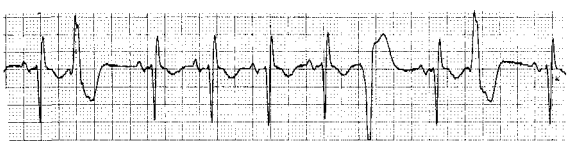




3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

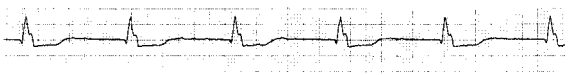
Rhythm	ECG Characteristics	Treatment
Premature ventricular complexes	• Rate: 60-100 beats/min or the rate of the basic rhythm. • Rhythm: Irregular because of the early beats. • P waves: Not related to the PVCs. Sinus rhythm is usually not interrupted by the premature beats, so sinus P waves can often be seen occurring regularly throughout the rhythm. • PR interval: Not present before most PVCs. If a P wave happens, by coincidence, to precede a PVC, the PR interval is short. • QRS complex: Wide and bizarre; $>$ 0.10 second in duration. May vary in morphology (size, shape) if they originate from more than one focus in the ventricles. • Conduction: Wide QRS complexes. Some PVCs may conduct retrograde into the atria, resulting in inverted P waves following the PVC.	• Eliminate underlying cause. • Drug therapy is not usually used, but, if desired, lidocaine, amiodarone, procainamide, beta-blockers may be effective.

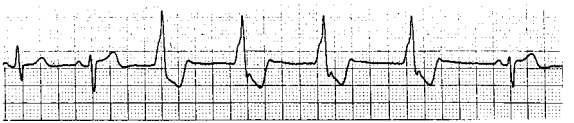




3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

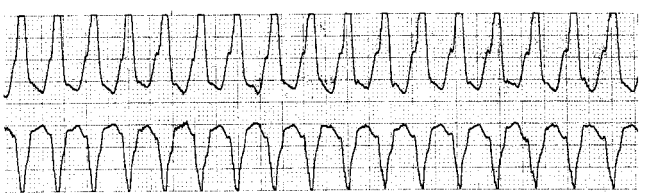
Rhythm	ECG Characteristics	Treatment
Ventricular rhythm	• Rate: <50 beats/min for ventricular rhythm and 50-100 beats/min for accelerated ventricular rhythm. • Rhythm: Usually regular. • P waves: May be seen but at a slower rate than the ventricular focus, with dissociation from the QRS. • PR interval: Not measured. • QRS complex: Wide and bizarre. • Conduction: If sinus rhythm is the basic rhythm, atrial conduction is normal. Impulses originating in the ventricles conduct via muscle cell-to-cell conduction, resulting in the wide QRS complex.	• For ventricular escape rhythms, use atropine to increase sinus rate and overdrive ventricular rhythm. • Use ventricular pacing to increase ventricular rate if escape rhythm is too slow.





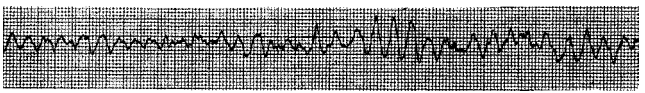
3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

Rhythm	ECG Characteristics	Treatment
Ventricular tachycardia	• Rate: Ventricular rate is faster than 100 beats/min. • Rhythm: Usually regular but may be slightly irregular. • P waves: P waves may be seen but will not be related to QRS complexes (dissociated from QRS complexes). If sinus rhythm is the underlying basic rhythm, regular P waves are often buried within QRS complexes. • PR interval: Not measurable because of dissociation of P waves from QRS complexes. • QRS complex: Wide and bizarre; >0.10 second in duration. • Conduction: Impulse originates in one ventricle and spreads via muscle cell-to-cell conduction through both ventricles. There may be retrograde conduction through the atria, but more often the sinus node continues to fire regularly and depolarize the atria normally.	• Treatment depends on how rhythm is tolerated. • Lidocaine, amiodarone, or magnesium should be given if patient is stable. • Cardioversion is preferred for hemodynamic instability. • Defibrillation should be performed if VT is pulseless.



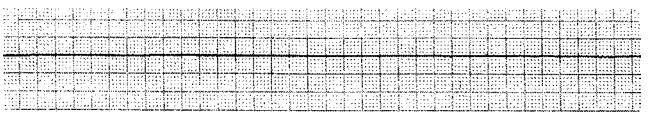
3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

Rhythm	ECG Characteristics	Treatment
Ventricular fibrillation	• Rate: Rapid, uncoordinated, ineffective. • Rhythm: Chaotic, irregular. • P waves: None seen. • PR interval: None. • QRS complex: No formed QRS complexes seen; rapid, irregular undulations without any specific pattern. • Conduction: Multiple ectopic foci firing simultaneously in ventricles and depolarizing them irregularly and without any organized pattern. Ventricles are not contracting.	• Immediate defibrillation. • CPR required until defibrillator is available. • Amiodarone, lidocaine, magnesium are commonly used. • After conversion, use IV antiarrhythmic that facilitates conversion to prevent recurrence.



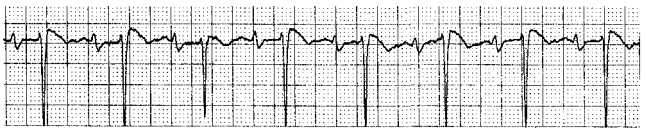
3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

Rhythm	ECG Characteristics	Treatment
Ventricular asystole	• Rate: None. • Rhythm: None. • P waves: May be present if the sinus node is functioning. • PR interval: None. • QRS complex: None. • Conduction: Atrial conduction may be normal if the sinus node is functioning. There is no conduction into the ventricles.	• Provide immediate CPR. • Give IV epinephrine. • Give atropine. • Identify and treat cause.



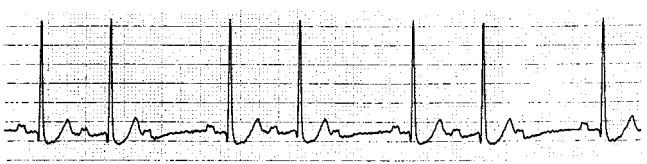
3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

Rhythm	ECG Characteristics	Treatment
First-degree AV block	• Rate: Can occur at any sinus rate, usually 60-100 beats/min. • Rhythm: Regular. • P waves: Normal; precede every QRS. • PR interval: Prolonged above 0.20 second. • QRS complex: Usually normal. • Conduction: Normal through the atria, usually delayed through the AV node. Ventricular conduction is normal.	• Treatment is usually not necessary.



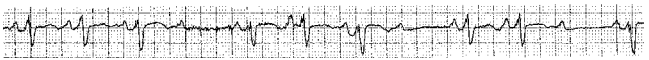
3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

Rhythm	ECG Characteristics	Treatment
Second-degree AV block type I (Wenckebach; (Mobitz I)	• Rate: Can occur at any sinus or atrial rate. • Rhythm: Irregular. Overall appearance of the rhythm demonstrates "group beating." • P waves: Normal. Some P waves are not conducted to the ventricles, but only one at a time fails to conduct to the ventricle. • PR interval: Gradually lengthens in consecutive beats. The PR interval preceding the pause is longer than that following the pause • QRS complex: Usually normal unless there is associated bundle branch block. • Conduction: Normal through the atria, progressively delayed through the AV node until an impulse fails. Conduction ratios can vary, with ratios as low as 2:1 (every other P wave is blocked), up to high ratios such as 15:14 (every 15th P wave blocked).	• Treatment depends on conduction ratio, ventricular rate, and symptoms. • Atropine is used for slow ventricular rate. • No treatment is given with normal ventricular rate. • Discontinue digitalis, beta-blockers, and calcium channel blockers. • Temporary pacemaker may be needed for slow ventricular rate.



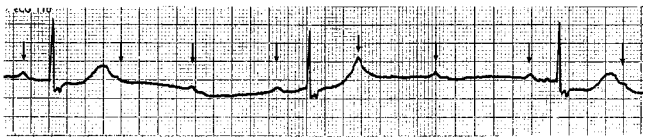
3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

Rhythm	ECG Characteristics	Treatment
Second-degree AV block type II (Mobitz II)	• Rate: Can occur at any basic rate. • Rhythm: Irregular due to blocked beats. • P waves: Usually regular and precede each QRS. Periodically a P wave is not followed by a QRS complex. • PR interval: Constant before conducted beats. The PR interval preceding the pause is the same as that following the pause. • QRS complex: Usually wide due to associated bundle branch block. • Conduction: Normal through the atria and through the AV node but intermittently blocked in the bundle branch system and fails to reach the ventricles. Conduction through the ventricles is abnormally slow due to associated bundle branch block. Conduction ratios can vary from 2:1 to only occasional blocked beats.	• Pacemaker is often needed. • Atropine is not recommended.



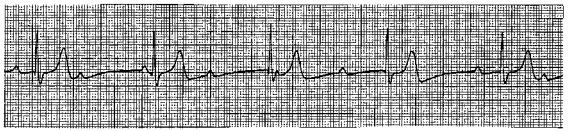
3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

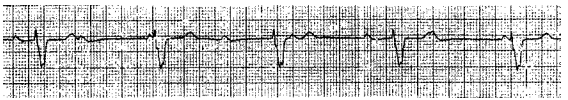
Rhythm	ECG Characteristics	Treatment
High-Grade (Advanced) High AV block	• Rate: Atrial rate <135 beats/min. • Rhythm: Regular or irregular, depending on conduction pattern. • P waves: Normal; present before every conducted QRS, but two or more consecutive P waves may not be followed by QRS complexes. • PR interval: Constant before conducted beats; may be normal or prolonged. • QRS complex: Usually normal in type I and wide in type II advanced blocks. • Conduction: Normal through the atria. Two or more consecutive atrial impulses fail to conduct to the ventricles. Ventricular conduction is normal in type I and abnormally slow in type II advanced blocks.	• Treatment is necessary if patient is symptomatic. • Atropine may increase ventricular rate. • Pacemaker is often required.



3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

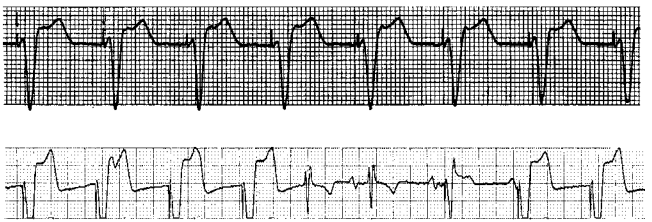
Rhythm	ECG Characteristics	Treatment
Third-degree AV block (complete)	• Rate: Atrial rate is usually normal; ventricular rate is <45 beats/min. • Rhythm: Regular. • P waves: Normal but dissociated from QRS complexes. • PR interval: No consistent PR intervals because there is no relationship between P waves and QRS complexes. • QRS complex: Normal if ventricles controlled by a junctional rhythm; wide if controlled by a ventricular rhythm. • Conduction: Normal through the atria. All impulses are blocked at the AV node or in the bundle branches, so there is no conduction to the ventricles. Conduction through the ventricles is normal if a junctional escape rhythm occurs, and abnormally slow if a ventricular escape rhythm occurs.	• Pacemaker. • Atropine is usually not effective. • With severely decreased cardiac output, perform CPR until pacemaker available.





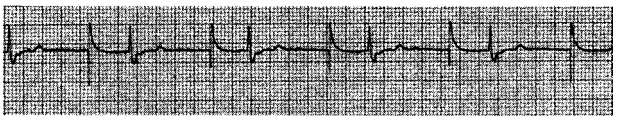
3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

Rhythm	ECG Characteristics	Treatment
Ventricular paced rhythm with capture	• Rate: Depends on type of pacemaker. • Rhythm: Regular. • P waves: Absent or present but dissociated from QRS complexes. • PR interval: None. • QRS complex: Pacemaker spike followed immediately by wide, bizarre QRS complex.	• None.



3.12 ► Cardiac Rhythms, ECG Characteristics, and Treatment Guide (*continued*)

Rhythm	ECG Characteristics	Treatment
Ventricular paced rhythm without capture	• Conduction: Abnormal. • ECG characteristics depend on nature of intrinsic rhythm. • Pacemaker spike has no fixed relationship to QRS complexes.	• If hemodynamically stable, elective correction/replacement of pacemaker. • If hemodynamically unstable, treatment as for third-degree AV block.



3.13 ► Guidelines for Management of Atrial Fibrillation and Atrial Flutter (Class I Recommendations Only)

Pharmacologic Heart Rate Control During Atrial Fibrillation

1. Control of heart rate using either a beta-blocker or nondihydropyridine CCB (in most cases) for patients with persistent or permanent AF (Level B).
2. Administration of AV nodal blocking agents is recommended to achieve heart rate control in patients who develop postoperative AF (Level B).
3. In the absence of preexcitation, IV administration of beta-blockers (esmolol, metoprolol, or propranolol) or nondihydropyridine CCBs (verapamil, diltiazem) to slow ventricular response to AF in the acute setting, exercising caution in patients with hypotension or HF (Level B).
4. IV administration of digoxin or amiodarone to control heart rate in patients with AF and HF who do not have an accessory pathway (Level B).
5. Oral digoxin is effective to control heart rate at rest and is indicated for patients with HF, LV dysfunction, or for sedentary individuals (Level C).
6. In IV amiodarone is recommended to slow a rapid ventricular response to AF and improve LV function in patients with acute MI (Level C).
7. IV beta-blockers and nondihydropyridine CCBs are recommended to slow a rapid ventricular response to AF in patients with acute MI who do not have clinical LV dysfunction, bronchospasm, or AV block (Level C).

Preventing Thromboembolism

1. Antithrombotic therapy is recommended for all patients with AF except those with lone AF or contraindications (Level A).
2. For patients without mechanical heart valves at high risk of stroke (prior stroke, TIA, or systemic embolism; rheumatic mitral stenosis), chronic oral anticoagulant therapy with a vitamin K antagonist is recommended in a dose to achieve the target INR of 2.0 to 3.0 unless contraindicated (Level A).
3. Anticoagulation with a vitamin K antagonist is recommended for patients with more than one moderate risk factor (age $\geq$75, hypertension, HF, LVEF $<$35%, diabetes) (Level A).
4. INR should be determined at least weekly during initiation of therapy and monthly when anticoagulation is stable (Level A).

3.13 ► Guidelines for Management of Atrial Fibrillation and Atrial Flutter (Class I Recommendations Only) (*continued*)

Preventing Thromboembolism

5. Aspirin 325 mg daily is an alternative to vitamin K antagonists in low-risk patients or those with contraindications to anticoagulation (Level A).
6. For patients with mechanical heart valves, the target intensity of anticoagulation should be based on the type of prosthesis, maintaining an INR of at least 2.5 (Level B).
7. For patients with AF of ⩾48 hours duration, or when the duration is unknown, anticoagulation (INR: 2.0-3.0) is recommended for at least 3 weeks prior to and 4 weeks after cardioversion (electrical or pharmacologic) (Level B).
8. For patients with AF of >48 hours duration requiring immediate cardioversion, heparin should be administered concurrently (unless contraindicated) by an initial IV bolus followed by a continuous infusion in a dose adjusted to prolong the aPTT to 1.5 to 2 times the reference control value. Oral anticoagulation (INR: 2.0-3.0) should be given for at least 4 weeks after cardioversion. Limited data support SQ administration of LMWH in this category of patient condition (Level C).
9. For patients with AF of <48 hours duration and hemodynamic instability (angina, MI, shock, or pulmonary edema), cardioversion should be performed immediately without delay for prior anticoagulation (Level C).

Cardioversion of Atrial Fibrillation

1. Administration of flecainide, dofetilide, propafenone, or ibutilide is recommended for pharmacologic cardioversion (Level A).
2. Immediate electrical (direct-current) cardioversion is recommended for patients with AF involving preexcitation when very rapid tachycardia or hemodynamic instability occurs (Level B).
3. When a rapid ventricular response does not respond promptly to pharmacologic measures in patients with myocardial ischemia, symptomatic hypotension, angina, or HF, immediate R-wave-synchronized cardioversion is recommended (Level C).

3.13 ► Guidelines for Management of Atrial Fibrillation and Atrial Flutter (Class I Recommendations Only) (*continued*)

Cardioversion of Atrial Fibrillation

4. Electrical cardioversion is recommended in patients without hemodynamic instability when symptoms of AF are unacceptable to the patient. In case of early relapse of AF after cardioversion, repeated electrical cardioversion attempts may be made following administration of antiarrhythmic medication (Level C).
5. Electrical cardioversion is recommended for patients with acute MI and severe hemodynamic compromise, intractable ischemia, or inadequate rate control with drugs (Level C).

There are no Class I recommendations for pharmacologic conversion of atrial fibrillation.

Maintenance of Sinus Rhythm

1. An oral beta-blocker to prevent postoperative AF is recommended for patients undergoing cardiac surgery (unless contraindicated) (Level A).
2. Before initiating antiarrhythmic drug therapy, treatment of precipitating or reversible causes of AF is recommended (Level C).

Level of Evidence Definitions:

Level A: Data derived from multiple randomized clinical trials or meta-analyses.
Level B: Data derived from a single randomized trial or nonrandomized studies.
Level C: Only consensus opinion of experts, case studies, or standard of care.

Fuster V, Ryden LE, Asinger RW, Cannom DS, Crijns HJ, Frye RL, et al. ACC/AHA/ESC Guidelines for the Management of Patients With Atrial Fibrillation: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the European Society of Cardiology Committee for Practice Guidelines (Writing Committee to Revise the 2001 Guidelines for the Management of Patients with Atrial Fibrillation). *Circulation.* 2006;114:700-752.

Abbreviations: AF, atrial fibrillation; aPTT, activated partial thromboplastin time; CCB, calcium channel blocker; HF, heart failure; INR, international normalized ratio; LMWH, low molecular weight heparin; LV, left ventricular; MI, myocardial infarction; TIA, transient ischemic attack.

3.14 ► Guidelines for Management of Supraventricular Arrhythmias (Class I Recommendations Only)

Acute Management of Hemodynamically Stable and Regular Tachycardia

Narrow QRS (SVT) and SVT with BBB:

1. Vagal maneuvers (Valsalva, CSM) (Level B)
2. Adenosine (Level A)
3. Verapamil, diltiazem (Level A)

Preexcited SVT/AF:

1. Flecainide (Level B)
2. Ibutilide (Level B)
3. Procainamide (Level B)
4. Electrical cardioversion (Level C)

Wide QRS Tachycardia of Unknown Origin:

1. Procainamide (Level B)
2. Sotalol (Level B)
3. Amiodarone (Level B)
4. Electrical cardioversion (Level B)

Wide QRS Tachycardia of Unknown Origin in Patients with Poor LV Function:

1. Amiodarone (Level B)
2. Lidocaine (Level B)
3. Electrical cardioversion (Level B)

3.14 ► Guidelines for Management of Supraventricular Arrhythmias (Class I Recommendations Only) (*continued*)

Long-Term Treatment of Recurrent AVNRT

1. Catheter ablation (Level B)
2. Verapamil for recurrent symptomatic AVNRT (Level B)
3. Diltiazem or beta-blockers for recurrent symptomatic AVNRT (Level C)

Infrequent, Well Tolerated Episodes of AVNRT:
1. Vagal maneuvers (Level B)
2. Pill-in-the-pocket (single-dose oral diltiazem plus propranolol) (Level B)
3. Verapamil, diltiazem, beta-blockers, catheter ablation (Level B)

Focal and Nonparoxysmal Junctional Tachycardia Syndromes

Nonparoxysmal Junctional Tachycardia:
1. Reverse digitalis toxicity (Level C)
2. Correct hypokalemia (Level C)
3. Treat myocardial ischemia (Level C)

Long-Term Therapy of Accessory Pathway–Mediated Arrhythmias

1. Catheter ablation for WPW syndrome (preexcitation and symptomatic arrhythmias) that are well tolerated; or with AF and rapid conduction or poorly tolerated CMT (Level B)
2. Vagal maneuvers for single or infrequent episodes (Level B)
3. Pill-in-the-pocket (verapamil, diltiazem, beta-blockers) for single or infrequent episodes (Level B)

Contraindicated: Verapamil, diltiazem, digoxin

3.14 ► Guidelines for Management of Supraventricular Arrhythmias (Class I Recommendations Only) (*continued*)

Treatment of Focal Atrial Tachycardia

Acute Treatment:
1. Electrical cardioversion if hemodynamically unstable (Level B)
2. Beta-blockers, verapamil, diltiazem for rate control (in absence of digitalis therapy) (Level C)

Prophylactic Therapy:
1. Catheter ablation for recurrent symptomatic or incessant AT (Level B)
2. Beta blockers, verapamil, diltiazem (Level C)

Level of Evidence Definitions:
Level A: Data derived from multiple randomized clinical trials or meta-analyses
Level B: Data derived from a single randomized trial or nonrandomized studies
Level C: Only consensus opinion of experts, case studies, or standard-of-care

Blomstrom-Lundqvist C, Scheinman MM, Aliot EM, et al. ACC/AHA/ESC Guidelines for the Management of Patients with Supraventricular Arrhythmias–executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the European Society of Cardiology Committee for Practice Guidelines (Writing Committee to Develop Guidelines for the Management of Patients with Supraventricular Arrhythmias). Circulation. *2003: 108: 1871-1909.*

Abbreviations: AF, atrial fibrillation; AVNRT, atrioventricular nodal reentry tachycardia; BBB, bundle branch block; CMT, circus movement tachycardia; LV, left ventricular; SVT, supraventricular tachycardia; WPW, Wolff-Parkinson-White.

3.15 ► Guidelines for Management of Ventricular Arrhythmias (Class I Recommendations Only)

Sustained Monomorphic Ventricular Tachycardia

1. Wide QRS tachycardia should be presumed to be VT if the diagnosis is unclear. (Level C)
2. Electrical cardioversion with sedation is recommended with hemodynamically unstable sustained monomorphic VT (Level C).

Contraindicated: Calcium channel blockers (verapamil, diltiazem) should not be used to terminate wide QRS tachycardia of unknown origin, especially with history of myocardial dysfunction.

Polymorphic Ventricular Tachycardia

1. Electrical cardioversion with sedation is recommended for sustained PVT with hemodynamic compromise (Level B).
2. IV beta-blockers are useful if ischemia is suspected or cannot be excluded (Level B).
3. IV amiodarone is useful for recurrent PVT in the absence of QT prolongation (congenital or acquired) (Level C).
4. Urgent angiography and revascularization should be considered with PVT when myocardial ischemia cannot be excluded (Level C).

Torsades de Pointes

1. Withdrawal of any offending drugs and correction of electrolyte abnormalities are recommended for TdP (Level A).
2. Acute and long-term pacing is recommended for TdP due to heart block and symptomatic bradycardia (Level A).

