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PROCEDURES in CRITICAL CARE



C. William Hanson, III

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Notice

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Professional

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This text is dedicated to the residents, fellows, and fellow intensivists with whom it has been my privilege to work over the past 25 years both at Stanford University and the University of Pennsylvania.

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Contents

Preface

Today's intensive care unit is a technologically rich environment where skilled teams employ advanced treatments to monitor and support organ systems in patients with medical illnesses, following traumatic injuries, or after surgery. While the invasive procedures undertaken in the intensive care unit (ICU) may come with benefits, they often come with risks, including those of infection, bleeding, procedural errors, and device failure. For a variety of reasons, including increasing specialization, workforce turnover, and constrained training hours, it is not uncommon for nursing and medical practitioners to have limited exposure to advanced critical care procedures. This book was designed to illustrate the fundamentals of a broad variety of techniques organized by organ system, and to thereby serve as an introduction to critical care interventions. Each procedure chapter consists of an introduction, definitions and terms, techniques, pearls and pitfalls, as well as a series of illustrative line art and photographs. The book is designed for students, novice practitioners, and experts who want exposure to procedures outside of their general field of expertise. In addition to the printed material, a DVD containing narrated video segments depicting procedures commonly performed in the ICU has been included as part of the book.

C. William Hanson III, MD

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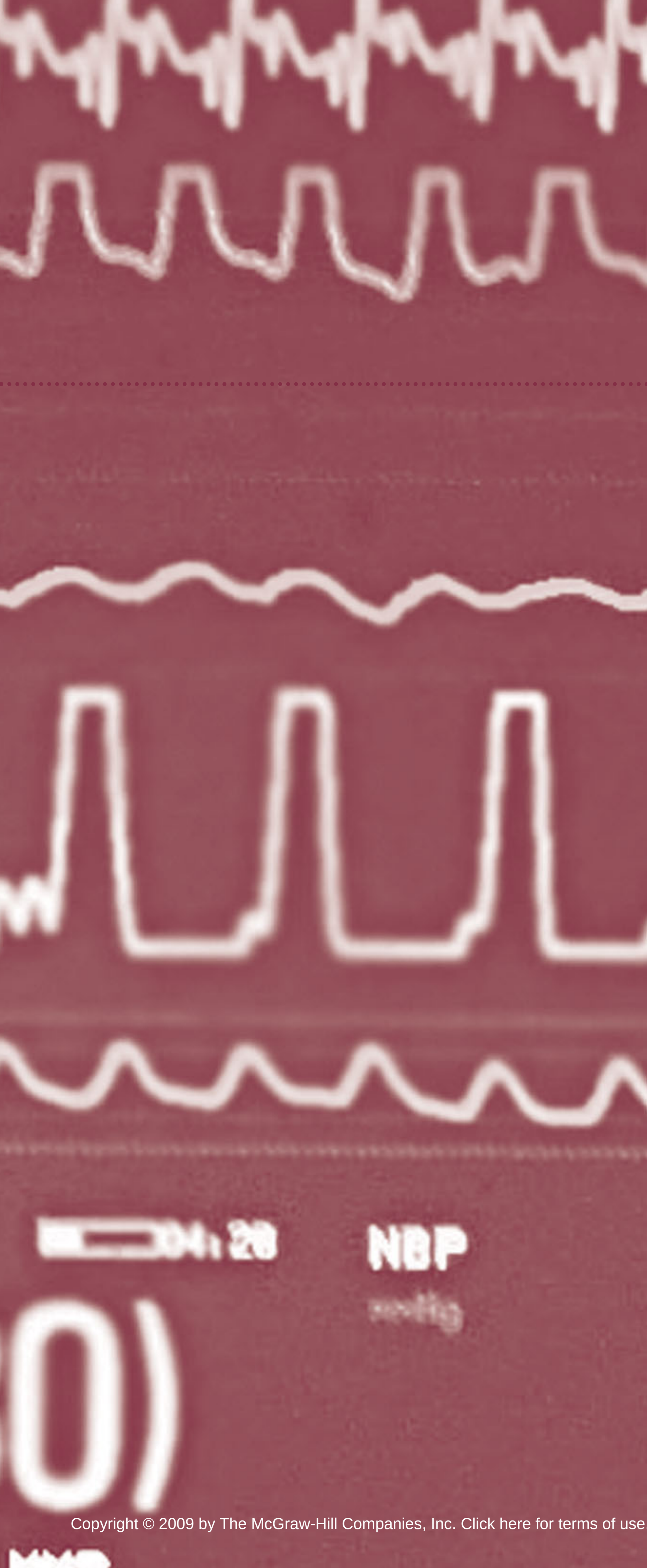