Incessant Ventricular Tachycardia

1. Revascularization and beta blockade followed by IV antiarrhythmic drugs such as procainamide or amiodarone are recommended for recurrent or incessant PVT (Level B).

3.15 ► Guidelines for Management of Ventricular Arrhythmias (Class I Recommendations Only) (*continued*)

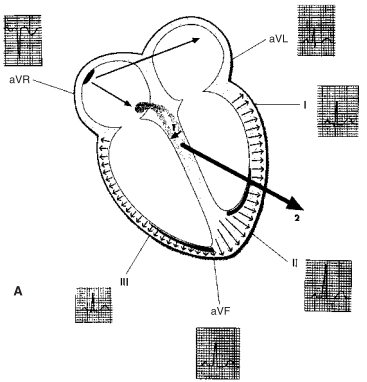
Level of Evidence Definitions:

Level A: Data derived from multiple randomized clinical trials or meta-analyses.
Level B: Data derived from a single randomized trial or nonrandomized studies.
Level C: Only consensus opinion of experts, case studies, or standard of care.

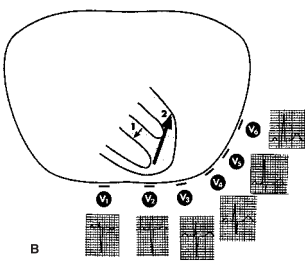
Zipes DP, Camm JA, Borggrefe M., Buxton AE, Chaitman B, Fromer M, et al. ACC/AHA/ESC 2006 Guidelines for Management of Patients with Ventricular Arrhythmias and the Prevention of Sudden Cardiac Death: executive summary: a report of the American College of Cardiology/American Heart Association Task Force and the European Society of Cardiology Committee for Practice Guidelines (Writing Committee to Revise the 2001 Guidelines for the Management of Patients with Atrial Fibrillation). Circulation. *2006;114:1088-1132.*

Abbreviations PVT, polymorphic ventricular tachycardia; TdP, torsades de pointes; VT, ventricular tachycardia.

3.16 ► Normal 12-Lead ECG Waves

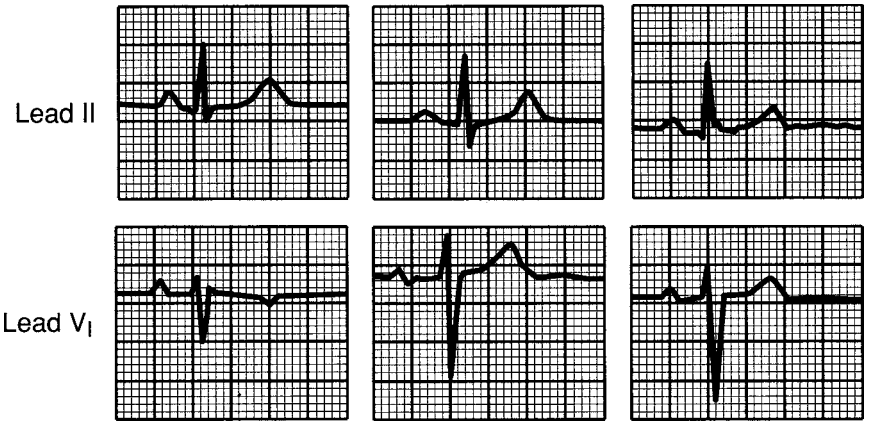


(A) Normal sequence of depolarization through the heart as recorded by each of the frontal plane leads.

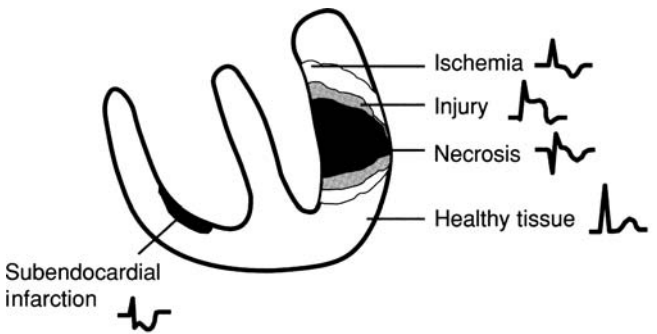


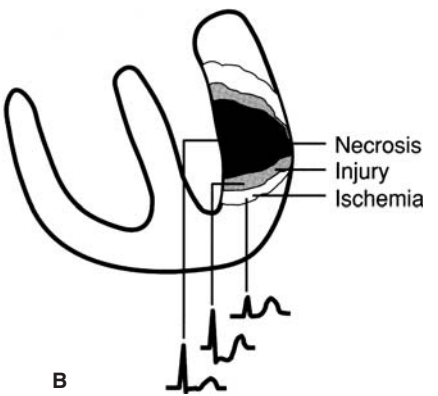
(B) Cross-section of the thorax illustrating how the six precordial leads record normal electrical activity in the ventricles. The small arrow (*1*) shows the initial direction of depolarization through the septum, followed by the direction of ventricular depolarization, indicated by the larger arrow (*2*).

3.17 ► Normal ST Segment and T Waves



3.18 ► Zones of Myocardial Ischemia, Injury, and Infarction with Associated ECG Changes

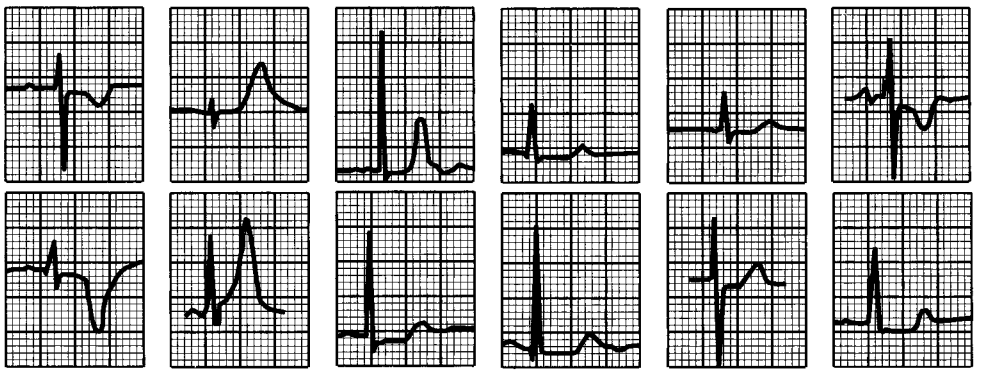




(A) Indicative changes of ischemia, injury, and necrosis seen in leads facing the injured area.

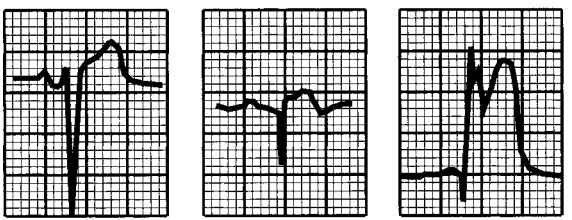
(B) Reciprocal changes often seen in leads not directly facing the involved area.

3.19 ► ECG Patterns Associated with Myocardial Ischemia

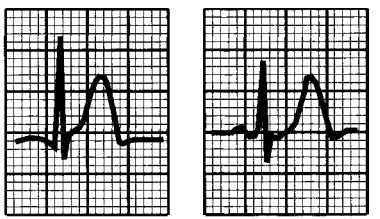


- T-wave inversion
- Tall, wide-based T waves
- Inverted U waves
- ST segment hangs on baseline > 0.12 second
- Sharp ST-T angle
- ST depression (horizontal or downsloping)

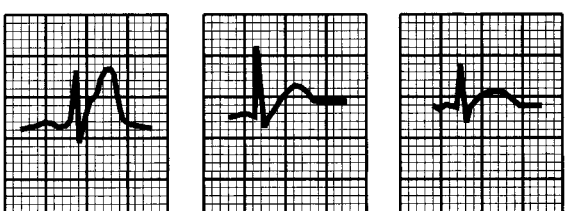
3.20 ► ECG Patterns Associated with Acute Myocardial Injury



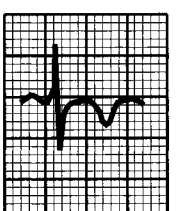
• ST elevation 1 mm or more



• Tall, peaked T waves



• ST segment pulled up to peak of T wave

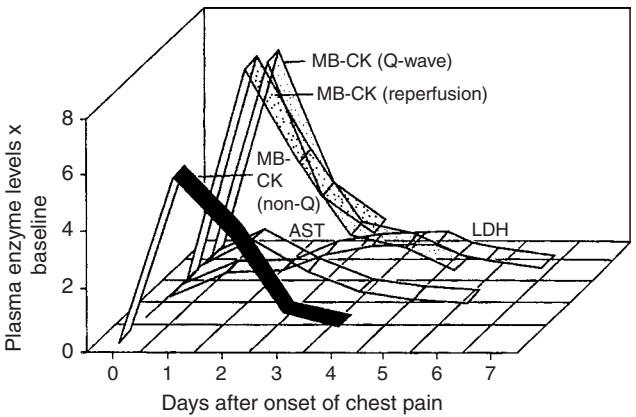


• Symmetrical T inversion

3.21 ► ECG Changes Associated with Myocardial Infarction

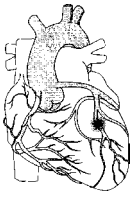
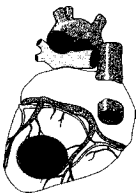
Location of MI	Indicative Changes	Reciprocal changes
Anterior	V_1-V_4	I, aVL, II, III, aVF
Septal	V_1, V_2	I, aVL
Inferior	II, III, aVF	I, aVL, V_1-V_4
Posterior	None	V_1-V_4
Lateral	I, aVL, V_5, V_6	II, III, aVF, V_1, V_2
Right ventricle	V_3R-V_6R	

3.22 ► Typical Plasma Profiles

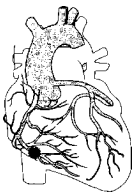
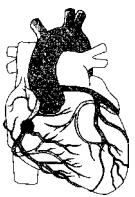


Typical plasma profiles for the MB isoenzymes of creatine kinase (MB-CK), aspartate amino transferase (AST), and lactate dehydrogenase (LDH) activities following onset of acute myocardial infarction. (*Used with permission, Alexander R, Pratt C. Diagnosis and management of acute myocardial infarction. In: Fuster V, Alexander R, O'Rouke R, eds.* Hurst's The Heart. *10th ed. New York, NY: McGraw-Hill; 2001.*)

3.23 ► Clinical Presentation of Myocardial Ischemia and Infarction

Type MI	Arterial Involvement	Muscle Area Supplied	Assessment	ECG Changes	Likely Arrhythmias	Possible Complications
Anteroseptal wall 	LAD	Anterior LV wall, Anterior LV septum Apex LV Bundle of His Bundle branches	↓ LV Function → ↓ CO, ↓ BP ↑ PAD, ↑ PCWP S_3 and S_4, with HF Rales with pulmonary edema	**Indicative:** ST elevation with or without abnormal Q waves in V_{1-4} Loss of R waves in precordial leads **Reciprocal:** ST depression in II, III, aVF.	RBBB, LBBB AV blocks Atrial fibrillation or flutter Ventricular tachycardia (VT) Tachycardia (septal)	Cardiogenic shock VSD Myocardial rupture Heart blocks may be permanent (LBBB) High mortality associated with this location of MI
Posterior septal lateral 	RCA Circumflex branches (right and left)	Posterior surface of LV, SA node 45% AV node 10% Left atrium Lateral wall of LV	Murmurs indicating VSD (septal) PA catheter to assess R to L shunt in VSD Signals/symptoms of LV aneurysm with lateral displaced PMI leading to signs and symptoms of mitral regurgitation	**Lateral Indicative:** ST elevation I, aVL, $V_{5, 6}$ Loss of R wave and ↑ ST in I, aVL, V_{5-6} **Posterior Indicative:** Tall, broad R waves (>0.04 second) in V_{1-3} ↑ ST V_4R (right sided 12 lead, V_4 position) **Posterior Reciprocal:** ST depression in $V_{1,2}$, upright T wave in $V_{1,2}$	Bradycardia Mobitz I (posterior)	RV involvement Aneurysm development Papillary muscle dysfunction Heart blocks frequently resolve

3.23 ► Clinical Presentation of Myocardial Ischemia and Infarction (*continued*)

Type MI	Arterial Involvement	Muscle Area Supplied	Assessment	ECG Changes	Likely Arrhythmias	Possible Complications
Inferior or "diaphragmatic" 	RCA	RV, RA SA Node 50% AV Node 90% RA, RV Inferior LV Posterior IV Septum Posterior LBBB Posterior LV	Symptomatic bradycardia: ↓ BP LOC changes diaphoresis ↓ CO ↑ PAD ↑ PCWP Murmurs: associated with papillary muscle dysfunction mid/holosystolic rales, pulmonary edema, nausea	**Indicative:** ↑ ST segments in II, III, aVF Q waves in II, III, aVF **Reciprocal:** ST depression in I, aVL, V_{1-4}	AV blocks; often progress to CHB which may be transient or permanent; Wenckebach; bradyarrhythmias	Hiccups Nausea/vomiting Papillary muscle dysfunction MR Septal rupture (0.5%-1%) RV involvement associated with atrial infarcts especially with atrial arrhythmias
Right ventricular infarction 	RCA	RA, RV, Inferior LV SA Node AV Node Posterior IV septum	Kussmaul's sign JVD Hypotension ↑ SVR, ↓ PCWP ↑ CVP S_3 with noncompliant RV Clear breath sounds initially Hepatomegaly; peripheral edema: cool, clammy, pale skin	**Indicative:** 1- to 2-mm ST-segment elevation in V_4R ST- and T-wave elevation in II, III, aVF Q waves in II, III, aVF ST-elevation decreases in amplitude over V_{1-6}	First-degree AV block Second-degree AV block, type I Incomplete RBBB Transient CHB Atrial fibrillation VT/VF	Hypotension requiring large volumes initially to maintain systemic pressure. Once RV contractility improves fluids will mobilize, possibly requiring diuresis

3.24 ► Evidence-Based Practice: Acute Coronary Syndrome ST-Elevation MI and Non–ST-Elevation MI

Diagnosis

- Diagnosis of AMI is based on two of three findings:[a,b]
  1. History of ischemic-like symptoms
  2. Changes on serial ECGs
  3. Elevation and fall in level of serum cardiac biomarkers
- Of AMI patients, 50% do not present with ST-segment elevation. Other indicators:[a,b]
  1. ST-segment depression may indicate non–ST-elevation MI (NSTEMI).
  2. New LBBB.
  3. ST-segment depression that resolves with relief of chest pain.
  4. T-wave inversion in all chest leads may indicate NSTEMI with a critical stenosis in the proximal LAD.

Acute Management

- Optimal time for initiation of therapy is within 1 hour of symptom onset. Rarely feasible due to delay in treatment-seeking behavior.[a,b]
- Initial ECG should be obtained within 10 minutes of emergency department arrival.[a,b]
- Oxygen, nitroglycerine, and aspirin should be administered if not contraindicated.[a,b]
- Reperfusion strategy: STEMI only.[a,b]
  1. Fibrinolytic agent should be initiated within 30 minutes of arrival if no contraindication
  2. If primary PCI to be done, culprit vessel should be opened within 90 minutes of arrival
- Reperfusion strategy for NSTEMI.[a,b]
  1. Fibrinolytics not recommended
  2. PCI to be done within 24 hours of arrival
- Weight-based heparin or low-molecular-weight heparin.[a,b]
- IV beta-blocker should be given within 12 hours of arrival.[a,b]
- Lipid-lowering agent should be initiated.[a,b]

Data compiled from: [a]Antman, et al (2004); [b]Casey (2002).

3.25 ► Summary of Causes of Axis Deviations

Axis: −30° to +90°
- Normal

Left Axis Deviation: −31° to −90°
- Left ventricular hypertrophy
- Left anterior fascicular block
- Inferior myocardial infarction
- Left bundle branch block
- Congenital defects
- Ventricular tachycardia
- Wolff-Parkinson-White syndrome

Right Axis Deviation: +91° to +180°
- Right ventricular hypertrophy
- Left posterior fascicular block
- Right bundle branch block
- Dextrocardia
- Ventricular tachycardia
- Wolff-Parkinson-White syndrome

Indeterminant Axis: −90° to −180°
- Ventricular tachycardia
- Bifascicular block

3.26 ► ECG Clues for Differentiating Aberration from Ventricular Ectopy

	Aberrancy	Ventricular Ectopy
P waves	Precede QRS complexes	Dissociated from QRS or occur at rate slower than QRS; if 1:1 V-A conduction is present, retrograde P waves follow every QRS
Precordial QRS concordance	Positive concordance may occur with WPW	Negative concordance favors VT; positive concordance favors VT if WPW ruled out
Fusion or capture beats		Strong evidence in favor of VT
QRS axis	Often normal; may be deviated to right or left	Indeterminant axis favors VT; often deviated to left or right
RBBB QRS morphology	Triphasic rsR′ in V_1: triphasic qRs in V_6	Monophasic R wave or diphasic qR complex in V_1: left "rabbit ear" taller in V_1: monophasic QS or diphasic rS in V_6
LBBB QRS morphology	Narrow R wave ($<$0.04 second) in V_1; straight downstroke of S wave in V_1 (often slurs or notches on upstroke); usually no Q wave in V_6	Wide R wave ($>$0.03 second) in V_1 or V_2; slurring or notching on downstroke of S wave in V_1; delay of greater than 0.06 second to nadir of S wave in V_1 or V_2; any Q wave in V_6

3.27 ► Pacemaker Codes

First Letter: Chamber Paced	Second Letter: Chamber Sensed	Third Letter: Response to Sensing	Fourth Letter: Rate Modulation	Fifth Letter: Multisite Pacing[a]
O = None	O = None	O = None	O = None	O = None
A = Atrium	A = Atrium	I = Inhibited	R = Rate modulation	A = Atrial
V = Ventricle	V = Ventricle	T = Triggered		V = Ventricular
D = Dual (A&V)	D = Dual (A&V)	D = Dual (I&T)		D = Dual

[a] Multiside indicates either pacing in both atria or both ventricles or pacing multiple sites with a chamber.

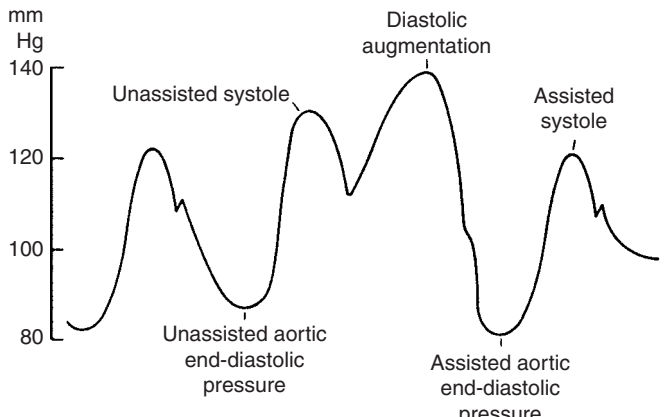
3.28 ► Dual-Chamber Pacing Modes

Mode	Chamber(s) Paced	Chamber(s) Sensed	Response to Sensing
DVI	Atrium and ventricle	Ventricle	Inhibited
VDD	Ventricle	Atrium and ventricle	Atrial sensing triggers ventricular pacing Ventricular sensing inhibits ventricular pacing
DDI	Atrium and ventricle	Atrium and ventricle	Inhibited
DDD	Atrium and ventricle	Atrium and ventricle	Atrial sensing inhibits atrial pacing, triggers ventricular pacing Ventricular sensing inhibits atrial and ventricular pacing

Cardiovascular concepts

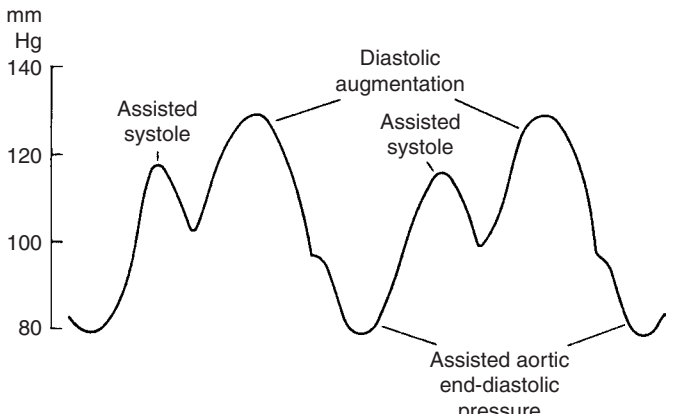
Section 4

4.1 ► Intra-Aortic Balloon Pump Frequency of 1:2



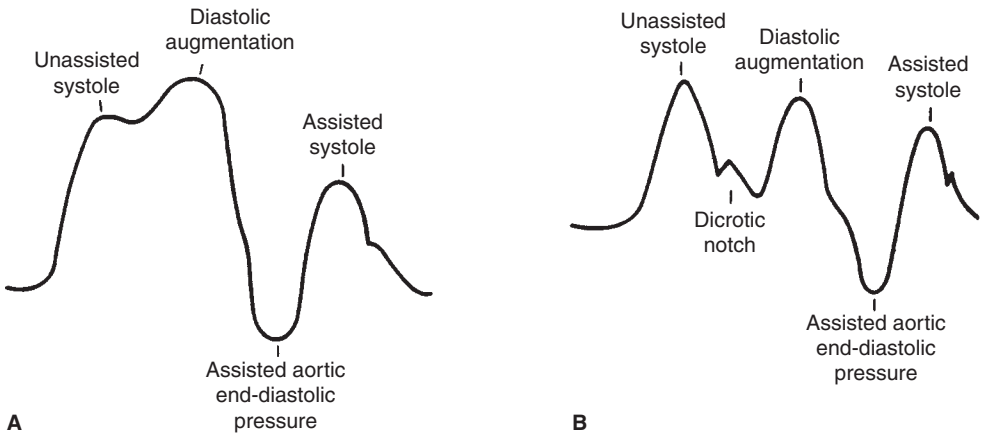
(*Datascope Corporation: Mechanics of intra-aortic balloon counterpulsation. Montvale, NJ: Datascope, 1989.*)

4.2 ► Intra-Aortic Balloon Pump Frequency of 1:1



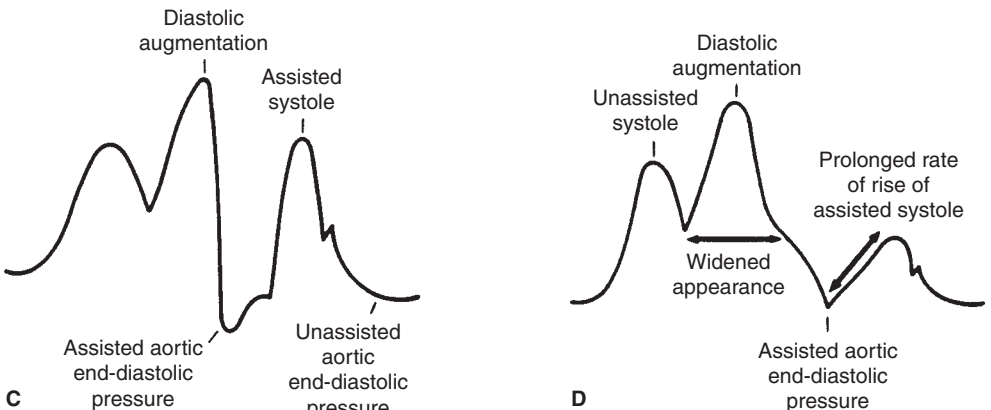
(*Datascope Corporation: Mechanics of intra-aortic balloon counterpulsation. Montvale, NJ: Datascope, 1989.*)

4.3 ► Inaccurate Intra-Aortic Balloon Pump Timing



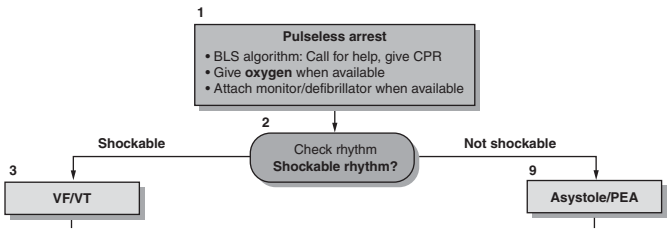
(A) Early inflation. **(B)** Late inflation.

4.3 ► Inaccurate Intra-Aortic Balloon Pump Timing (*continued*)

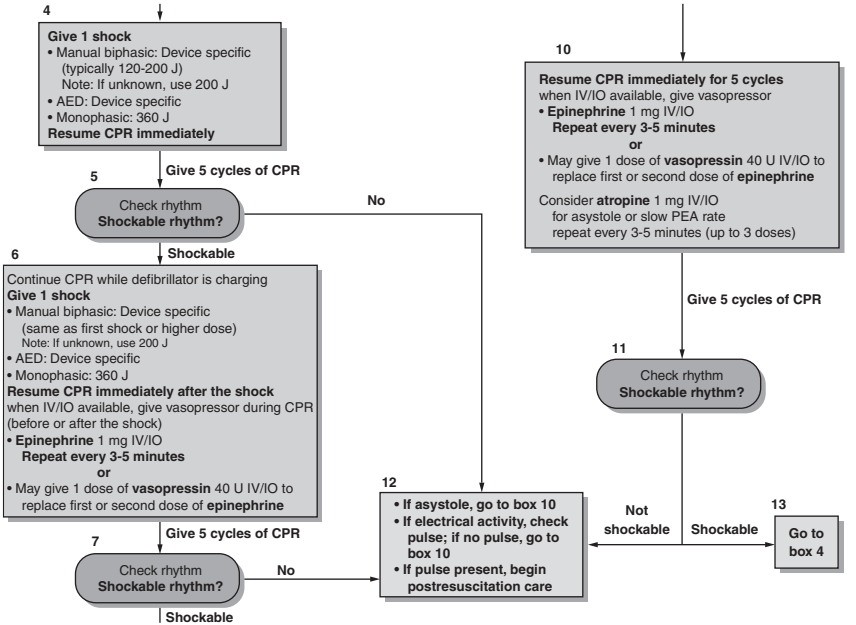


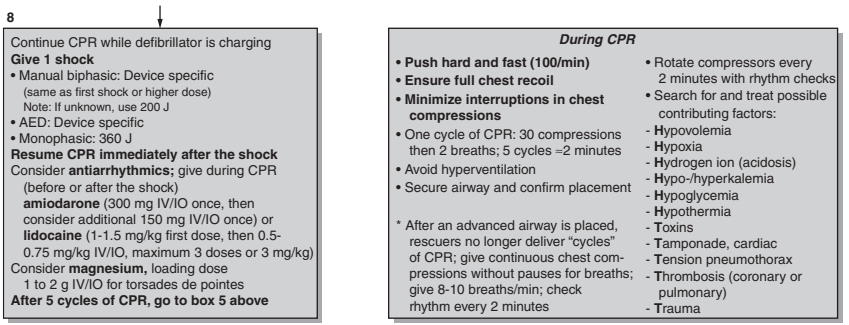
(C) Early deflation. **(D)** Late deflation. (*Datascope Corporation: Mechanics of intra-aortic balloon counterpulsation. Montvale, NJ: Datascope, 1989.*)

4.4 ► Advanced Cardiovascular Life Support (ACLS) Pulseless Arrest Algorithm



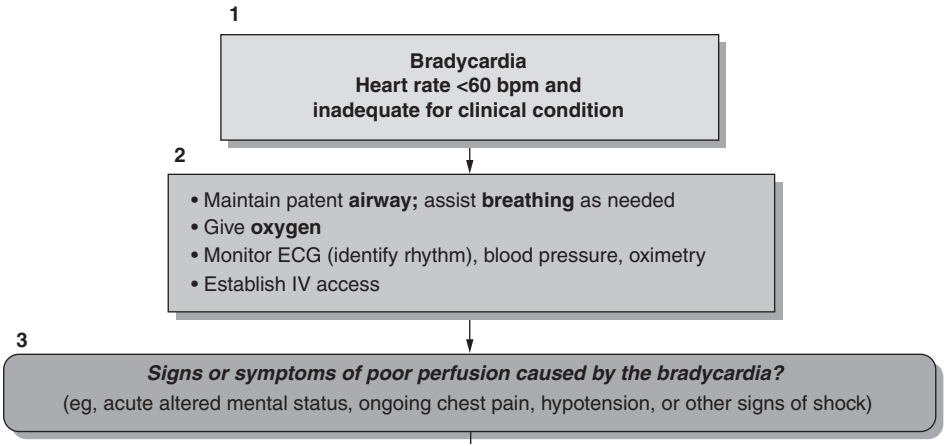
(*continued*)

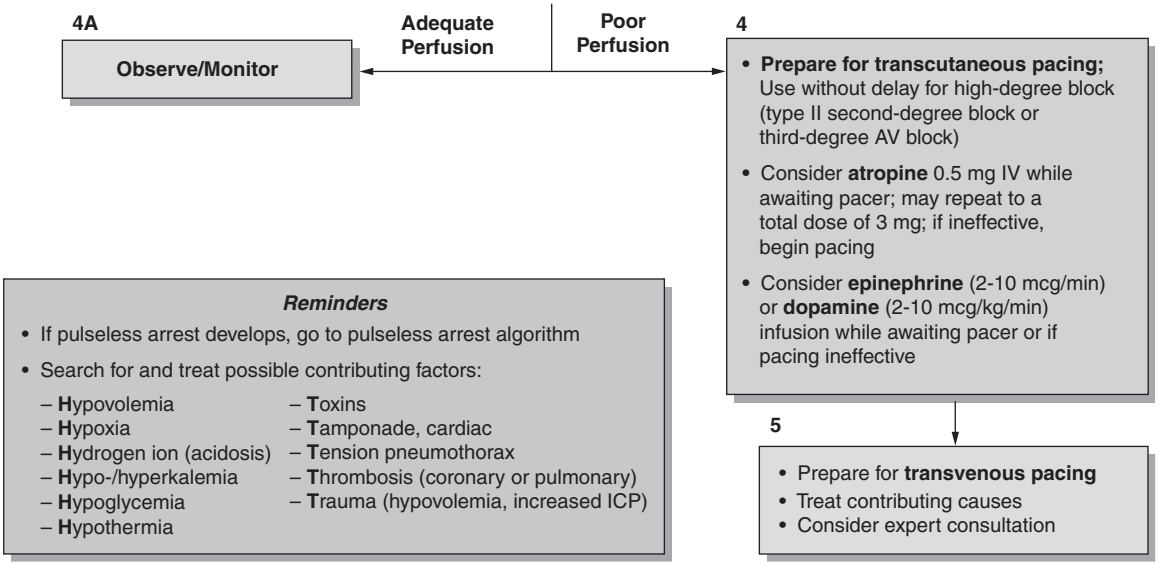

4
Give 1 shock
• Manual biphasic: Device specific (typically 120-200 J)
Note: If unknown, use 200 J
• AED: Device specific
• Monophasic: 360 J
Resume CPR immediately
Give 5 cycles of CPR
5
Check rhythm
Shockable rhythm?
No
Shockable
6
Continue CPR while defibrillator is charging
Give 1 shock
• Manual biphasic: Device specific (same as first shock or higher dose)
Note: If unknown, use 200 J
• AED: Device specific
• Monophasic: 360 J
Resume CPR immediately after the shock
when IV/IO available, give vasopressor during CPR (before or after the shock)
• Epinephrine 1 mg IV/IO
Repeat every 3-5 minutes
or
• May give 1 dose of vasopressin 40 U IV/IO to replace first or second dose of epinephrine
Give 5 cycles of CPR
7
Check rhythm
Shockable rhythm?
No
Shockable
12
• If asystole, go to box 10
• If electrical activity, check pulse; if no pulse, go to box 10
• If pulse present, begin postresuscitation care
10
Resume CPR immediately for 5 cycles
when IV/IO available, give vasopressor
• Epinephrine 1 mg IV/IO
Repeat every 3-5 minutes
or
• May give 1 dose of vasopressin 40 U IV/IO to replace first or second dose of epinephrine
Consider atropine 1 mg IV/IO
for asystole or slow PEA rate
repeat every 3-5 minutes (up to 3 doses)
Give 5 cycles of CPR
11
Check rhythm
Shockable rhythm?
Not shockable
Shockable
13
Go to box 4



(Used with permission from 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circultion. *Dec 13, 2005;112[24 suppl]:IV59. http://circ.ahajournals.org/content/vol112/24_suppl/. Accessed July 15, 2009.)* Abbreviations: AED, automated external defibrillator; BLS, basic life support; CPR, cardiopulmonary resuscitation; IO, intraosseous; IV, intravenous; PEA, pulseless electrical activity; U, units; VF, ventricular fibrillation; VT, ventricular tachycardia.

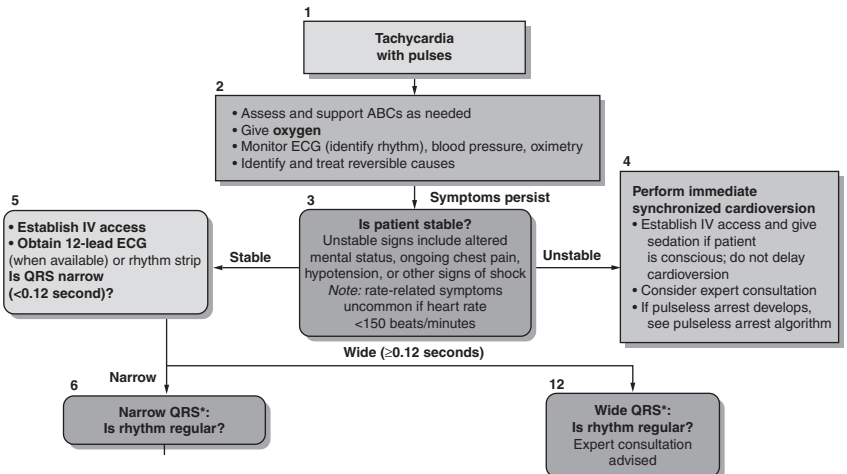
4.5 ► Advanced Cardiovascular Life Support (ACLS) Bradycardia Algorithm

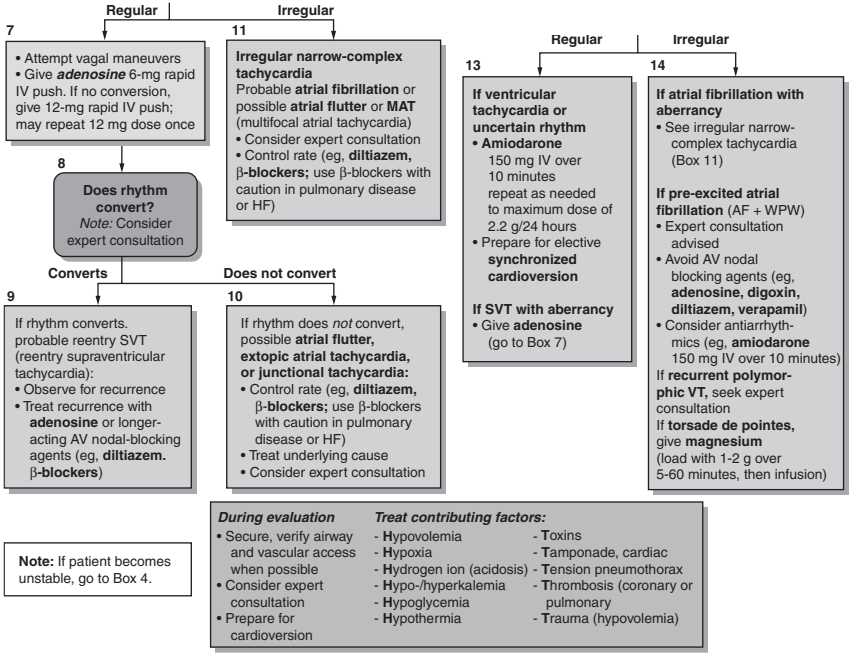




(Used with permission from 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. *Dec 13, 2005;112[24 suppl]:IV68. http://circ.ahajournals.org/content/vol112/24_suppl/. Accessed July 15, 2009.)* Abbreviations: IV, intravenous; mcg, micrograms.

4.6 ► Advanced Cardiovascular Life Support (ACLS) Tachycardia Algorithm





(Used with permission from 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. *Dec 13, 2005;112[24 suppl]:IV70. http://circ.ahajournals.org/content/vol112/24_suppl/. Accessed July 15 2009.)* Abbreviations: AF, atrial fibrillation; HF, heart failure; SVT, supraventricular tachycardia; WPW, Wolff-Parkinson-White.

4.7 ► Problems Encountered with Arterial Catheters

Problem	Cause	Prevention	Treatment
Hematoma after withdrawal of needle	Bleeding or oozing at puncture site	Maintain firm pressure on site during withdrawal of catheter and for 5-15 minutes (as necessary) after withdrawal. Apply elastic tape (Elastoplast) firmly over puncture site. For femoral arterial puncture sites, leave a sandbag on site for 1-2 hours to prevent oozing. If patient is receiving unfractionated, discontinue 2 hours before catheter removal.	Continue to hold pressure to puncture site until oozing stops. Apply sandbag to femoral puncture site for 1-2 hours after removal of catheter.
Decreased or absent pulse distal to puncture site	Spasm of artery Thrombosis of artery	Introduce arterial needle cleanly, nontraumatically. Use 1 U of unfractionated/1 mL IV fluid.	Call physician to inject lidocaine locally at insertion site and 10 mg into arterial catheter. Arteriotomy and Fogarty catheterization may be needed both distally and proximally from the puncture site result in return of pulse in >90% of cases if brachial or femoral artery is used.
Bleedback into tubing or transducer	Insufficient pressure on IV bag Loose connections	Maintain 300 mm Hg pressure on IV bag. Use Luer-Lock stopcocks; tighten periodically.	Replace transducer. "Fast flush" through system. Tighten all connections.

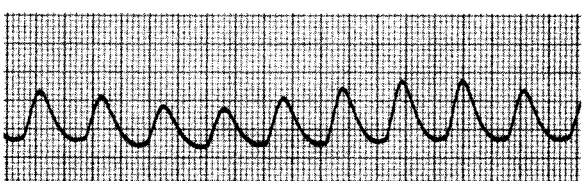
4.7 ► Problems Encountered with Arterial Catheters (*continued*)

Problem	Cause	Prevention	Treatment
Hemorrhage	Loose connections	Keep all connecting sites visible. Observe connecting sites frequently. Use built-in alarm system. Use Luer-Lock stopcocks.	Tighten all connections.
Emboli	Clot from catheter tip into bloodstream	Always aspirate and discard before flushing. Use continuous flush device. Gently flush <2-4 mL.	Remove catheter.
Local infection	Forward movement of contaminated catheter Break in sterile technique Prolonged catheter use	Carefully secure catheter at insertion site. Always use aseptic technique. Leave dressing in place until catheter is removed, changed, or dressing becomes damp, loosened, or soiled.	Remove catheter. Prescribe antibiotic.
Sepsis	Break in sterile technique Prolonged catheter use Bacterial growth in IV fluid	Use percutaneous insertion. Always use aseptic technique. Change IV fluid bag, stopcocks, transducer, and tubing every 72 hours. Do not use IV fluid containing glucose. Use a closed-system flush system rather than an open system Carefully flush remaining blood from stopcocks after blood sampling.	Remove catheter. Prescribe antibiotic.

Adapted from: Daily E, Schroeder J. Techniques in Bedside Hemodynamic Monitoring. *5th ed. St Louis, MO: CV Mosby; 1994: 165-166.*

4.8 ► Inaccurate Arterial Pressure Measurements

Problem	Cause	Prevention	Treatment
Damped pressure tracing	Catheter tip against vessel wall	Usually cannot be avoided.	Call physician to pull back, rotate, or reposition catheter while observing pressure waveform.
	Partial occlusion of catheter tip by clot	Use continuous infusion under pressure. Briefly "fast flush" after blood withdrawal (2-4 mL).	Aspirate clot with syringe and flush with saline (<2-4 mL). Consider line removal.
	Clot in stopcock or transducer	Carefully flush catheter after blood withdrawal and reestablish IV drip. Use continuous flush device.	Flush stopcock and transducer; if no improvement, change stopcock and transducer.
	Air bubbles in transducer or connector tubing	Carefully flush transducer and tubing when setting up system and attaching to catheter.	Check system; flush rapidly; disconnect transducer and flush out air bubbles.
	Compliant tubing	Use stiff, short tubing.	Shorten tubing or replace softer tubing with stiffer tubing.



4.8 ► Inaccurate Arterial Pressure Measurements (*continued*)

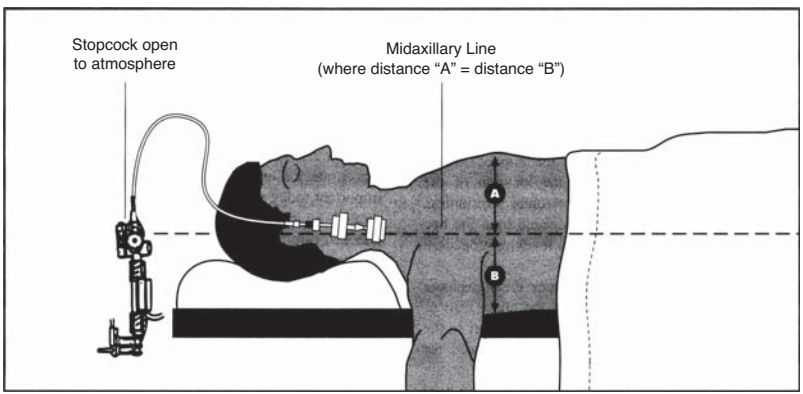
Problem	Cause	Prevention	Treatment
Abnormally high or low readings	Change in transducer air-reference level	Maintain air-reference port of transducer at midchest and/or catheter tip level for serial pressure measurements.	Recheck patient and transducer positions.
No pressure available	Transducer not open to catheter Settings on monitor amplifiers incorrect—still on zero, cal, or off Incorrect scale selection	Follow routine, systematic steps for setting up system and turning stopcocks. Select scale appropriate to expected range of physiologic signal.	Check system—stopcocks, monitor, and amplifier setup. Select appropriate scale.

Adapted from: Daily E, Schroeder J. Techniques in Bedside Hemodynamic Monitoring. *5th ed. St Louis, MO: CV Mosby; 1994*:161

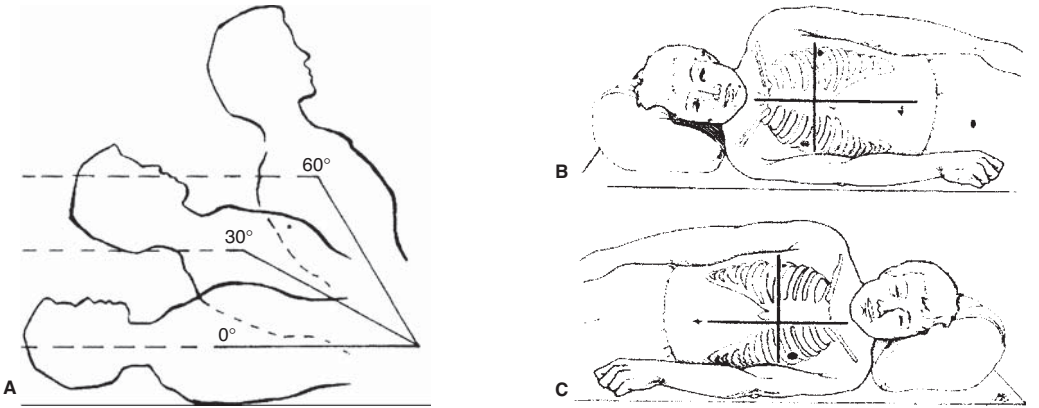
4.9 ► Pulmonary Artery Port Functions

Type of Port	Functions
Distal tip port	Measures pressure at the tip of the catheter in the PA. With proper inflation of the balloon, measures the pulmonary capillary wedge pressure (PCWP). Used to sample SvO_2 levels and for other blood sampling needs.
Proximal lumen port	Measures pressure 30 cm from the distal tip, usually in the right atrium (RA). Central venous pressure (CVP) and RA pressure (RAP) are synonymous terms. Injection site for cardiac output (CO) determinations. Used to draw blood samples for laboratory tests requiring venous blood. If coagulation studies are drawn, completely remove unfractionated heparin from line prior to obtaining sample. Used for IV fluids and drug administration, if necessary.
Balloon inflation port	Inflated periodically with $<$1.5 mL of air to obtain PCWP tracing.
Ventricular port (on selected models of PA catheters)	Measures right ventricle (RV) pressure. Used for insertion of a temporary pacemaker electrode in the RV.
Ventricular infusion port (on selected models of PA catheters)	An additional lumen for IV fluid or drug administration. Located close to the proximal lumen exit area. May be used for CO determinations or CVP measurements, if necessary.
Cardiac output port (thermistor lumen)	Measures blood temperature near the distal tip when connected to the cardiac output computer. May be used to monitor body (core) temperature continuously.

4.10 ► Leveling of the PA Catheter

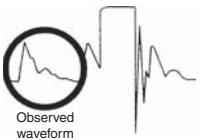


Typical leveling of PA catheter with stopcock attached to the transducer for mounting on a pole. The stopcock close to the transducer is opened to atmospheric pressure (air) horizontal to the fourth ICS at the midaxillary line.



(A) The level of the phlebostatic axis as the patient moves flat to a higher level of backrest. The level of the axis for referencing and zeroing the air-fluid interface rotates on the axis and remains horizontal as the patient moves from flat to increasingly higher backrest positions. For accurate hemodynamic pressure readings at different backrest elevations, the air-fluid interface must be at the level of the phlebostatic axis. (*From Bridges EJ, Woods SL. Pulmonary artery pressure measurement: state of the art.* Heart Lung. *1993;22*[*2*]*:101.*) **(B)** For the right lateral position, the reference point is at the intersection of the fourth ICS and the midsternum. **(C)** For the left lateral position, the reference point is the intersection of the fourth ICS and the left parasternal border. (*From Keckeisen M, Chulay M, Gawlinski A, eds. Pulmonary artery pressure monitoring. In:* Hemodynamic Monitoring Series. *Aliso Viejo, CA: AACN; 1998:12.*)

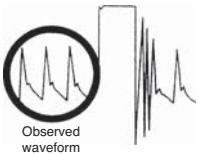
4.12 ► Assessing Damping Concepts from Square Wave Test

Square Wave Test	Clinical Effect	Corrective Action
Optimally damped  Optimally damped system. When the fast flush of the continuous flush system is activated and quickly released, a sharp upstroke terminates in a flat line at the maximal indicator on the monitor and hard copy. This is followed by an immediate and rapid downstroke extending below the baseline with just 1 or 2 oscillations within 0.12 second (minimal ringing) and a quick return to baseline. The patient's pressure waveform is also clearly defined with all components of the waveform, such as the dicrotic notch on an arterial waveform, clearly visible. Intervention: There is no adjustment in the monitoring system required. (*Reprinted from Darovic GO, Vanriper S, Vanriper J. Fluid-filled monitoring systems. In: Darovic GO, ed.* Hemodynamic Monitoring: Invasive and Noninvasive Clinical Application. *3rd ed. Philadelphia, PA: WB Saunders Co; 1995:161-162. Used with permission from Elsevier.*)	Produces accurate waveform and pressure.	None required.

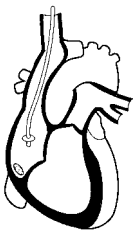
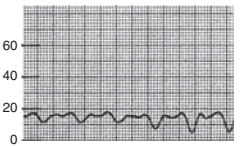
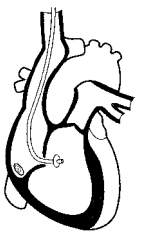
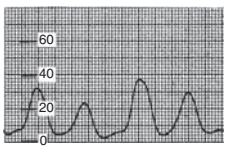
4.12 ► Assessing Damping Concepts from Square Wave Test (*continued*)

Square Wave Test	Clinical Effect	Corrective Action
Overdamped  Observed waveform Overdamped system. The upstroke of the square wave appears somewhat slurred, the waveform does not extend below the baseline after the fast flush, and there is no ringing after the flush. The patient's waveform displays a falsely decreased systolic pressure and a falsely high diastolic pressure as well as poorly defined components of the pressure tracing such as a diminished or absent dicrotic notch on arterial waveforms. Interventions: To correct the problem, (1) check for the presence of blood clots, blood left in the catheter following blood sampling, or air bubbles at any point from the catheter tip to the transducer and eliminate them as necessary; (2) use low compliance (rigid), short (<3-4 ft) monitoring tubing; (3) ensure there are no loose connections; and (4) check for kinks in the line. (*Reprinted from Darovic GO, Vanriper S, Vanriper J. Fluid-filled monitoring systems. In: Darovic GO, ed.* Hemodynamic Monitoring: Invasive and Noninvasive Clinical Application. *3rd ed. Philadelphia, PA: WB Saunders Co; 1995:161-162. Used with permission.*)	Produces a falsely low systolic and high diastolic value.	Check the system for air, blood, loose connections or kinks in the tubing or catheter. Verify extension tubing has not been added.

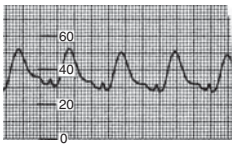
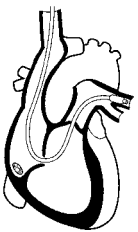
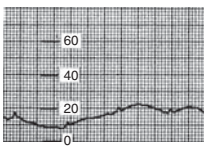
4.12 ► Assessing Damping Concepts From Square Wave Test (*continued*)

Square Wave Test	Clinical Effect	Corrective Action
Underdamped  Observed waveform Underdamped system. The waveform is characterized by numerous amplified oscillations above and below the baseline following the fast flush. The monitored pressure wave displays falsely high systolic pressure (overshoot), possibly falsely low diastolic pressures, and "ringing" artifacts on the waveform. Intervention: To correct the problem, remove all air bubbles in the fluid system. Use large bore, shorter tubing, or a damping device. (*Reprinted from Darovic GO, Vanriper S, Vanriper J. Fluid-filled monitoring systems. In: Darovic GO, ed.* Hemodynamic Monitoring: Invasive and Noninvasive Clinical Application. *3rd ed. Philadelphia, PA: WB Saunders Co; 1995:161-162. Used with permission from Elsevier.*)	Produces a falsely high systolic and low diastolic value.	Remove unnecessary tubing and stopcocks. Add a damping device.

4.13 ► Pressure Waveforms Observed During Pulmonary Artery Catheter Insertion

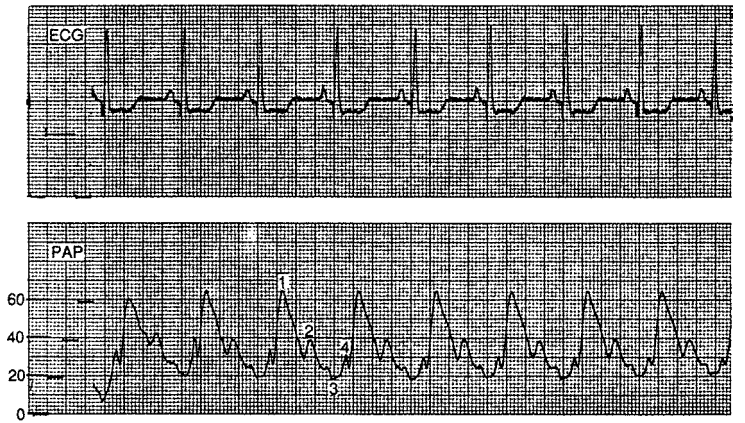
Location	Pressure Waveform	Normal Pressures
Right atrium 		2-8 mm Hg
Right ventricle 		Systolic, 20-30 mm Hg Diastolic, 0-5 mm Hg

4.13 ► Pressure Waveforms Observed During Pulmonary Artery Catheter Insertion (*continued*)

Location	Pressure Waveform	Normal Pressures
Pulmonary artery 		Systolic, 20-30 mm Hg Diastolic, 10-15 mm Hg
Pulmonary artery wedge 		8-12 mm Hg

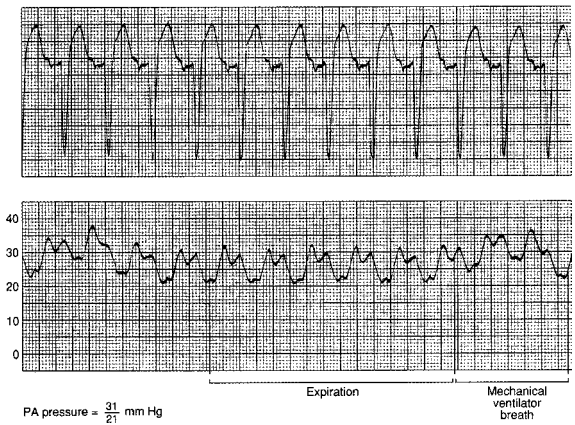
With permission from: Boggs R, Wooldridge-King M. AACN Procedure Manual. *3rd ed. Philadelphia, PA: WB Saunders; 1993:308, 324, 326, 334.*

4.14 ► Pulmonary Artery Waveform and Components



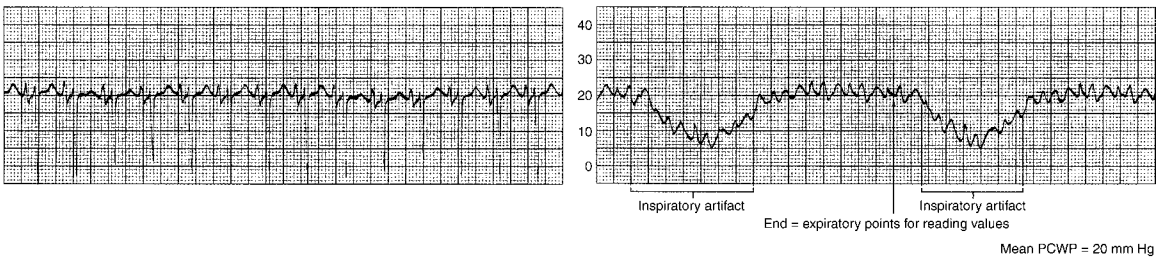
1, PA systole; 2, dichrotic notch; 3, PA end diastole; 4, anacrotic notch of PA valve opening. (*From: Boggs R, Wooldridge-King M.* AACN Procedure Manual for Critical Care, *3rd ed. Philadelphia, PA: WB Saunders; 1993:316.*)

4.15 ► Effect of a Mechanical Ventilator Breath on PA Waveform



(*From: Ahrens TS.* Hemodynamic Waveform Recognition. *Philadelphia, PA: WB Saunders; 1993:92.*)

4.16 ► Reading End Expiration Before a Spontaneous Breath



(*From: Ahrens TS, Taylor L:* Hemodynamic Waveform Analysis. *Philadelphia: WB Saunders; 1992:170.*)

4.17 ► Evidence-Based Practice: Pulmonary Artery Pressure Measurement

- Verify the accuracy of the transducer-patient interface by performing a square waveform test at the beginning of each shift.[a,b]
- Position the patient supine prior to PAP/RAP (CVP)/PCWP measurements. Head of bed elevation can be at any angle from 0° (flat) to 60°.[a,b]
- Level the transducer air-fluid interface to the phlebostatic axis (4th ICS/½ AP diameter of the chest) with the patient in a supine position prior to PAP/RAP/PCWP measurements.[a,b]
- Obtain PAP/RAP/PCWP measurements from a graphic (analog) tracing at end-expiration.[a,b]
- Use a simultaneous ECG tracing to assist with proper PAP/RAP/PCWP waveform identification.[a,b]
- PA catheters can be safely withdrawn and removed by competent registered nurses.[a,b]

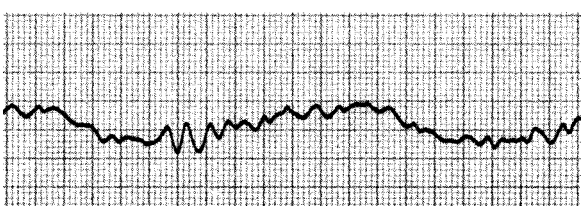
Data from: [a]American Association of Critical-Care Nurses (2004); [b]Keckeisen (1998).

4.18 ► Problems Encountered with Pulmonary Artery Catheters

Problem	Cause	Prevention	Treatmen
Phlebitis or local infection at insertion site	Mechanical irritation or contamination	Prepare skin properly before insertion. Use sterile technique during insertion and dressing change. Insert smoothly and rapidly. Use Teflon-coated introducer. Change IV fluid bag, transducer, stopcocks, and connecting tubing every 72 hours. Remove catheter or change insertion site.	Remove catheter. Apply warm compresses. Give pain medication as necessary.
Ventricular irritability	Looping of excess catheter in RA	Carefully secure catheter at insertion site; check chest film.	Call physician to reposition catheter; remove loop.
	Migration of catheter from PA to RV	Position catheter tip in main right or left PA.	Inflate balloon to encourage catheter flotation out to PA.
	Irritation of the endocardium during catheter passage	Keep balloon inflated during advancement; advance gently.	

4.18 ► Problems Encountered with Pulmonary Artery Catheters (*continued*)

Problem	Cause	Prevention	Treatment
Apparent wedging of catheter with balloon deflated	Forward migration of catheter tip caused by blood flow, excessive loop in RV, or inadequate suturing of catheter at insertion site	Check catheter tip by radiograph or fluoroscopy; position in main right or left PA. Carefully secure catheter at insertion site.	Aspirate blood from catheter; if catheter is wedged, sample will be arterialized and obtained with difficulty. If wedged, call physician to slowly pull back catheter until PA waveform appears. If not wedged, gently aspirate and flush catheter with saline; catheter tip can partially clot, causing damping that resembles damped PAW waveform.

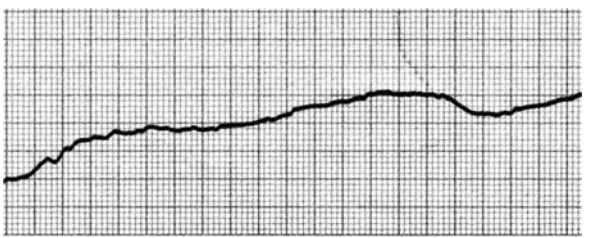


4.18 ► Problems Encountered with Pulmonary Artery Catheters (*continued*)

Problem	Cause	Prevention	Treatment
Pulmonary hemorrhage or infarction, or both	Distal migration of catheter tip Continuous or prolonged wedging of catheter	Check chest film immediately after insertion. Leave balloon deflated. Carefully secure catheter at insertion site. Call physician to pull catheter back to PA if it spontaneously wedges. Do not flush catheter when in wedge position.	Deflate balloon (passively). Place patient on side (catheter tip down). Stop anticoagulation. Consider “wedge” angiogram.
	Overinflation of balloon while catheter is wedged Failure of balloon to deflate	Inflate balloon slowly with only enough air to obtain a PAW waveform. Do not inflate 7-Fr catheter with more than 1.25-1.5 mL air.	

4.18 ► Problems Encountered with Pulmonary Artery Catheters (*continued*)

Problem	Cause	Prevention	Treatment
"Overwedging" or damped PAW	Overinflation of balloon	Do not inflate if resistance is met. Watch waveform during inflation; inject only enough air to obtain PAW pressure. Do not inflate 7-Fr catheter with more than 1.25-1.5 mL air.	Deflate balloon; reinflate slowly with only enough air to obtain PAW pressure.
	Eccentric inflation of balloon	Check inflated balloon shape before insertion.	



4.18 ► Problems Encountered with Pulmonary Artery Catheters (*continued*)

Problem	Cause	Prevention	Treatment
PA balloon rupture	Overinflation of balloon Frequent inflations of balloon Syringe deflation damaging wall of balloon	Inflate slowly with only enough air to obtain a PAW pressure. Monitor PAD pressure as reflection of PAW and LVEDP. Allow passive deflation of balloon. Remove syringe after inflation.	Remove syringe to prevent further air injection. Monitor PAD pressure.
Infection	Nonsterile insertion techniques	Use sterile techniques. Use sterile catheter sleeve.	Remove catheter. Use antibiotics.
	Contamination via skin	Prepare skin with effective antiseptic (chlorhexidine). Reassess need for catheter after 3 days. Avoid internal jugular approach.	
	Contamination through stopcock ports or catheter hub	Use a closed-system flush system rather than an open system. Use sterile dead-end caps on all stopcock ports. Change tubing, continuous flush device transducer, and flush solution every 72 hours. Do not use IV flush solution that contains glucose.	

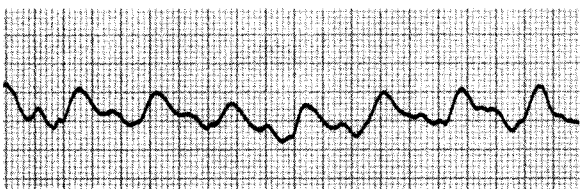
4.18 ► Problems Encountered with Pulmonary Artery Catheters (*continued*)

Problem	Cause	Prevention	Treatment
	Fluid contamination from transducer through cracked membrane	Check transducer for cracks. Change transducers every 72 hours. Do not use IV flush solution that contains glucose.	
	Prolonged catheter placement	Change catheter and/or insertion site with any local signs of infection and for infections without an obvious source (should obtain cultures). Remove catheter as soon as clinically feasible.	
		Catheter should be advanced expeditiously during insertion with balloon inflated.	
Heart block during insertion of catheter	Mechanical irritation of bundle of His in patients with preexisting left bundle branch block	Insert transvenous pacing catheter before PA catheter insertion.	Use temporary pacemaker or flotation catheter with pacing wire.

Abbreviations: PA, pulmonary artery; PAW, pulmonary artery wedge; RV, right ventricle;
Adapted from: Daily E, Schroeder J. Techniques in Bedside Hemodynamic Monitoring. *5th ed. St Louis, MO: CV Mosby; 1994*:134-135

4.19 ► Inaccurate Pulmonary Artery Pressure Measurements

Problem	Cause	Prevention	Treatment
Damped waveforms and inaccurate pressures	Partial clotting at catheter tip	Maintain adequate flush bag pressures. Flush with large volume after blood sampling.	Aspirate, then flush catheter with fast flush (not in PAW position).
	Tip moving against wall	Obtain more stable catheter position.	Call physician to reposition catheter.
	Kinking of catheter	Restrict catheter movement at insertion site.	Reposition to straighten catheter. Replace catheter.

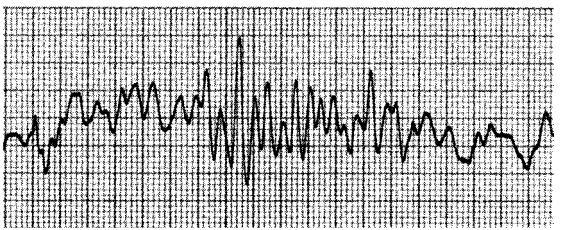


4.19 ► Inaccurate Pulmonary Artery Pressure Measurements (*continued*)

Problem	Cause	Prevention	Treatment
Abnormally low or negative pressures	Incorrect air-reference level (above midchest level)	Maintain transducer air-reference port at midchest level; rezero after patient position changes.	Remeasure level of transducer air-reference and reposition at midchest level; rezero.
	Incorrect zeroing and calibration of monitor	Zero and calibrate monitor properly. Use Luer-Lock stopcocks.	Recheck zero and calibration of monitor.
	Loose connection	Use Luer-Lock stopcocks.	Check all connections.
Abnormally high pressure reading	Pressure trapped by improper sequence of stopcock operation	Turn stopcocks in proper sequence when two pressures are measured on one transducer.	Thoroughly flush transducers with IV solution; rezero and turn stopcocks in proper sequence.
	Incorrect air-reference level (below midchest level)	Maintain transducer air-reference port at midchest level; recheck and rezero after patient position changes.	Check air-reference level; reset at midchest and rezero.
Inappropriate pressure waveform	Migration of catheter tip (eg, in RV or PAW instead of in PA)	Establish optimal position carefully when introducing catheter initially. Secure catheter at insertion site and tape catheter to patient's skin.	Review waveform; if RV, call physician to reposition catheter. Check position under x-ray and/or fluoroscopy after reposition.

4.19 ► Inaccurate Pulmonary Artery Pressure Measurements (*continued*)

Problem	Cause	Prevention	Treatment
No pressure available	Transducer not open to catheter Amplifiers still on cal, zero, or off	Follow routine, systematic steps for pressure measurement.	Check system, stopcocks.
Noise or fling in pressure waveform	Excessive catheter movement, particularly in PA	Avoid excessive catheter length in ventricle.	Try different catheter tip position.
	Excessive tubing length	Use shortest tubing possible (<3-4 ft).	Eliminate excess tubing.
	Excessive stopcocks	Minimize number of stopcocks.	Eliminate excess stopcocks.



Abbreviations: PA, pulmonary artery; PAW, pulmonary artery wedge; RV, right ventricle.
Adapted from: Daily E, Schroeder J. Techniques in Bedside Hemodynamic Monitoring. *5th ed. St Louis, MO: CV Mosby; 1994:137.*

4.20 ► Troubleshooting Problems with Thermodilution Cardiac Output Measurements

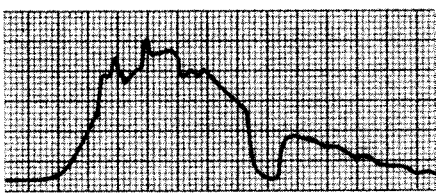
Problem	Cause	Action
Cardiac output values lower than expected	Injectate volume greater than designated amount	Inject exact volume to correspond to computation constant used.
		Discontinue rapid infusion through proximal or distal port.
	Catheter tip in RV or RA	Verify PA waveform from distal lumen. Reposition catheter.
	Incorrect variables entered into monitor	Recheck and correct variables (height, weight).
	Left-to-right shunt (VSD)	Check RA and PA oxygen saturations.
		Use alternative CO measurement technique.
	Catheter kinked or thermistor partially obstructed with clot	
	Faulty catheter (communication between proximal and distal lumens)	Check for kinks at insertion site; straighten catheter; aspirate and flush catheter. Replace catheter.

4.20 ► Troubleshooting Problems with Thermodilution Cardiac Output Measurements (*continued*)

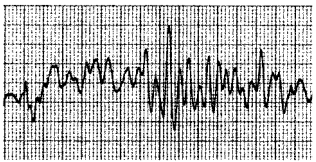
Problem	Cause	Action
Cardiac output values higher than expected	Injectate volume less than designated amount	Inject exact volume to correspond to computation constant. Carefully remove all air bubbles from syringe.
	Catheter too distal (PAW)	Verify PA waveform from distal lumen. Pull catheter back.
	RA port lies within sheath	Advance catheter.
	Thermistor against wall of PA	Reposition patient. Rotate catheter to turn thermistor away from wall. Reposition catheter.
	Fibrin covering thermistor	Check a-vDo_2; change catheter.
	Incorrect variables	Recheck and correct variables (height, weight).
	Right-to-left shunt (VSD) Severe tricuspid regurgitation	Use alternative CO measurement technique.
	Incorrect injectate temperature	Use closed injectate system with in-line temperature probe. Handle syringe minimally. Do not turn stopcock to reestablish IV infusion through proximal port between injections; reduce or discontinue IV flow through VIP port.
		Try to determine cause of interference.

4.20 ► Troubleshooting Problems with Thermodilution Cardiac Output Measurements (*continued*)

Problem	Cause	Action
Irregular upslope of CO curve	Magnetic interference producing numerous spikes in CO curve	
	Long lag time between injection and upstroke of curve	Press start button after injection completed to delay computer sampling time.
	Uneven injection technique	Inject smoothly and quickly (10 mL in ≤4 seconds).
	RA port partially occluded with clot	Always check catheter patency by withdrawing, then flushing proximal port before CO determinations.
	Catheter partially kinked	Check for kinks, particularly at insertion site; straighten catheter; reposition patient.



Problem	Cause	Action
Irregular downslope of CO curve	Cardiac arrhythmias (PVC, AF, etc)	Note ECG during CO determinations. Try to inject during a stable period. Increase the number of CO determinations.
	Marked movement of catheter tip	Obtain x-ray film to determine position of tip. Advance catheter tip away from pulmonic value.
	Marked variation in PA baseline temperature	Use iced temperature injectate to increase signal/noise ratio. Increase the number of CO determinations. Inject at various times during respiratory cycle.
	Curve prematurely terminated	Press start button after injection completed to delay computer sampling time.
	Right-to-left shunt	Use alternative CO measurement technique.



Abbreviations: AV, atrioventricular; CO, cardiac output; CPR, cardiopulmonary resuscitation; ECG, electrocardiogram; IV, intravenous; NSR, normal sinus rhythm; MAT, multifocal atrial tachycardia; PAC, premature atrial contraction; PJC, premature junctional complex; PVC, premature ventricular complexes; VT, ventricular tachycardia.

Adaption from: Daily E, Schroeder J. Techniques in Bedside Hemodynamic Monitoring. *5th ed. St Louis, MO; CV Mosby; eds, 1994: 183–184 Cardiac output waveforms from: Gardner P. Cardiac output: theory, technique and troubleshooting. In: Underhill SL, Woods S, Froelicher E, et al.* Cardiac Nursing. *2nd ed. Philadelphia, PA: JB Lippincott; 1989:465.*

4.21 ► Common Inotropic Therapies in Treating Abnormal Hemodynamics

Drug	Dosage	Onset of Action	Route
Dobutamine (Dobutrex)	1-20 mcg/kg/min	1-2 minutes	IV
Dopamine (Intropin)	2-10 mcg/kg/min	1-2 minutes	IV
Milrinone (Primacor)	Loading 0.75 mg/kg, then 5-10 mcg/kg/min	<5 minutes	IV
Digoxin (Lanoxin) (normally not used in acute LV failure)	0.5 mg at first; then 0.25 every 6 hours until desired effect, then 0.125-0.25 mg/day	1-2 hours	IV

4.22 ► Common Preload Reducers for Abnormal Hemodynamics

Drug	Dosage	Onset of Action	Route
Diuretic Agents			
Furosemide (Lasix)	20 mg or higher	<5 minutes	IV/PO
Bumetanide (Bumex)	0.5-10 mg/day	<5 minutes	IV/PO
Ethacrynic Acid (Edecrin)	50-100 mg/day	<5 minutes	IV/PO
Chlorothiazide (Diuril)	500-2000 mg/day	1-2 hours	IV/PO
Metolazone (Zaroxolyn)	2.5-20 mg/day	1 hour	PO
Mannitol (Osmitrol)	12.5-200 g/day	<5 minutes	IV
Vasodilating Agents			
Dopamine (Intropin)	1-2 mcg/kg/min	<5 minutes	IV
Nitroglycerine (Tridil, Nitrostat IV)	5-400 mcg	1-2 minutes	IV

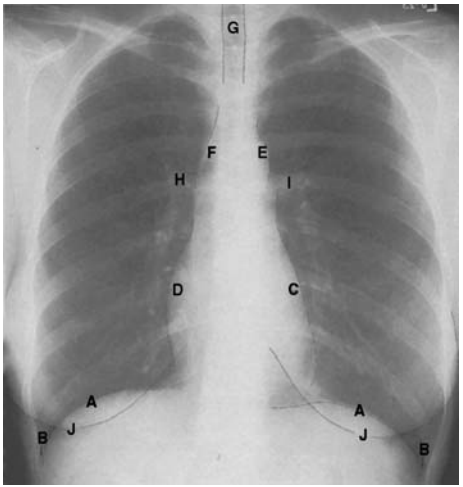
4.23 ► Common Afterload Reducing Agents

Drug	Dose	Onset of Action	Route
Smooth Muscle Relaxants and Alpha Inhibitors			
Nitroprusside (Nipride)	0.5-10 mcg/kg/min	1-2 minutes	IV
Nitroglycerine (Tridil, Nitrostat IV)	5-400 mcg	1-2 minutes	IV
Diazoxide (Hyperstat IV)	50-150 mg	1-2 minutes	IV
Hydralazine (Apresoline)	10-40 mg	10-20 minutes	IV/IM
Methyldopa (Aldomet)	250 mg-1 g	2 hours	IV
Trimethaphan (Arfonad)	3-6 mg/min	1-2 minutes	IV
Phentolamine (Regitine)	0.1-2 mg/min	<1 minute	IV
Angiotension-Converting Enzyme Inhibitors			
Captopril (Capoten)	25-400 mg/day in 2-3 doses	15-30 minutes	PO
Enalapril/Enalaprilat (Vasotec/Vasotec IV)	2.5-4.0 mg/day	15 minutes	PO/IV
Lisinopril (Zestril)	10-40 mg/day	1 hour	PO

Respiratory Concepts

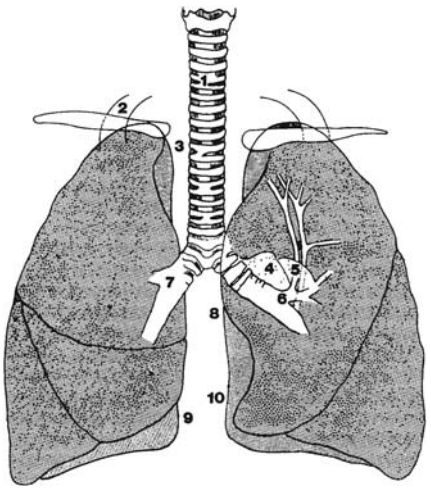
Section 5

5.1 ► Normal Chest X-Ray



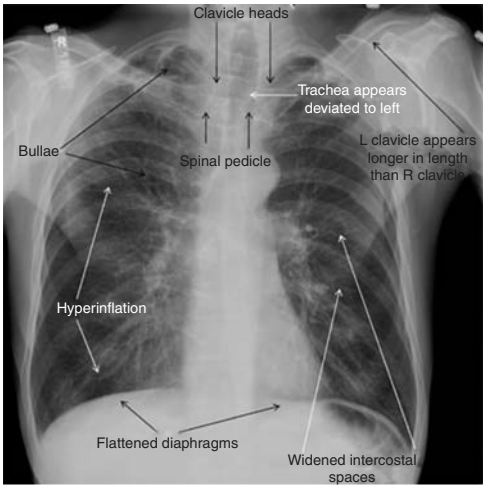
Normal chest x-ray film taken of a 28-year-old woman from a PA view. Some anatomic structures can be seen on the x-ray: **(A)** diaphragm; **(B)** costophrenic angle; **(C)** left ventricle; **(D)** right atrium; **(E)** aortic arch (referred to as aortic knob); **(F)** superior vena cava; **(G)** trachea; **(H)** right bronchus (right hilum); **(I)** left bronchus (left hilum); and **(J)** breast shadows.

5.2 ► Mediastinal Structures Visible on a Chest X-Ray



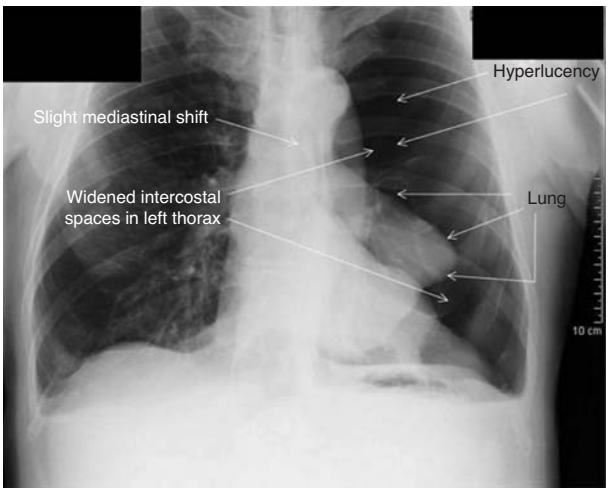
(1) Trachea, **(2)** first rib, **(3)** superior vena cava, **(4)** aortic knob, **(5)** pulmonary artery, **(6)** left main bronchus, **(7)** right main bronchus, **(8)** left atrium, **(9)** right atrium, and **(10)** left ventricle. (*From: Sanchez F. Fundamentals of chest x-ray interpretation.* Crit Care Nurse. *1986;6*[*5*]*:53.*)

5.3 ► Chest X-Ray of COPD



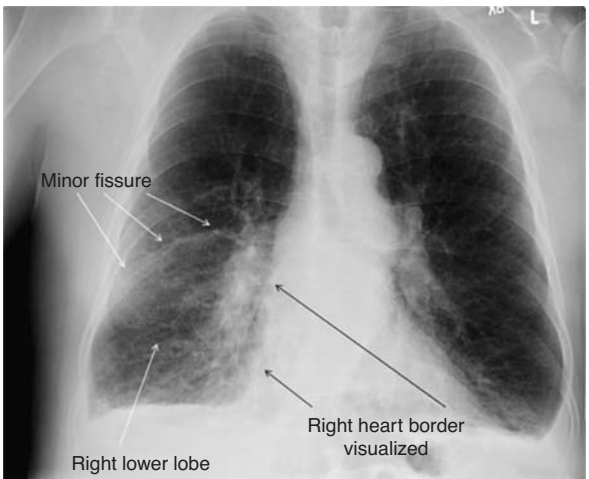
COPD, flattened diaphragms, hyperinflation, widened intercostals spaces, apical bullae, and chest rotation. (*Reprinted from: Siela D. Chest radiograph evaluation and interpretation.* AACN Adv Crit Care. *2008;19:444-473.*)

5.4 ► Chest X-Ray of Pneumothorax



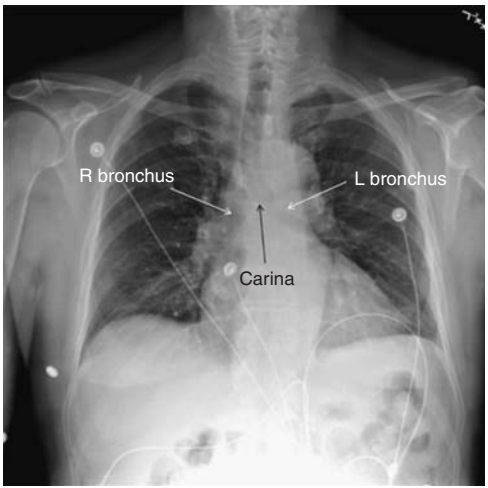
Left pneumothorax, hyperlucency, and widened intercostals spaces. (*Reprinted from: Siela D. Chest radiograph evaluation and interpretation.* AACN Adv Crit Care. *2008;19:444-473.*)

5.5 ► Chest X-Ray of Right Lower Lobe Pneumonia



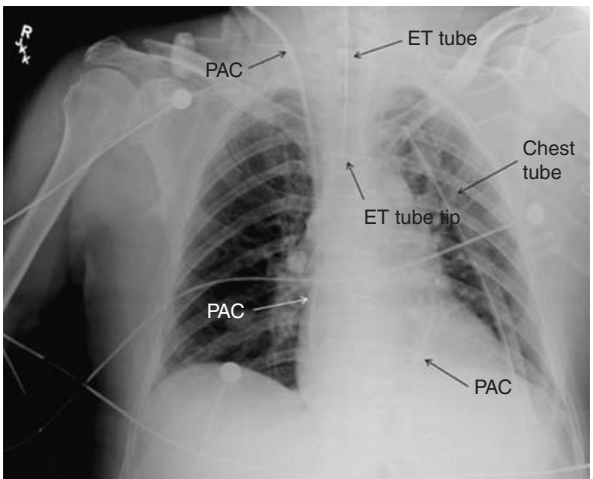
Right lower lobe pneumonia with minor fissure visualized. (*Reprinted from: Siela D. Chest radiograph evaluation and interpretation.* AACN Adv Crit Care. *2008;19:444-473.*)

5.6 ► Chest X-Ray Showing Carina and Right Bronchus



Carina and right bronchus. (*Reprinted from: Siela D. Chest radiograph evaluation and interpretation*. AACN Adv Crit Care. *2008;19:444-473*.)

5.7 ► Chest X-Ray with PA Catheter, ET Tube, and Chest Tube



Pulmonary artery catheter, endotracheal tube, and left chest tube. (*Reprinted from: Siela D. Chest radiograph evaluation and interpretation.* AACN Adv Crit Care. *2008;19:444-473.*)

5.8 ► Acid-Base Abnormalities

	Primary ABG Abnormalities			*ABG Changes with Compensation (if present)*	
Acid-Base Abnormality	**pH**	**$Paco_2$**	**HCO_3^-**	**Respiratory ($Paco_2$)**	**Metabolic (HCO_3^-)**
Alkalemia					
Metabolic	↑		↑	↑	
Respiratory	↑	↓			↓
Acidemia					
Metabolic	↓		↓	↓	
Respiratory	↓	↑			↑

5.9 ► Indications for Mechanical Ventilation

Basic Physiologic Impairment	Best Available Indicators	Approximate Normal Range	Values Indicating Need for Ventilatory Support
Inadequate alveolar ventilation (acute ventilatory failure)	$Paco_2$, mm Hg	36-44	Acute increase from normal or patient's baseline
	Arterial pH	7.36-7.44	$<$7.25-7.30
Hypoxemia (acute oxygenation failure)	Alveolar-to-arterial Po_2 gradient breathing 100% O_2, mm Hg	25-65	$>$350
	Intrapulmonary right-to-left shunt fraction, percentage	$<$5	$>$20-25
	Pao_2/Fio_2, mm Hg	350-400	$<$200
Inadequte lung expansion	Tidal volume, mL/kg	5-8	$<$4-5
	Vital capacity	60-75	$<$10
	Respiratory rate, breaths/min (adults)	12-20	$>$35
Inadequate respiratory muscle strength	Maximum inspiratory pressure, cm H_2O	-80 to -100	≥ -20
	Maximum voluntary ventilation, L/min	120-180	$<2 \times$ resting ventilatory requirement
	Vital capacity, mL/kg	60-75	$<$10-15
Excessive work of breathing	Minute ventilation necessary to maintain normal $Paco_2$, L/min	5-10	$>$15-20
	Dead space ratio, percentage	0.25-0.40	$>$0.60
	Respiratory rate, breaths/min (adults)	12-20	$>$35
Unstable ventilatory drive	Breathing pattern; clinical setting		

From: Luce J, Pierson D, eds. Critical Care Medicine. *Philadelphia: WB Saunders; 1988:219.*

5.10 ► Pulmonary Specific Wean Criteria Thresholds

Traditional Weaning Criteria

- Negative inspiratory pressure (NIP) $\leq$ –20 cm H_2O
- Positive expiratory pressure (PEP) $\geq$ +30 cm H_2O
- Spontaneous tidal volume (SV_T) $\geq$5 mL/kg
- Vital capacity (VC) $\geq$15 mL/kg
- Fraction of inspired oxygen (Fio_2) $\leq$50%
- Minute ventilation (MV) $\leq$10 L/min

Integrated Weaning Criteria

- Index of rapid shallow breathing or frequency tidal volume ratio (fx/V_t) $\leq$105

5.11 ► Burns' Wean Assessment Program (BWAP)[a]

I. General Assessment

Yes	No	Not Assessed	
_____	_____	_____	1. Hemodynamically stable (pulse rate, cardiac output)?
_____	_____	_____	2. Free from factors that increase or decrease metabolic rate (seizures, temperature, sepsis, bacteremia, hypo/hyperthyroid)?
_____	_____	_____	3. Hematocrit >25% (or baseline)?
_____	_____	_____	4. Systemically hydrated (weight at or near baseline, balanced intake and output)?
_____	_____	_____	5. Nourished (albumin >2.5, parenteral/enteral feedings maximized)? *If albumin is low and anasarca or third spacing is present, score for hydration should be "no."
_____	_____	_____	6. Electrolytes within normal limits (including Ca^{++}, Mg^{+}, PO_4)? *Correct Ca^{++} for albumin level.
_____	_____	_____	7. Pain controlled (subjective determination)?
_____	_____	_____	8. Adequate sleep/rest (subjective determination)?
_____	_____	_____	9. Appropriate level of anxiety and nervousness (subjective determination)?
_____	_____	_____	10. Absence of bowel problems (diarrhea, constipation, ileus)?
_____	_____	_____	11. Improved general body strength/endurance (ie, out of bed in chair, progressive activity program)?
_____	_____	_____	12. Chest x-ray improving?

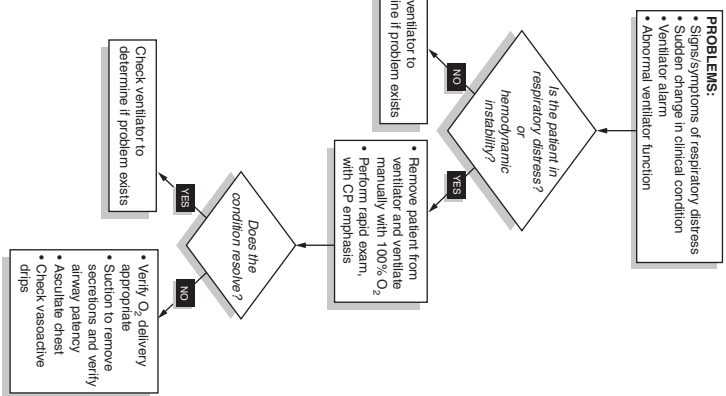
5.11 ► Burns' Wean Assessment Program (BWAP)[a] (*continued*)

II. Respiratory Assessment

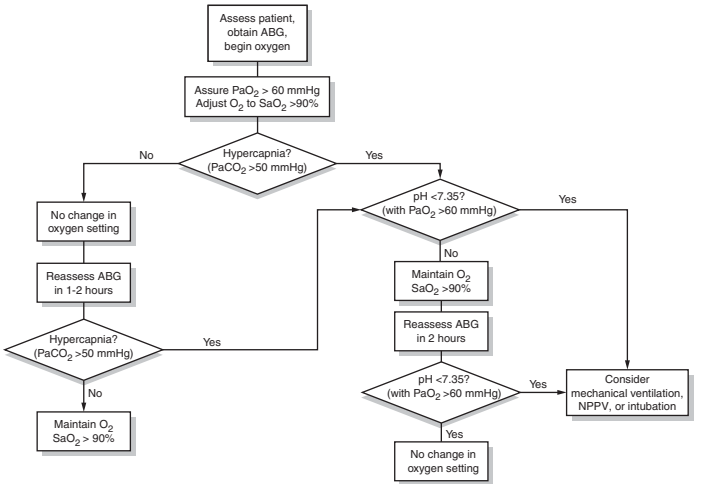
Yes	No	Not Assessed	
			Gas Flow and Work of Breathing
_____	_____	_____	13. Eupneic respiratory rate and pattern (spontaneous RR <25, without dyspnea, absence of accessory muscle use)? *This is assessed off the ventilator while measuring #20-23.
_____	_____	_____	14. Absence of adventitious breath sounds (rhonchi, rales, wheezing)?
_____	_____	_____	15. Secretions thin and minimal?
_____	_____	_____	16. Absence of neuromuscular disease/deformity?
_____	_____	_____	17. Absence of abdominal distention/obesity/ascites?
_____	_____	_____	18. Oral ETT > #7.5 or trach > #6.5?
			Airway Clearance
_____	_____	_____	19. Cough and swallow reflexes adequate?
			Strength
_____	_____	_____	20. NIP <20 (negative inspiratory pressure)?
_____	_____	_____	21. PEP >30 (positive expiratory pressure)?
			Endurance
_____	_____	_____	22. STV >5 mL/kg (spontaneous tidal volume)?
_____	_____	_____	23. VC >10-15 mL/kg (vital capacity)?
			ABGs
_____	_____	_____	24. pH 7.30-7.45?
_____	_____	_____	25. $Paco_2$, 40 mm Hg (or baseline) with mV <10 L/min? *This is evaluated while on ventilator.
_____	_____	_____	26. Pao_2 >60 on Fio_2 <40%?

[a]The BWAP score is obtained by dividing the total number of BWAP factors scored as "yes" by 26. ©Burns 1990.

5.12 ► Algorithm for Management of Ventilator Alarms and/or Development of Acute Respiratory Distress



5.13 ► Algorithm to Correct Hypoxemia in an Acute COPD Patient



Algorithm to correct hypoxemia in an acute III COPD patient. ABG: arterial blood gas; NPPV: noninvasive positive pressure ventilation; O_2: oxygen; $Paco_2$: arterial carbon dioxide tension; Pao_2: arterial oxygen tension; Sao_2: arterial oxygen saturation. (*From: American Thoracic Society and European Respiratory Society. Standards for the diagnosis and management of patients with COPD 2004;183. Available: http://www.thoracic.org/sections/copd/resources. Accessed December 11, 2009.*)

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Neurologic Concepts

Section 6

6.1 ► Glasgow Coma Scale

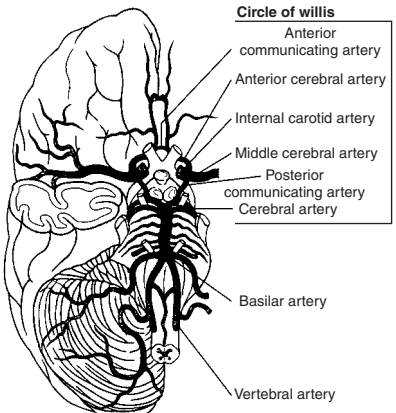
Behavior	Score[a]
Eye Opening (E)	
Spontaneous	4
To verbal stimuli	3
To pain	2
None	1
Motor Response (M)	
Obeys commands	6
Localizes pain	5
Withdraws to pain	4
Abnormal flexion	3
Extensor response	2
None	1
Verbal Response (V)	
Oriented	5
Confused	4
Inappropriate words	3
Incomprehensible sounds	2
None	1

[a]Coma score = E + M + V (scores range from 3-15).

6.2 ► Cranial Nerve Function

Nerve	Function
I. Olfactory	Sense of smell
II. Optic	Visual fields, visual acuity
III. Oculomotor	Most extraocular eye movements, ability to elevate eyelid, muscular contraction of the iris in response to light
IV. Trochlear	Eye movement down and toward the nose
V. Trigeminal	Facial sensation, including cornea, nasal mucosa, and oral mucosa; muscles of chewing and mastication
VI. Abducens	Lateral eye movement
VII. Facial	Facial muscles, including eyelid closure; taste in anterior two thirds of the tongue; secretion of saliva and tears
VIII. Acoustic	Hearing and equilibrium
IX. Glossopharyngeal	Gag reflex, muscles that control swallowing and phonation; taste in posterior third of tongue
X. Vagus (overlapping innervation)	Salivary gland secretion; vagal control of heart, lungs, and gastrointestinal tract
XI. Spinal accessory	Sternocleidomastoid and trapezius muscle strength
XII. Hypoglossal	Tongue movement

6.3 ► Circle of Willis



The circle of Willis as seen from below the brain. (*Reprinted from: Perry L, Sands JK. Vascular and degenerative problems of the brain. In: Phipps WJ, Marek JF, Monahan FD, Neighbors M, Sands JK, eds.* Medical-Surgical Nursing: Health and Illness Perspectives. *St Louis, MO: Mosby; 2003:1365.*)

6.4 ► Incomplete Spinal Cord Injury Syndromes

Syndrome	Pathophysiolgy	Motor Function Below Level of Injury	Sensory Function Below Level of Injury
Central cord syndrome	Injury to central gray matter with preservation of outer white matter	Weakness/paralysis of upper extremities greater than lower extremities	Sensory loss greater in upper extremities than lower extremities
Anterior cord syndrome	Injury to anterior portion of spinal cord, disruption of blood flow through anterior spinal artery	Paralysis	Loss of pain and temperature with preservation vibration and position sense
Posterior cord syndrome	Injury to posterior column	None	Loss of vibration and position sense with preservation of pain and temperature sensation
Brown-Séquard syndrome	Lateral injury to one side of the cord	Ipsilateral motor paralysis	Ipsilateral loss of vibration and position sense Contralateral loss of pain and temperature sensation

6.5 ► Spinal Cord Injury–Functional Goals for Specific Levels of Complete Injury

Level	Action/Muscles Tested	Abilities	Functional Goals
C1-C3		C3-limited movement of head and neck	**Breathing:** Depends on a ventilator for breathing. **Communication:** Talking is sometimes difficult, very limited or impossible. If ability to talk is limited, communication can be accomplished independently with a mouth stick and assistive technologies like a computer for speech or typing. Effective verbal communication for the individual with SCI is essential to direct caregivers in the person's daily activities, like bathing, dressing, personal hygiene, transferring as well as bladder and bowel management. **Daily tasks:** Assistive technology allow for independence in tasks such as turning pages, using a telephone, and operating lights and appliances. **Mobility:** Can operate an electric wheelchair by using a head control, mouth stick, or chin control. A power tilt wheelchair is also used for independent pressure relief.
C3-C4		Usually has head and neck control. Individuals at C4 level may shrug their shoulders.	**Breathing:** May initially require a ventilator for breathing, usually adjust to breathing fulltime without ventilatory assistance. **Communication:** Normal. **Daily tasks:** With specialized equipment, some may have limited independence in feeding and independently operate an adjustable bed with an adapted controller.

6.5 ► Spinal Cord Injury–Functional Goals for Specific Levels of Complete Injury (*continued*)

Level	Action/Muscles Tested	Abilities	Functional Goals
C5	*Elbow flexors* (biceps brachii)	Typically has head and neck control, can shrug shoulder and has shoulder control. Can bend his/her elbows and turn palms face up.	**Daily tasks:** Independence with eating, drinking, face washing, brushing of teeth, face shaving and hair care after assistance in setting up specialized equipment. **Health care:** Can manage their own health care by doing self-assist coughs and pressure reliefs by leaning forward or side to side. **Mobility:** May have strength to push a manual wheelchair for short distances over smooth surfaces. A power wheelchair with hand controls is typically used for daily activities. Driving may be possible after being evaluated by a qualified professional to determine special equipment needs.
C6	*Wrist extensors* (extensor carpi ulnaris, extensor carpi radialis longus and radialis brevis)	Has movement in head, neck, shoulders, arms, and wrists. Can shrug shoulders, bend elbows, turn palms up and down, and extend wrists.	**Daily tasks:** With help of some specialized equipment, can perform with greater ease and independence daily tasks of feeding, bathing, grooming, personal hygiene, and dressing. May independently perform light housekeeping duties. **Health care:** Can independently do pressure reliefs, skin checks, and turn in bed. **Mobility:** Can independently do transfers but often require a sliding board. Can use a manual wheelchair for daily activities but may use power wheelchair for greater independence.

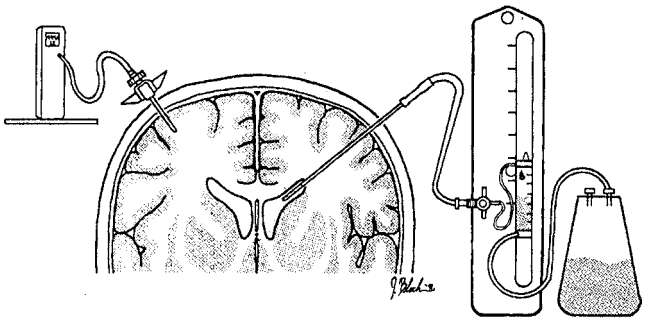
6.5 ► Spinal Cord Injury–Functional Goals for Specific Levels of Complete Injury (*continued*)

Level	Action/Muscles Tested	Abilities	Functional Goals
C7	*Elbow extensors* (triceps brachii)	Has similar movement as an individual with C6, with added ability to straighten his/her elbows.	**Daily tasks:** Able to perform household duties. Need fewer adaptive aids in independent living. **Health care:** Able to do wheelchair pushups for pressure reliefs. **Mobility:** Daily use of manual wheelchair. Can transfer with greater ease.
C8	*Finger flexors* (flexor digitorum profundus-distal phalanx of the middle finger)	Has added strength and precision of fingers that result in limited or natural hand function.	**Daily tasks:** Can live independently without assistive devices in feeding, bathing, grooming, oral and facial hygiene, dressing, bladder management, and bowel management.
T1	*Finger abductors* (abductor digiti minimi)		
T2-T6		Has normal motor function in head, neck, shoulders, arms, hands, and fingers. Has increased use of rib and chest muscles, or trunk control.	**Mobility:** Has increased ability to do some unsupported seated activities. A few individuals are capable of limited walking with orthodic aids. This requires extremely high energy and puts stress on the upper body, offering no functional advantage. Can lead to damage of upper joints.

6.5 ► Spinal Cord Injury–Functional Goals for Specific Levels of Complete Injury (*continued*)

Level	Action/Muscles Tested	Abilities	Functional Goals
T7-L1		Has added motor function from increased abdominal control.	**Daily tasks:** Able to perform unsupported seated activities. **Health care:** Has improved cough effectiveness.
L2	*Hip flexors* (iliopsoas)	Has additional return of motor movement in the hips and knees.	**Mobility:** Walking can be a viable function, with the help of specialized leg and ankle braces. Lower levels walk with greater ease with the help of assistive devices.
L3	*Knee extensors* (quadriceps femoris)		
L4	*Ankle dorsiflexors* (tibialis anterior)		
L5	*Long toe extensors* (hallucis longus)		
S1-S5	*Ankle plantar flexors* (gastrocnemius)	Depending on level of injury, there are various degrees of return of voluntary bladder, bowel and sexual functions.	**Mobility:** Increased ability to walk with fewer or no supportive devices.

6.6 ► Intracranial Pressure Monitoring Systems



On the right, a ventriculostomy connects to a CSF collection system. A three-way stopcock allows either pressure monitoring or drainage of CSF. On the left, a transducer is inserted into the brain parenchyma and anchored to the skull by a bolt mechanism. The transducer is attached to an external monitoring device. (*Reprinted from: Bergsneider M, Becker DP. Intracranial pressure monitoring. In: Shoemaker WC, Ayres SM, Grenvik A, Holbrook PR, eds.* Textbook of Critical Care. *3rd ed. Philadelphia, PA: WB Saunders;1995, p. 313.*)

Pharmacology Tables

Section 7

7.1 ► Intravenous Medication Administration Guidelines

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Abciximab			
Bolus dose	0.25 mg/kg	D_5W in 250 mL	Bolus infused over 10-60 minutes
Infusion dose	0.125 mcg/kg/min for 12 hours		Maximum infusion rate = 10 mcg/min
Acetazolamide	5 mg/kg/24h or 250 mg qd-qid	Undiluted	Infuse at 500 mg/min
Acyclovir	5 mg/kg q8h	D_5W 100 mL	Infuse over at least 60 minutes
Adenosine	6 mg initially, then 12 mg ×2 doses	Undiluted	Inject over 1-2 seconds Drug interactions: theophylline (1); persantine (2)
Alteplase			
Acute MI	100 mg over 3 hours	100 mg in NS 200 mL	In acute MI infuse 10 mg over 2 minutes, then 50 mg over 1 hour, and then 40 mg over 2 hours.
PE	100 mg over 2 hours		
Amikacin			
Standard dose	7.5 mg/kg q12h	D_5W 50 mL	Infuse over 30 minutes
Single daily dose	20 mg/kg q24h	D_5W 50 mL	Drug interactions: neuromuscular blocking agents (3) Therapeutic levels: Peak: 20-40 mg/L; trough: <8 mg/L Single daily dose: trough level at 24 hours = 0 mg/L; peak levels unnecessary

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Aminophylline			
Loading dose	6 mg/kg	D_5W 50 mL	Infuse loading dose over 30 minutes Maximum loading infusion rate 25 mg/min Aminophylline = 80% theophylline
Infusion dose		500 mg in D_5W 500 mL	Drug interactions: cimetidine, ciprofloxacin, erythromycin, clarithromycin (4)
CHF	0.3 mg/kg/h		
Normal	0.6 mg/kg/h		Therapeutic levels: 10-20 mg/L
Smoker	0.9 mg/kg/h		
Ammonium chloride	mEq Cl = Cl deficit (in mEq/L) $\times$ 0.2 $\times$ wt (kg)	100 mEq in NS 500 mL	Maximum infusion rate is 5 mL/min of a 0.2-mEq/mL solution; correct 1/3 to 1/2 of Cl deficit while monitoring pH and Cl; administer remainder as needed
Amphotericin B	0.5-1.5 mg/kg q24h	D_5W 250 mL	Infuse over 2-6 hours Do not mix in electrolyte solutions (eg, saline, lactated Ringer solution)

[a] Usual dose ranges are listed; refer to appropriate disease state for specific dose.

Abbreviations: bid, twice a day; HF, heart failure; conc, concentration; D_5W, destrose-5%-water; DVT, deep venous thrombosis; HPLC, high-performance liquid chromatography; IM, intramuscular; IV, intravenous; IVP, IV push; IVPB, IV piggyback; MI, myocardial infarction; NS, normal saline; NSAID, nonsteroidal anti-inflammatory drug; PCP, *Pneumocystis carinii* pneumonia; PE, pulmonary embolism; PO, orally; prn, as needed; qd, daily; SW, sterile water.

Drug interactions: (1) antagonizes adenosine effect; (2) potentiates adenosine effect; (3) potentiates effect of neuromuscular blocking agents; (4) inhibits theophylline metabolism; (5) antagonizes effect of neuromuscular blocking agents: (6) metabolism inhibited by cimetidine; (7) metabolism inhibited by ciprofloxacin; (8) increased digoxin concentrations; (9) metabolism inhibited by erythromycin; (10) increased nephrotoxicity; (11) increased heparin requirements.

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Ampicillin	0.5-3 g q4-6h	NS 100 mL	Infuse over 15-30 minutes
Ampicillin/sulbactam	1.5-3 g q6h	NS 100 mL	Infuse over 15-30 minutes
Anistreplase (APSAC)	30 U IV	SW 5 mL	Infuse over 5 minutes, give with aspirin 325 mg PO immediately Preparation should be discarded if not used within 6 hours
Argatroban			
Bolus dose	350 mcg/kg	250 mg in NS 250 mL	Titrate to aPTT or ACT
Infusion dose	25 mcg/kg/min		
Atenolol	5 mg IV over 5 minutes, 5 mg IV 10 minutes later	Undiluted	Inject 1 mg/min
Atracurium			
Intubating dose	0.4-0.5 mg/kg	Undiluted	Inject over 60 sec to prevent histamine release
Maintenance dose	0.08-0.1 mg/kg	Undiluted	Inject over 60 sec to prevent histamine release
Infusion dose	5-9 mcg/kg/min	1000 mg in D_5W 150 mL	Continuous infusion. Final volume = 250 mL, conc = 4 mg/mL Drug interactions: aminoglycosides (3); anticonvulsants (5)
Aztreonam	0.5-2 g q6-12h	D_5W 100 mL	Infuse over 15-30 minutes

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Bivalirudin			
Bolus dose	1 mg/kg	250 mg in D_5W 500 mL	Infuse bolus over 2 min
Infusion dose	2.5 mg/kg/h $\times$4 hours; if necessary 0.2 mg/kg/h for up to 20 hours		Titrate to aPTT or ACT
Bumetanide			
Bolus dose	0.5-1 mg	Undiluted	Maximum injection rate: 1 mg/min
Infusion dose	0.08-0.3 mg/h	2.4 mg in NS 100 mL	Continuous infusion
Calcium (elemental)	100-200 mg of elemental calcium IV over 15 minutes followed by 100 mg/h	1000 mg in NS 1000 mL	Ca chloride 1 g = 272 mg (13.6 mEq) of elemental calcium Ca gluconate 1 g = 90 mg (4.65 mEq) of elemental calcium
Cefazolin	0.5-1 g q6-8h	D_5W 50 mL	Infuse over 15-30 minutes
Cefepime	1-2 g q8-12h	1-2 g in D_5W 100 mL	Infuse over 15 minutes
Cefonicid	1-2 g q24h	D_5W 50 mL	Infuse over 15-30 minutes
Cefoperazone	1-2 g q12h	D_5W 50 mL	Infuse over 15-30 minutes
Cefotaxime	1-2 g q4-6h	D_5W 50 mL	Infuse over 15-30 minutes
Cefotetan	1-2 g q12h	D_5W 50 mL	Infuse over 15-30 minutes
Cefoxitin	1-2 g q4-6h	D_5W 50 mL	Infuse over 15-30 minutes
Ceftazidime	0.5-2 g q8-12h	D_5W 50 mL	Infuse over 15-30 minutes
Ceftizoxime	1-2 g q8-12h	D_5W 50 mL	Infuse over 15-30 minutes
Ceftriaxone	0.5-2 g q12-24h	D_5W 50 mL	Infuse over 15-30 minutes
Cefuroxime	0.75-1.5 g q8h	D_5W 50 mL	Infuse over 15-30 minutes

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Chlorothiazide	0.5-1 g qd-bid	SW 18 mL	Inject over 3-5 minutes
Chlorpromazine	10-50 mg q4-6h	Dilute with NS to a final concentration of 1 mg/mL	Inject at 1 mg/minutes
Cimetidine			
IVPB	300 mg q6-8h	D_5W 50 mL	Infuse over 15-30 minutes IVP dose may be injected over at least 5 minutes
Infusion dose	37.5 mg/h	D_5W 250 mL	Continuous infusion Drug interactions: theophylline, warfarin, phenytoin, lidocaine, benzodiazepines (6)
Ciprofloxacin	200-400 mg q8-12h	Premix solution 2 mg/mL	Infuse over 60 minutes Drug interactions: theophylline, warfarin (7)
Cisatricurium			
Infusion dose	1-3 mcg/kg/min		
Clevidipine	1-16 mg/h	Undiluted	Continuous infusion
Clindamycin	150-900 mg q8h	D_5W 250 mL	Infuse over 30-60 minutes
Conivaptan			
Bolus dose	20 mg	D_5W 100 mL	Infuse over 30 minutes
Infusion dose	20 mg	D_5W 250 mL	Infuse over 24 hours

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Conjugated estrogens	0.6 mg/kg/d ×5 days	NS 50 mL	Infuse over 15-30 minutes
Cosyntropin	0.25 mg IV	Undiluted	Inject over 60 seconds
Cyclosporine	5-6 mg/kg q24h	D_5W 100 mL	Infuse over 2-6 hours Drug interactions: digoxin (8); erythromycin (9); amphotericin, NSAID (10) IV dose = 1/3 PO dose Therapeutic levels: trough: 50-150 ng/mL (whole blood—HPLC)
Dantrolene			
Bolus dose	1-2 mg/kg	SW 60 mL	Administer as rapidly as possible
Maximum dose	10 mg/kg		Do not dilute in dextrose or electrolyte-containing solutions
Maintenance dose	2.5 mg/kg q4h ×24h	SW 60 mL	Infuse over 60 minutes
Daptomycin	4-6 mg/kg q24h	250 or 500 mg in NS 50 mL	Infuse over 30 minutes
Desmopressin	0.3 mg/kg	NS 50 mL	Infuse over 15-30 minutes
Dexamethasone	0.5-20 mg	NS 50 mL	May give doses ≤10 mg undiluted IVP over 60 seconds
Dexmedetomidine			
Bolus dose	1 mcg/kg	200 mcg in NS 50 mL	Infuse bolus over 10 minutes
Infusion dose	0.2-1 mcg/kg/h		

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Diazepam	2.5-5 mg q2-4h	Undiluted	Inject 2-5 mg/minutes Active metabolites contribute to activity
Diazoxide	50-150 mg q5-15 min	Undiluted	Inject over 30 seconds Maximum 150 mg/dose
Digoxin			
Digitalizing dose	0.25 mg q4-6h up to 1 mg	Undiluted	Inject over 3-5 min
Maintenance dose	0.125-0.25 mg q24h		Drug interactions: amiodarone, cyclosporine, quinidine, verapamil (8) Therapeutic levels: 0.5-2.0 ng/mL
Diltiazem			
Bolus dose	0.25-0.35 mg/kg	Undiluted	Inject over 2 minutes
Infusion dose	5-15 mg/h	125 mg in D_5W 100 mL	Continuous infusion (final conc = 1 mg/mL)
Diphenhydramine	25-100 mg IV q 2-4h	Undiluted	Inject over 3-5 minutes Competitive histamine antagonist, doses >1000 mg/24 h may be required in some instances
Dobutamine	2.5-20 mcg/kg/min	500 mg in D_5W 250 mL	Continuous infusion
Dolasetron	1.8 mg/kg or 100 mg	Undiluted or 100 mg in D_6W 50 mL	Infuse undiluted drug over at least 30 seconds Infuse piggyback over 15 minutes Administer 30 L, minutes prior to chemo or 1 hour prior to anesthesia

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Dopamine			
Renal dose	<5 mcg/kg/min	400 mg in D_5W 250 mL	Continuous infusion
Inotrope	5-10 mcg/kg/min	400 mg in D_5W 250 mL	Continuous infusion
Pressor	>10 mcg/kg/min	400 mg in D_5W 250 mL	Continuous infusion
Doripenem	500 mg q-8h	D_5W or NS 100 mL	Infuse over 60 minutes-4 hours
Doxacurium			
Intubating dose	0.025-0.08 mg/kg	Undiluted	Inject over 5-10 seconds
Maintenance dose	0.005-0.01 mg/kg	Undiluted	Inject over 5-10 seconds
Infusion dose	0.25 mcg/kg/min	25 mg in D_5W 50 mL	Continuous infusion Dose based on lean body weight Drug interactions: aminoglycosides (3); anticonvulsants (5)
Doxycycline	100-200 mg q12-24h	D_5W 250 mL	Infuse over 60 minutes
Drotrecogin alfa	24 mcg/kg/h	100 or 200 mcg/mL dilution in NS	Infuse through dedicated line or lumen (multilumen catheter). Total infusion time is 96 hours

[a] Usual dose ranges are listed; refer to appropriate disease state for specific dose.

Abbreviations: bid, twice a day; HF, heart failure; conc, concentration; D_5W, destrose-5%-water; DVT, deep venous thrombosis; HPLC, high-performance liquid chromatography; IM, intramuscular; IV, intravenous; IVP, IV push; IVPB, IV piggyback; MI, myocardial infarction; NS, normal saline; NSAID, nonsteroidal anti-inflammatory drug; PCP, *Pneumocystis carinii* pneumonia; PE, pulmonary embolism; PO, orally; prn, as needed; qd, daily; SW, sterile water.

Drug interactions: (1) antagonizes adenosine effect; (2) potentiates adenosine effect; (3) potentiates effect of neuromuscular blocking agents; (4) inhibits theophylline metabolism; (5) antagonizes effect of neuromuscular blocking agents: (6) metabolism inhibited by cimetidine; (7) metabolism inhibited by ciprofloxacin; (8) increased digoxin concentrations; (9) metabolism inhibited by erythromycin; (10) increased nephrotoxicity; (11) increased heparin requirements.

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Droperidol	0.625-10 mg q1-4h	Undiluted	Inject over 3-5 minutes
Enalaprilat	0.625-1.25 mg q6h	Undiluted	Inject over 5 minutes Initial dose for patients on diuretics is 0.625 mg
Epinephrine	1-4 mcg/min	1 mg in D_5W 250 mL	Continuous infusion
Eptifibatide			
Bolus dose	180 mcg/kg	Undiluted	Maximum infusion duration of 72 hours
Infusion dose	2 mcg/kg/min until discharge or CABG		
Ertapenem	1 g q24h	1 g in NS 50 mL	Infuse over 30 minutes
Erythromycin	0.5-1 g q6h	NS 250 mL	Infuse over 60 minutes Drug interactions: theophylline (4); cyclosporine (9)
Erythropoietin	12.5-600 U/kg 1-3 ×per week	Undiluted	Inject over 3-5 minutes
Esmolol			
Bolus dose	500 mcg/kg	Undiluted	Inject over 60 seconds
Infusion dose	50-400 mcg/kg/min	5 g in D_5W 500 mL	Continuous infusion
Ethacrynic acid	50 mg May repeat ×1	D_5W 50 mL	Inject over 3-5 minutes Maximum single dose 100 mg
Etidronate	7.5 mg/kg qd ×3 days	NS or D_5W 500 mL	Infuse over at least 2 hours
Famotidine	20 mg q12h	D_5W 100 mL	Infuse over 15-30 minutes
Fenoldopam			
Infusion dose	0.1-1.6 mcg/kg/min	20 mg in D_5W 250 mL	Titrate to BP

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Fentanyl			
Bolus dose	25-75 mcg q1-2h	Undiluted	Inject over 5-10 seconds
Infusion dose	50-100 mcg/h	Undiluted	Continuous infusion
Filgastrim	1-20 mcg/kg ×2-4 weeks	D_5W	Preferred route of administration is subcutaneous
Fluconazole	100-800 mg q24h	Premix solution 2 mg/mL	Maximum infusion rate 200 mg/h (IV rate is 15-30 minutes)
Flumazenil			
Reversal of conscious sedation	0.2 mg initially, then 0.2 mg q60 sec to a total of 1 mg	Undiluted	Inject over 15 seconds Maximum dose of 3 mg in any 1-hour period
Benzodiazepine overdose	0.2 mg initially, then 0.3 mg ×1 dose, then 0.5 mg q30s up to a total of 3 mg	Undiluted	Inject over 30 seconds Maximum dose of 3 mg in any 1-hour period
Continuous infusion	0.1-0.5 mg/h	5 mg in D_5W 1000 mL	Continuous infusion
Foscarnet			
Induction dose	60 mg/kg q8h	Undiluted	Infuse over 1 hour
Maintenance dose	90-120 mg/kg q24h	Undiluted	Infuse over 2 hours

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Fosphenytoin		NS 250 mL	Infuse no faster than 150 mg/min
Status epilepticus			
Loading dose	15-20 mg/kg		
Nonemergency			
Loading dose	10-20 mg/kg		
Maintenance dose	4-6 mg/kg/day		
Furosemide			
Bolus dose	10-100 mg q1-6h	Undiluted	Maximum injection rate 40 mg/min
Infusion dose	1-15 mg/h	100 mg in NS 100 mL	Continuous infusion
Gallium nitrate	100-200 mg/m^2 qd $\times$5 days	D_5W 1000 mL	Infuse over 24 hours
Ganciclovir	2.5 mg/kg q12h	D_5W 100 mL	Infuse over 1 hour
Gentamicin			
Loading dose	2-3 mg/kg	D_5W 50 mL	Infuse over 30 minutes
Maintenance dose	1.5-2.5 mg/kg q8-24h	D_5W 50 mL	Infuse over 30 minutes
Single daily dose	5-7 mg/kg q24h	D_5W 50 mL	Infuse over 30 minutes Critically ill patients have an increased volume of distribution requiring increased doses Drug interactions: neuromuscular blocking agents Therapeutic levels: Peak: 4-10 mg/L Trough: $<$2 mg/L Single daily dose: trough level at 24 hours = 0 mg/L; peak levels unnecessary

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Glycopyrrolate	5-15 mcg/kg	Undiluted	Inject over 60 seconds
Granisetron	10 mcg/kg	D_5W 50 mL	Infuse over 15 minutes
Haloperidol (lactate)			
Bolus dose	1-10 mg q2-4h	Undiluted	Inject over 3-5 minutes
Infusion dose	10 mg/h	100 mg in D_5W 100 mL	Continuous infusion In urgent situations the dose may be doubled every 20-30 minutes until an effect is obtained Decanoate salt is only for IM administration
Heparin	10-25 U/kg/h	25,000 U in D_5W 500 mL	Drug interactions: nitroglycerin (11)
Hydralazine	10-25 mg q2-4h	Undiluted	
Hydrochloric acid	mEq = (0.5 × BW × (103 − serum Cl))	100 mEq in SW 1000 mL	Maximum infusion rate = 0.2 mEq/kg/h
Hydrocortisone	12.5-100 mg q6-12h	Undiluted	Inject over 60 seconds
Hydromorphone	0.5-2 mg q4-6h	Undiluted	Inject over 60 seconds Dilaudid-HP available as 10 mg/mL
Ibutilide			Infuse over 10 minutes
Patient >60 kg	1 mg	NS 50 mL	Repeat dose possible 10 minutes after completion of initial bolus
Patient <60 kg	0.01 mg/kg		

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Inamrinone			
Loading dose	0.75-3 mg/kg	Undiluted	Inject over 1-2 minutes Do not mix in dextrose-containing solutions; may be injected into running dextrose infusions through a Y-connector or directly into tubing
Infusion dose	5-20 mcg/kg/min	300 mg in NS 120 mL	
Imipenem	0.5-1 g q6-8h	D_5W 100 mL	Infuse over 30-60 minutes
Isoproterenol	1-10 mcg/min	2 mg in D_5W 500 mL	Continuous infusion
Ketamine			
Bolus dose	1-4.5 mg/kg	Undiluted	Inject over 60 seconds
Infusion dose	5-45 mcg/kg/min	200 mg in D_5W 500 mL	Continuous infusion
Labetalol			
Bolus dose	20 mg, then double q10min (maximum total dose of 300 mg)	Undiluted	Inject over 2 minutes
Infusion dose	1-4 mg/min	200 mg in D_5W 160 mL	Continuous infusion
Lepirudin			
Bolus dose	0.4 mg/kg	100 mg in D_5W 50 mL	Titrated to aPTT, 12-hour expiration once compounded
Infusion dose	0.15 mg/kg/h for 2-10 days		
Levofloxacin	250-750 mg q24-48h	D_5W 50-150 mL	Infuse over 60 minutes (250 mg, 500 mg) Infuse over 90 minutes (750 mg)

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Levothyroxine	25-200 mg q24h	Undiluted	Inject over 5-10 second IV dose = 75% of PO dose
Lidocaine			
Bolus dose	1 mg/kg	Undiluted	Inject over 60 seconds
Infusion dose	1-4 mg/min	2 g in D_5W 500 mL	Continuous infusion Drug interactions: cimetidine (6) Therapeutic levels: 1.5-5.0 mg/L
Linezolid	600 mg q12h	600 mg in D_5W 300 mL	Infuse over 30-120 minutes Linezolid may exhibit a yellow color that can intensify over time without adversely affecting potency
Lorazepam			
Bolus dose	0.5-2 mg q1-4h	Dilute 1:1 with NS before administration	Inject 2 mg/minutes
Infusion dose	0.06 mg/kg/h	20 mg in D_5W 250 mL	Monitor for lorazepam precipitate in solution Use in-line filter during continuous infusion to avoid infusing precipitate into patient

[a] Usual dose ranges are listed; refer to appropriate disease state for specific dose.

Abbreviations: bid, twice a day; HF, heart failure; conc, concentration; D_5W, destrose-5%-water; DVT, deep venous thrombosis; HPLC, high-performance liquid chromatography; IM, intramuscular; IV, intravenous; IVP, IV push; IVPB, IV piggyback; MI, myocardial infarction; NS, normal saline; NSAID, nonsteroidal anti-inflammatory drug; PCP, *Pneumocystis carinii* pneumonia; PE, pulmonary embolism; PO, orally; prn, as needed; qd, daily; SW, sterile water.

Drug interactions: (1) antagonizes adenosine effect; (2) potentiates adenosine effect; (3) potentiates effect of neuromuscular blocking agents; (4) inhibits theophylline metabolism; (5) antagonizes effect of neuromuscular blocking agents: (6) metabolism inhibited by cimetidine; (7) metabolism inhibited by ciprofloxacin; (8) increased digoxin concentrations; (9) metabolism inhibited by erythromycin; (10) increased nephrotoxicity; (11) increased heparin requirements.

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Magnesium (elemental)			Magnesium1 g = 8 mEq
Magnesium deficiency	25 mEq over 24 hours followed by 6 mEq over the next 12 hours	25 mEq in D_5W 1000 mL	Continuous infusion
Acute myocardial infarction	15-45 mEq over 24-48 hours followed by 12.5 mEq/day for 3 days	25 mEq in D_5W 1000 mL	Continuous infusion
Ventricular arrythmias	16 mEq over 1 hour followed by 40 mEq over 6 hours	40 mEq in D_5W 1000 mL	16 mEq (2 g) may be diluted in 100 mL D_5W and infused over 1 hour
Mannitol			
Diuretic		Undiluted	Inject over 30-60 minutes
Bolus dose	0.25-0.5 g/kg		
Maintenance dose	0.25-0.5 g/kg q4h		
Cerebral edema	1.5-2 g/kg over 30-60 minutes		
Meperidine	25-100 mg q2-4h	Undiluted	Inject over 60 seconds Avoid in renal failure
Meropenem	0.5-2 g q8-24h	NS 50 mL or undiluted	Infuse over 15-30 min or bolus dose over 3-5 minutes
Methadone	5-20 mg qd	Undiluted	Inject over 3-5 minutes Accumulation with repetitive dosing
Methyldopate	0.25-1 g q6h	D_5W 100 mL	Infuse over 30-60 minutes
Methylprednisolone	10-500 mg q6h	Undiluted	Inject over 60 seconds

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Metoclopramide			
Small intestine intubation	10 mg × 1	Undiluted	Inject over 3-5 minutes
Antiemetic	2 mg/kg before chemo, then 2 mg/kg q2h ×2, then q3h ×3	D_5W 50 mL	Infuse over 15-30 minutes
Metoprolol	5 mg q2min ×3	Undiluted	Inject over 3-5 min
Metronidazole	500 mg q6h	Premix solution 5 mg/mL	Infuse over 30 minutes
Midazolam			
Bolus dose	0.025-0.35 mg/kg q1-2h	Undiluted	Inject 0.5 mg/min
Infusion dose	0.5-5 mcg/kg/min	50 mg in D_5W 100 mL	Continuous infusion Unpredictable clearance in critically ill patients Drug interactions: cimetidine (6)
Milrinone			
Loading dose	50 mcg/kg	1 mg/mL	Infuse over 10 min Available in 5-mL syringe
Maintenance dose	0.375-0.75 mcg/kg/min	50 mg in D_5W 250 mL	Continuous infusion
Mivacurium			
Intubating dose	0.25 mg/kg	Undiluted	Inject over 60 seconds
Maintenance dose	0.1 mg/kg	Undiluted	Inject over 60 seconds
Infusion dose	9-10 mcg/kg/min	50 mg in D_5W 100 mL	Continuous infusion Drug interactions: aminoglycosides (3); anticonvulsants (5)

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Morphine			
Bolus dose	2-10 mg	Undiluted	Inject over 60 seconds
Infusion dose	2-5 mg/h	100 mg in D_5W 100 mL	Continuous infusion
Moxifloxacin	400 mg q24h	400 mg in NS 250 mL	Infuse over 60 minutes
Nafcillin	0.5-2 g q4-6h	D_5W 100 mL	Infuse over 30-60 minutes
Naloxone			
Postoperative opiate depression			
Loading dose	0.1-0.2 mg q2-3min	Undiluted	Infuse over 60 minutes
Infusion dose	3-5 mcg/kg/h	2 mg in D_5W 250 mL	Continuous infusion
Opiate overdose			
Loading dose	0.4-2 mg q2-3min	Undiluted	Infuse over 60 seconds
Infusion dose	2.5-5 mcg/kg/h	2 mg in D_5W 250 mL	Continuous infusion
Neostigmine	25-75 mcg/kg	Undiluted	Inject over 60 seconds
Nesiritide			
Bolus dose	2 mcg/kg	1.5 mg in preservative-free	Monitor for hypotension
Infusion dose	0.01 mcg/kg/min	D_5W 250 mL	
Nitroglycerin	10-300 mcg/min	50 mg in D_5W 250 mL	Continuous infusion Drug interactions: heparin (11)

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Nitroprusside	0.5-10 mcg/kg/min	50 mg in D_5W 250 mL	Continuous infusion Maintain thiocyanate $<$10 mg/dL
Norepinephrine	4-10 mcg/min	4 mg in D_5W 250 mL	Continuous infusion
Ofloxacin	200-400 mg q12h	D_5W 100 mL	Infuse over 60 minutes
Ondansetron			
Chemotherapy-induced nausea and vomiting	32 mg 30 min before chemotherapy	D_5W 50 mL	Infuse over 15-30 minutes
Postoperative nausea and vomiting	4 mg $\times$1 dose	Undiluted	Inject over 2-5 minutes
Oxacillin	0.5-2 g q4-6h	D_5W 100 mL	Infuse over 30 minutes
Pamidronate	60-90 mg $\times$1 dose	D_5W 1000 mL	Infuse over 24 hours
Pancuronium			
Intubating dose	0.06-0.1 mg/kg	Undiluted	Inject over 60 seconds
Maintenance dose	0.01-0.015 mg/kg	Undiluted	Inject over 60 seconds
Infusion dose	1 mcg/kg/min	50 mg in D_5W 250 mL	Continuous infusion Metabolite contributes to activity Drug interactions: aminoglycosides (3); anticonvulsants (5)
Penicillin G	8-24 MU divided q4h	D_5W 100 mL	Infuse over 15-30 minutes
Pentamidine	4 mg/kg q24h	D_5W 50 mL	Infuse over 60 minutes

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Pentobarbital			
Bolus dose	5-10 mg/kg	NS 100 mL	Infuse over 2 hours
Infusion dose	0.5-1 mg/kg/h initially, then 0.5-4 mg/kg/h	NS 250 mL 2 g in NS 250 mL	Continuous infusion Therapeutic levels: 20-50 mg/L
Phenobarbital		NS 100 mL	Infuse over 2 hours
Bolus dose	5-10 mg/kg	NS 250 mL	Continuous infusion
Infusion dose	0.5-1 mg/kg/h initially, then 0.5-4 mg/kg/h	2 g in NS 250 mL	Therapeutic levels: 20-50 mg/L
Phentolamine			
Bolus dose	2.5-10 mg prn q5-15min	Undiluted	Inject over 3-5 minutes
Continuous infusion	1-10 mg/min	50 mg in D_5W 100 mL	Continuous infusion
Phenylephrine	20-30 mcg/min	15 mg in D_5W 250 mL	Continuous infusion; 0.5 mg over 20-30 seconds
Phenytoin			Maximum infusion rate is 50 mg/min
Status epilepticus		Undiluted	Drug interactions: cimetidine; neuromuscular blocking agents
Bolus dose	15-20 mg/kg		Therapeutic levels: 10-20 mg/L
Infusion dose	5 mg/kg/day (divided into 2 or 3 doses)		
Phosphate (potassium)	0.08-0.64 mmol/kg	Function of K^+ concentration	Infuse over 6-8 hours 1 mmol of PO_4 = P 31 mg Solution should be made no more concentrated than 0.4 mEq/mL K^+

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Piperacillin	2-4 g q4-6h	D_5W 100 mL	Infuse over 15-30 minutes
Piperacillin/tazobactam	3.375 g IV q6h	D_5W 100 mL	Infuse over 30 minutes Each 2.25-g vial contains 2 g piperacillin and 0.25 g tazobactam
Potassium chloride	5-40 mEq/h	40 mEq in 1000 mL (NS, D_5W, etc)	Cardiac monitoring should be used with infusion rates >20 mEq/h
Prednisolone	4-60 mg q24h	Undiluted	Inject over 60 seconds
Procainamide			
Loading dose	15 mg/kg	D_5W 50 mL	Maximum infusion rate 25-50 mg/min
Infusion dose	1-4 mg/min	2 g in D_5W 500 mL	Continuous infusion Therapeutic levels: Procainamide: 4-10 mg/L NAPA: 10-20 mg/L

[a] Usual dose ranges are listed; refer to appropriate disease state for specific dose.

Abbreviations: bid, twice a day; HF, heart failure; conc, concentration; D_5W, destrose-5%-water; DVT, deep venous thrombosis; HPLC, high-performance liquid chromatography; IM, intramuscular; IV, intravenous; IVP, IV push; IVPB, IV piggyback; MI, myocardial infarction; NS, normal saline; NSAID, nonsteroidal anti-inflammatory drug; PCP, *Pneumocystis carinii* pneumonia; PE, pulmonary embolism; PO, orally; prn, as needed; qd, daily; SW, sterile water.

Drug interactions: (1) antagonizes adenosine effect; (2) potentiates adenosine effect; (3) potentiates effect of neuromuscular blocking agents; (4) inhibits theophylline metabolism; (5) antagonizes effect of neuromuscular blocking agents: (6) metabolism inhibited by cimetidine; (7) metabolism inhibited by ciprofloxacin; (8) increased digoxin concentrations; (9) metabolism inhibited by erythromycin; (10) increased nephrotoxicity; (11) increased heparin requirements.

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Propofol			
Bolus dose	0.25-0.5 mg/kg	Undiluted	Infuse over 1-2 minutes
Infusion dose	5-50 mcg/kg/min	Undiluted	Continuous infusion
Propranolol			
Bolus dose	0.5-1 mg q5-15min	Undiluted	Infuse over 60 seconds
Infusion dose	1-4 mg/h	50 mg in D_5W 500 mL	Continuous infusion
Protamine	<30 min: 1-1.5 U mg/100 U; 30-60 minutes: 0.5-0.75 mg/100 U; >120 min: 0.25-0.375 mg/100 U	50 mg in SW 5 mL	Inject over 3-5 minutes; do not exceed 50 mg in 10 minutes
Pyridostigmine	100-300 mcg/kg	Undiluted	Use to reverse long-acting neuromuscular blocking agents Inject over 60 seconds
Quinidine gluconate	600 mg initially, then 400 mg q2h, maintenance 200-300 mg q6h	800 mg in D_5W 50 mL	Infusion rate 1 mg/min; use cardiac monitor Therapeutic levels: 1.5-5 mg/L
Quinupristin/dalfopristin	7.5 mg/kg q8-12h	D_5W 250 mL	Infuse over 60 minutes Central line preferred Flush with D_5W after peripheral infusion to minimize venous irritation

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Ranitidine			
IVPB	50 mg q6-8h	D_5W 50 mL	Infuse over 15-30 minutes IVP dose should be injected over at least 5 minutes
Infusion dose	6.25 mg/h	150 mg in D_5W 150 mL	Continuous infusion
Reteplase	10-U bolus × 2	SW 10 mL	Inject over 2 minutes, use dedicated IV line, flush heparin-coated catheters with NS D_5W after use
Rocuronium			
Intubating dose	0.45-1.2 mg/kg	Undiluted	Inject over 60 seconds
Maintenance dose	0.075-0.15 mg/kg	Undiluted	Inject over 60 seconds
Infusion dose	10-14 mcg/kg/min	50 mg in D_5W 100 mL	Continuous infusion
Streptokinase			
Acute MI	1.5 MU	D_5W 45 mL	Infuse over 30 minutes
DVT, PE	250,000 U over 30 minutes, then 100,000 U/h over 24-72 hours	D_5W 90 mL	Continuous infusion
Succinylcholine	0.6-2 mg/kg	Undiluted	Inject over 60 seconds
Tacrolimus	50-100 mcg/kg/day	5 mg in D_5W 250 mL	
Tenecteplase	30-50 mg	SW 10 mL	Inject over 5 seconds
t-PA	100 mg	100 mg in D_5W 100 mL	Infuse 60 mg/h during first hour, then 20 mg/h for 2 hours
Theophylline			Smokers: 0.9 mg/kg/h
Bolus dose	6 mg/kg	800 mg in 500 mL premixed	Nonsmokers: 0.6 mg/kg/h
Infusion dose	0.3-0.9 mg/kg/h		Liver and heart failure: 0.3 mg/kg/h

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Thiamine	100 mg qd × 3	D_5W 50 mL	Infuse over 15-30 minutes
Thiopental	3-4 mg/kg	Undiluted	Inject over 3-5 minutes
Ticarcillin	3 g q3-6h	D_5W 100 mL	Infuse over 15-30 minutes
Ticarcillin/clavulanate	3.1 g q4-6h	D_5W 100 mL	Infuse over 15-30 minutes
Tirofiban			
Bolus dose	0.4 mcg/kg/h	25 mg in D_5W 500 mL	Bolus infused over 30 minutes
Infusion dose	0.1 mcg/kg/min for 12-24 hours after angioplasty or arthrectomy		
Tobramycin			
Loading dose	2-3 mg/kg	D_5W 50 mL	Infuse over 30 minutes
Maintenance dose	1.5-2.5 mg/kg q8-24h	D_5W 50 mL	Infuse over 30 minutes Critically ill patients have an increased volume of distribution requiring increased doses Drug interactions: neuromuscular blocking agents (3) Therapeutic levels Peak: 4-10 mg/L Trough: <2 mg/L
Torsemide	5-20 mg qd	Undiluted	Inject over 60 seconds
Trimethaphan	0.5-5 mg/min	500 mg in D_5W 500 mL	Continuous infusion

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Trimethaprim-sulfamethoxazole			
Common infections	4-5 mg/kg q12h	TMP 16 mg-SMX 80 mg per D_5W 25 mL	Infuse over 60 minutes
PCP	5 mg/kg q6h	TMP 16 mg-SMX 80 mg per D_5W 25 mL	Infuse over 60 minutes Therapeutic levels: 100-150 mg/L
Urokinase Pulmonary embolism	4400 U/kg over 10 minutes, then 4400 U/h over 12 hours	D_5W 195 mL	Continuous infusion
Vancomycin	1 g q12h	D_5W 250 mL	Infuse over at least 1 hour to avoid "red-man" syndrome Therapeutic levels Peak: 20-40 mg/L Trough: $<$10 mg/L
Vasopressin			
GI hemorrhage Septic shock	0.2-0.3 U/min 0.01-0.04 U/min	100 U in D_5W 250 mL	Maximum infusion rate 0.9 U/min

7.1 ► Intravenous Medication Administration Guidelines (*continued*)

Drug	Usual IV Dose Range[a]	Standard Dilution	Infusion Times/Comments/Drug Interactions
Vecuronium			
Intubating dose	0.1-0.28 mg/kg	Undiluted	Inject over 60 seconds
Maintenance dose	0.01-0.015 mg/kg	Undiluted	Inject over 60 seconds
Infusion dose	1 mcg/kg/min	20 mg in D_5W 100 mL	Continuous infusion Metabolite contributes to activity Drug interactions: aminoglycosides (3); anticonvulsants (5)
Verapamil			
Bolus dose	0.075-0.15 mg/kg	Undiluted	Inject over 1-2 minutes Continuous infusion Drug interactions: digoxin (8)

[a] Usual dose ranges are listed; refer to appropriate disease state for specific dose.

Abbreviations: bid, twice a day; HF, heart failure; conc, concentration; D_5W, destrose-5%-water; DVT, deep venous thrombosis; HPLC, high-performance liquid chromatography; IM, intramuscular; IV, intravenous; IVP, IV push; IVPB, IV piggyback; MI, myocardial infarction; NS, normal saline; NSAID, nonsteroidal anti-inflammatory drug; PCP, *Pneumocystis carinii* pneumonia; PE, pulmonary embolism; PO, orally; prn, as needed; qd, daily; SW, sterile water.

Drug interactions: (1) antagonizes adenosine effect; (2) potentiates adenosine effect; (3) potentiates effect of neuromuscular blocking agents; (4) inhibits theophylline metabolism; (5) antagonizes effect of neuromuscular blocking agents: (6) metabolism inhibited by cimetidine; (7) metabolism inhibited by ciprofloxacin; (8) increased digoxin concentrations; (9) metabolism inhibited by erythromycin; (10) increased nephrotoxicity; (11) increased heparin requirements.

7.2 ► Neuromuscular Blocking Agents

Agent	Dose	Onset/Duration	Comments
Depolarizing Agents			
Succinylcholine	Intubating dose: 1-2 mg/kg	Onset: 1 minutes Duration: 10 minutes	Prolonged paralysis in pseudocholinesterase deficiencies Contraindications: Family history of malignant hyperthermia, neuromuscular disease, hyperkalemia, open eye injury, major tissue injury (burns, trauma, crush), increased intracranial pressure Side effects: bradycardia (especially in children), tachycardia, increased serum potassium concentration
Nondepolarizing Agents			
Short-Acting			
Mivacurium	Intubating dose: 0.25 mg/kg Maintenance dose: 0.1 mg/kg Continuous infusion: 9.0-10.0 mcg/kg/min	Onset: 5 minutes Duration: 15-20 minutes Duration: 15 minutes	Metabolized by pseudocholinesterase Intubating dose: initial 0.15 mg/kg followed in 30 seconds by 0.1 mg/kg

7.2 ► Neuromuscular Blocking Agents (*continued*)

Agent	Dose	Onset/Duration	Comments
Intermediate-Acting			
Atracurium	Intubating dose: 0.5 mg/kg Maintenance dose: 0.08-0.10 mg/kg Continuous infusion: 5-9 mcg/kg/min	Onset: 2 minutes Duration: 30-40 minutes Duration: 15-25 minutes	Histamine release with bolus doses >0.6 mg/kg and may precipitate asthma or hypotension Elimination independent of renal hepatic function Metabolized in the plasma by Hofmann elimination and ester hydrolysis Duration not prolonged by renal or liver failure Used when succinylcholine is contraindicated or not preferred
Cisatricurium	Intubating dose: 0.15-0.2 mg/kg Maintenance dose: 0.03 mg/kg Continuous infusion: 1-3 mcg/kg/min	Onset: 2 minutes Duration: 30-90 minutes Duration: 15-30 minutes	Decreased histamine release compared to atracurium Elimination independent of renal or hepatic function Metabolized in the plasma by Hofmann elimination and ester hydrolysis Duration not prolonged by renal or liver failure
Rocuronium	Intubating dose: 0.45-1.2 mg/kg Maintenance dose: 0.075-0.15 mg/kg Continuous infusion: 10-14 mcg/kg/min	Onset: 0.7-1.3 minutes Duration: 22-67 minutes Duration: 12-17 minutes	Not associated with histamine release Used when succinylcholine is contraindicated or not preferred Metabolized by liver; duration not significantly prolonged by renal failure, but prolonged in patients with liver disease No adverse cardiovascular effects

7.2 ► Neuromuscular Blocking Agents (*continued*)

Agent	Dose	Onset/Duration	Comments
Vecuronium	Intubating dose: 0.1-0.15 mg/kg Maintenance dose: 0.01-0.15 mg/kg Continuous infusion: 1 mcg/kg/min	Onset: 2 minutes Duration: 30-40 minutes Duration: 15-25 minutes	Not associated with histamine release Bile is the main route of elimination Metabolized by liver; minimal reliance on renal function, although active metabolite accumulates in real failure Used when succinylcholine is contraindicated or not preferred No adverse cardiovascular effects
Long-Acting			
Doxacurium	Intubating dose: 0.025-0.8 mg/kg Maintenance dose: 0.005-0.01 mg/kg Continuous infusion: 0.25 mcg/kg/min (not generally recommended)	Onset: 4-5 minutes Duration: 55-160 minutes Duration: 35-45 minutes	No adverse cardiovascular effects Predominantly renally eliminated; significant accumulation in renal failure
Pancuronium	Intubating dose: 0.06-0.1 mg/kg 0.1 mg/kg Maintenance dose: 0.01-0.015 mg/kg Continuous infusion: 1 mcg/kg/min (not generally recommended)	Onset: 2-3 minutes Duration: 60-100 minutes Duration: 25-60 minutes	Tachycardia (vagolytic effect) Metabolized by liver; minimal reliance on renal function, although active metabolite accumulates in renal failure

7.3 ► Vasoactive Agents

Agent and Dose	Receptor Specificity						Pharmacologic Effects			Comments
	α	β_1	β_2	DM	SM	VD	VC	INT	CHT	
Inotropes										
Dobutamine										Useful for acute management of low cardiac output states; in chronic CHF intermittent infusions palliate symptoms but do not prolong survival
2-10 mcg/kg/min	1+	3+	2+	—	—	1+	1+	3+	1+	
>10- 20 mcg/kg/min	2+	4+	3+	—	—	2+	1+	4+	2+	
Isoproterenol 2-10 mcg/kg/min	—	4+	3+	—	—	3+	—	4+	4+	Used primarily for temporizing treatment of life-threatening bradycardia
Inamrinone										Useful for acute management of low cardiac output states; can be combined with dobutamine
Loading dose: 0.75 mg/kg										
Maintenance dose:										Associated with the development of thrombocytopenia
5-15 mcg/kg/min	—	—	—	—	2+	2+	—	3+	3+	
Milrinone										Useful for acute management of low cardiac output states; can be combined with dobutamine
Loading dose: 50 mcg/kg over 10 min										
Maintenance dose:										
0.375-0.75 mcg/kg/min	—	—	—	—	2+	2+	—	3+	3+	

7.3 ► Vasoactive Agents (*continued*)

Agent and Dose	Receptor Specificity						Pharmacologic Effects			Comments
	α	β_1	β_2	DM	SM	VD	VC	INT	CHT	
Mixed										
Dopamine										Doses >20-30 mcg/kg/min usually produce no added response; 2 mcg/kg/min may protect kidneys when giving other vasopressors
2-5 mcg/kg/min	—	3+	—	4+	—	—	—	2+	1+	
5-10 mcg/kg/min	—	4+	2+	4+	—	—	—	4+	2+	
10-20 mcg/kg/min	3+	4+	1+	—	—	—	3+	3+	3+	
Epinephrine										Mixed vasoconstrictor/inotrope; stronger inotrope than norepinephrine; does not constrict coronary or cerebral vessels; give as needed to maintain BP
0.01-0.05 mcg/kg/min	1+	4+	2+	—	—	1+	1+	4+	2+	
>0.05 mcg/kg/min	4+	3+	1+	—	—	—	3+	3+	3+	
Vasopressors										
Norepinephrine										Mixed vasoconstrictor/inotrope; useful when dopamine inadequate; give as needed to maintain BP (usually ≤20 mcg/min)
2-20 mcg/min titrate to effect	4+	2+	—	—	—	—	4+	1+	2+	
Phenylephrine										Pure vasoconstrictor without direct cardiac effect; may cause reflex bradycardia; useful when other pressors cause tachyarrhythmias; give as much as needed to maintain BP
Start at 30 mcg/min IV and titrate	4+	—	—	—	—	—	4+	—	—	
Vasopressin										Pure vasoconstrictor without direct cardiac effect; may cause gut ischemia if dose is increased >0.04 U/min
0.01-0.04 U/min	—	—	—	—	—	—	4+	—	—	

7.3 ► Vasoactive Agents (*continued*)

Agent and Dose	Receptor Specificity						Pharmacologic Effects			Comments
	α	β_1	β_2	DM	SM	VD	VC	INT	CHT	
Vasodilators										
Nitroglycerin 20-100 mcg/min	—	—	—	—	4+	4+ A<V	—	—	1+	Tachyphylaxis, headache
Nitroprusside 0.5-10 mcg/kg/min	—	—	—	—	4+	4+ A=V	—	—	1+	Monitor thiocyanate levels if infusion duration >48 hours; maintain thiocyanate level <10 mg/dL

Abbreviations: α_1: α_1-adrenergic; β_1; β_1-adrenergic; β_2: β_2-adrenergic; DM: dopaminergic; SM: smooth muscle; VD: vasodilator; VC: vasoconstrictor; INT: inotropic; CHT: chronotropic. Vasoconstrictors usually are given by central vein and should be used only in conjunction with adequate volume repletion. All can precipitate myocardial ischemia. All except phenylephrine can cause tachyarrhythmias.

Modified from: Gonzalez ER, Meyers DG. Assessment and management of cardiogenic shock. In Oronato JC, ed. Clinics in Emergency Medicine: Cardiovascular Emergencies. *New York, NY: Churchill Livingstone; 1986:125, with permission.*

7.4 ► Antiarrhythmic Agents

Agents	Indications	Dosage	Comments
Class IA			
Procainamide	Ventricular ectopy; conversion of atrial fibrillation and atrial flutter; WPW	Loading dose: (IV) 15 mg/kg at 25-50 mg/min Maintenance dose: (IV) 2-5 mg/min	*N*-acetyl procainamide is active metabolite; lupus-like syndrome; rash; agranulocytosis; QT prolongation Therapeutic range: PA 4-10 mg/L, NAPA 10-20 mg/L
Quinidine	Ventricular ectopy; conversion of atrial fibrillation and atrial flutter; WPW	Quinidine sulfate: 200-300 mg PO q6h Quinidine sulfate: 324-648 mg PO q8h	Diarrhea, nausea, headache dizziness; hypersensitivity reactions including thrombocytopenia; hemolysis; fever hepatitis; rash QT prolongation; increased digoxin level Dosage adjustment should be made when switching from one salt to another: Quinidine sulfate (83% quinidine), gluconate (62% quinidine), polygalacturonate (60% quinidine) Therapeutic range: 2.5-5 mg/L
Disopyramide	Ventricular ectopy; conversion of atrial fibrillation and atrial flutter; WPW	100-300 mg PO q6h; SR: 100-300 mg PO q12h	Anticholinergic effects; negative inotropy; QT prolongation Therapeutic range: 2-4 mg/L

7.4 ► Antiarrhythmic Agents (*continued*)

Agents	Indications	Dosage	Comments
Class IB Lidocaine	Malignant ventricular ectopy; WPW	1.5 mg/kg IV over 2 minutes, then 1-4 mg/min	No benefit in atrial arrhythmias Seizures; paresthesias; delirium; levels increased by cimetidine; minimal hemodynamic effects Therapeutic range: 1.5-5 mg/L
Mexiletine	Malignant ventricular ectopy	150-300 mg PO q6-8h with food	No benefit in atrial arrhythmias Less effective than IA and IC agents Nausea; tremor; dizziness; delirium; levels increased by cimetidine Therapeutic range: 0.5-2 mg/L
Tocainide	Malignant ventricular ectopy	200-600 mg PO q8h with food	No benefit in atrial arrhythmias Less effective than IA and IC agents Nausea; tremor; dizziness; delirium; agranulocytosis; pneumonitis; minimal hemodynamic effects Therapeutic range: 4-10 mg/L

7.4 ► Antiarrhythmic Agents (*continued*)

Agents	Indications	Dosage	Comments
Class IC Flecainide	Life-threatening ventricular arrhythmias refractory to other agents Prevention of symptomatic, disabling, paroxysmal supraventricular arrhythmias, including atrial fibrillation or flutter and WPW in patients without structural heart disease	100-200 mg PO q12h	Proarrhythmic effects; moderate negative inotropy; dizziness; conduction abnormalities Therapeutic range: 0.2-1 mg/L
Propafenone	Life-threatening ventricular arrythmias refractory to other agents SVT, WPW, and paroxysmal atrial fibrillation or flutter in patients without structural heart disease	150-300 mg PO q8h	Proarrhythmic effects; negative inotropy; dizziness; nausea; conduction abnormalities
Class IB/IC (hybrid electrophysiologic effects) Moricizine	Life-threatening ventricular arrythmias refractory to other agents	100-300 mg PO q8h	Proarrhythmic effects; dizziness; nausea; headache

7.4 ► Antiarrhythmic Agents (*continued*)

Agents	Indications	Dosage	Comments
Class II (beta-blocking agents)			
Propranolol	Slowing ventricular rate in atrial fibrillation, atrial flutter, and SVT; suppression of PVCs	Up to 0.5-1 mg IV, then 1-4 mg/h (or 10-100 mg PO q6h)	Not cardioselective; hypotension; bronchospasm; negative inotropy
Esmolol	Slowing ventricular rate in atrial fibrillation, atrial flutter, SVT, and MAT	Loading dose: 500 mcg/over 1 minute Maintenance dose: 50 mcg/kg/min; rebolus and increase q5min by 50 mcg/kg/min to maximum of 400	Cardioselective at low doses; hypotension; negative inotropy; very short half-life
Metoprolol	Slowing ventricular rate in atrial fibrillation, atrial flutter, SVT, and MAT	Initial IV dose: 5 mg q5min up to 15 mg, then 25-100 mg PO q8-12h	Cardioselective at low doses; hypotension; negative inotropy
Class III			
Amiodarone	Life-threatening ventricular arrhythmias, supraventricular arrhythmias, including WPW refractory to other agents	800-1600 mg PO qd for 1-3 weeks, then 600-800 mg PO qd for 4 weeks, then 100-400 mg PO qd	Half-life >50 days; pulmonary fibrosis; corneal microdeposits; hypo/hyperthyroidism; bluish skin; hepatitis; photosensitivity; conduction abnormalities; mild negative inotropy; increased effect of coumadin; increased digoxin level Therapeutic range: 1-2.5 mg/L

7.4 ► Antiarrhythmic Agents (*continued*)

Agents	Indications	Dosage	Comments
Bretylium	Refractory ventricular tachycardia and ventricular fibrillation	5-10 mg/kg IV boluses q10 min up to 30 mg/kg, then 0.5-2 mg/min	Initial hypertension, then postural hypotension; nausea and vomiting; parotitis; catecholamine sensitivity
Sotalol	Life-threatening ventricular arrythmias	80-160 mg PO q12h; may increase up to 160 mg PO q8h	Beta-blocker with class III properties; proarrhythmic effects; QT prolongation
Dofetilide	Conversion of atrial fibrillation	250-500 mcg orally twice a day	Dose adjusted based on QTc interval and creatinine clearance
Class IV (calcium channel antagonists)			
Verapamil	Conversion of SVT; slowing ventricular rate in atrial fibrillation, atrial flutter, and MAT	IV bolus: 5-10 mg over 2-3 minutes (repeat in 30 min prn), continuous infusion: 2.5-5 mcg/kg/min PO: 40-160 mg PO q8h	Hypotension; negative inotropy; conduction disturbances; increased digoxin level; generally contraindicated in WPW
Diltiazem	Conversion of SVT; slowing ventricular rate in atrial fibrillation, atrial flutter, and MAT	IV bolus: 0.25 mg/kg over 2 minutes (repeatin 15 minutes prn with 0.35 mg/kg IV); Maintenance infusion: 5-15 mg/h PO: 30-90 mg PO q6h	Hypotension; less negative inotropy than verapamil; conduction disturbances; rare hepatic injury; generally contraindicated in WPW

7.4 ► Antiarrhythmic Agents (*continued*)

Agents	Indications	Dosage	Comments
Miscellaneous agents			
Adenosine	Conversion of SVT, including WPW	6-mg rapid IV bolus; if ineffective, 12-mg rapid IV bolus 2 minutes later; follow bolus with fast flush; use smaller doses if giving through central venous line	Flushing; dyspnea; nodal blocking effect increased by dipyridamole and decreased by theophylline and caffeine; very short half-life (≈10 seconds)
Atropine	Initial therapy for symptomatic bradycardia	0.5-mg IV bolus; repeat q5min prn to total of 2 mg IV	May induce tachycardia and ischemia
Digitalis	Slowing AV conduction in atrial fibrillation and atrial flutter	Loading dose: 0.5 mg IV, then 0.25 mg IV q4-6h up to 1 mg; Maintenance dose: 0.125-0.375 mg PO/IV qd	Heart block; arrhythmias; nausea; yellow vision; numerous drug interactions, generally contraindicated in WPW Therapeutic range: 0.5-2.0 mg/mL

Abbreviations: AV, atrioventricular; MAT, multifocal atrial tachycardia; SR: sustained release; SVT, supraventricular tachycardia; WPW, Wolff-Parkinson-White.

7.5 ► Therapeutic Drug Monitoring

Drug	Usual Therapeutic Range	Usual Sampling Time
Antibiotics		
Amikacin	Peak: 20-40 mg/L Trough: <10 mg/L	Peak: 30-60 minutes after a 30-minute infusion Trough: Just before next dose
Chloramphenicol	Peak: 10-25 mg/L Trough: 5-10 mg/L	Peak: 30-90 minutes after a 30-minute infusion Trough: Just before the next dose
Flucytosine	Peak: 50-100 mg/L Trough: <25 mg/L	Peak: 1-2 hours after an oral dose Trough: Just before the next dose
Gentamicin	Peak: 4-10 mg/L Trough: <2 mg/L	Peak: 30-60 minutes after a 30-minute infusion Trough: Just before the next dose
Tobramycin	Peak: 4-10 mg/L Trough: <2 mg/L	Peak: 30-60 minutes after a 30-minutes infusion Trough: Just before the next dose
Netilmicin	Peak: 4-10 mg/L Trough: <2 mg/L	Peak: 30-60 minutes after a 30-minutes infusion Trough: Just before the next dose
Vancomycin	Peak: 20-40 mg/L Trough: <20 mg/L	Peak: 1 hour after end of a 1-hour infusion Trough: Just before the next dose
Sulfonamides (sulfamethoxazole, sulfadiazine, cotrimoxazole)	Peak: 100-150 mg/L	Peak: 2 hours after 1-hour infusion Trough: Not applicable

7.5 ► Therapeutic Drug Monitoring (*continued*)

Drug	Usual Therapeutic Range	Usual Sampling Time
Antiarrhythmics		
Amiodarone	0.5-2 mg/L	Trough: Just before next dose
Digoxin	0.5-2 mcg/L	Peak: 8-12 hours after administered dose Trough: Just before next dose
Disopyramide	2-4 mg/L	Trough: Just before next dose
Flecainide	0.2-1.0 mg/L	Trough: Just before next dose
Lidocaine	1.5-5 mg/L	Anytime during a continuous infusion
Mexiletine	0.5-2 mg/L	Trough: Just before next dose
Procainamide/NAPA	Procainamide: 4-10 mg/L NAPA: 10-20 mg/L	IV: Immediately after IV loading dose: anytime during continuous infusion
Quinidine	2.5-5 mg/L	Trough: Just before next dose
Tocainide	4-10 mg/L	Trough: Just before next dose
Anticonvulsants		
Carbamazepine	4-12 mg/L	Trough: Just before next dose
Pentobarbital	20-50 mcg/L	IV: Immediately after IV loading dose: anytime during continuous infusion
Phenobarbital	15-40 mg/L	Trough: Just before next dose
Phenytoin	10-20 mg/L	IV: 2-4 hours after dose Trough: PO/IV: Just before next dose Free phenytoin level: 1-2 mg/L
Valproic acid	50-100 mg/L	Trough: Just before next dose

7.5 ► Therapeutic Drug Monitoring (*continued*)

Drug	Usual Therapeutic Range	Usual Sampling Time
Bronchodilators		
Theophylline	10-20 mg/L	IV: Prior to IV bolus dose, 30 minutes after end of bolus dose, anytime during continuous infusion PO: peak: 2 hours after rapid-release product, 4 hours after sustained-release product Trough: Just before next dose
Miscellaneous		
Cyclosporine	50-150 ng/mL (whole blood, HPLC)	Trough: IV, PO: Just before next dose

7.6 ► Tips for Calculating IV Medication Infusion Rates

Information Required to Calculate IV Infusion Rates to Deliver Specific Medication Doses

- Dose to be infused (eg, mg/kg/min, mg/min, mg/h)
- Concentration of IV solution (eg, dopamine 400 mg in D_5W 250 mL = 1.6 mg/mL; nitroglycerin 50 mg in D_5W 250 mL = 200 mcg/mL)
- Patient's weight

1. Calculate the IV infusion rate in milliliters per hour for a 70-kg patient requiring dobutamine 5 mcg/kg/min using a dobutamine admixture of 500 mg in D_5W 250 mL.
   - Dose to be infused: 5 mcg/kg/min
   - Dobutamine concentration: 500 mg/250 mL = 2 mg/mL or 2000 mcg/mL
   - Patient weight: 70 kg

Calculation:
5 mcg/kg/min × 70 kg = 350 mcg/min
350 mcg/min × 60 min/h = 21,000 mcg/h
21,000 mcg/h ÷ 2000 mcg/mL = 10.5 mL/h

Answer: Setting the infusion pump at 10.5 mL/h will deliver dobutamine at a dose of 5 mcg/kg/min.

2. Calculate the IV infusion rate in milliliters per hour for a 70-kg patient requiring nitroglycerin 50 mcg/min using a nitroglycerin admixture of 50 mg in D_5W 250 mL.
   - Dose to be infused: 50 mcg/min
   - Nitroglycerin concentration: 50 mg/250 mL = 0.2 mg/mL or 200 mcg/mL
   - Patient weight: 70 kg

Calculation:
50 mcg/min × 60 min/h = 3000 mcg/h
3000 mcg/h ÷ 200 mcg/mL = 15 mL/h

Answer: Setting the infusion pump at 15 mL/h will deliver nitroglycerin at a dose of 50 mcg/min.

7.6 ► Tips for Calculating Intravenous Medication Infusion Rates (*continued*)

3. Calculate the IV loading dose and infusion rate in milliliters per hour for a 70-kg patient requiring aminoph-ylline 0.6 mg/kg/h using an aminophylline admixture of 1 g in D_5W 500 mL. The loading dose should be diluted in D_5W 100 mL and infused over 30 minutes.
   - Desired dose: Loading dose: 6 mg/kg Maintenance infusion: 0.6 mg/kg/h
   - Aminophylline concentration: Aminophylline vial: 500 mg/20 mL = 25 mg/mL Aminophylline infusion: 1 g/500 mL = 2 mg/mL
   - Patient weight: 70 kg

Calculation:

Loading dose: 6 mg/kg 3 70 kg = 420 mg

420 mg ÷ 25 mg/mL = 16.8 mL

Infusion rate: Aminophylline 16.8 mL + D_5W 100 mL = 116.8 mL

116.8 mL ÷ 0.5/h = 233.6 mL/h

Answer: Setting the infusion pump at 234 mL/h will infuse the aminophylline loading dose over 1/2 hour

Maintenance dose: 0.6 mg/kg/h × 70 kg = 42 mg/h

42 mg/h ÷ 2 mg/mL = 21 mL/h

Answer: Setting the infusion pump at 21 mL/h will deliver the aminophylline maintenance dose at 42 mg/h, or 0.6 mg/kg/h.