SECTION I

ICU Basics

The ICU Room and Equipment

Introduction

The intensive care unit (ICU) room is a highly specialized environment, differing in many ways from a standard hospital room. ICU rooms are staffed with a higher nursing staffing ratio, typically one nurse to two rooms, and a premium is placed on patient visibility. Units are often constructed in such a manner that all patients can be under continuous observation from the central-nursing station, either directly or using cameras. Patients are individually monitored with a variety of bedside physiologic monitors, and ICU rooms are designed to have redundant gas and electric sources.

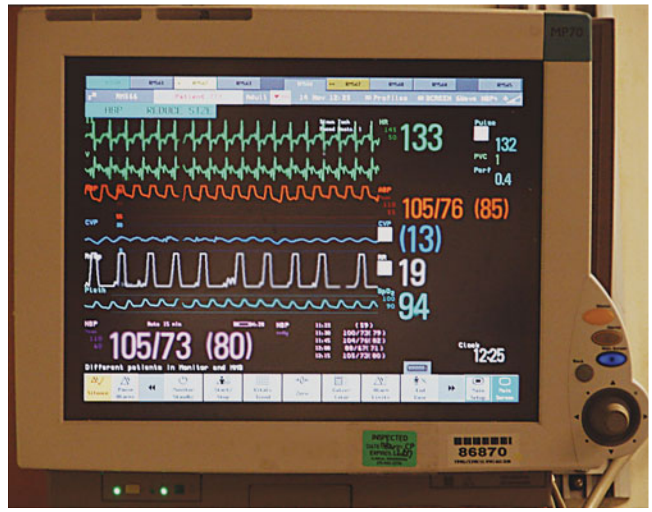

Figure 1-2. Physiologic monitor which display patient data in a central location as waveforms and numeric readouts.

Definitions and Terms

- Headwall: The wall behind the head of a patient in an ICU, in which electrical, gas, and equipment mounts are deployed—while headwalls are typical, columns and movable, jointed arms are used in some units (ie, pediatric) to permit more flexible bed/crib configurations (Figure 1-1).

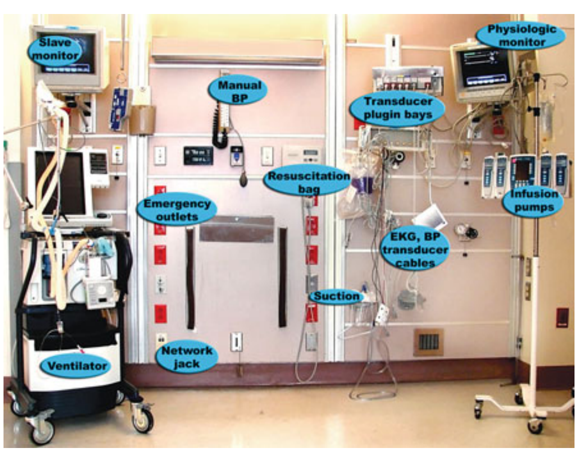

Figure 1-1. Typical ICU headwall with various components and utilities.

- Physiologic monitor: A piece of medical equipment that serves as a central aggregation and display location for many medically significant physiologic variables, including electrocardiogram (ECG), various pressure waveforms, noninvasive blood pressure, pulse oximetry, respiration, temperature, and so on (Figure 1-2).
- Telemetry: Electronic transmission of medical data to a central analysis station (Figure 1-3).
- Electrocardiography: Analysis and display of data regarding cardiac conduction and rhythm (Figure 1-4).
- Pulse oximetry: Photoelectric, noninvasive measurement of capillary oxygen levels using light transmission through a capillary bed to a receiver (Figure 1-5).
- Impedance pneumography: A technique by which respiratory rate is measured using electrical changes between ECG leads induced by changes in intrathoracic air volume during inspiration and expiration.

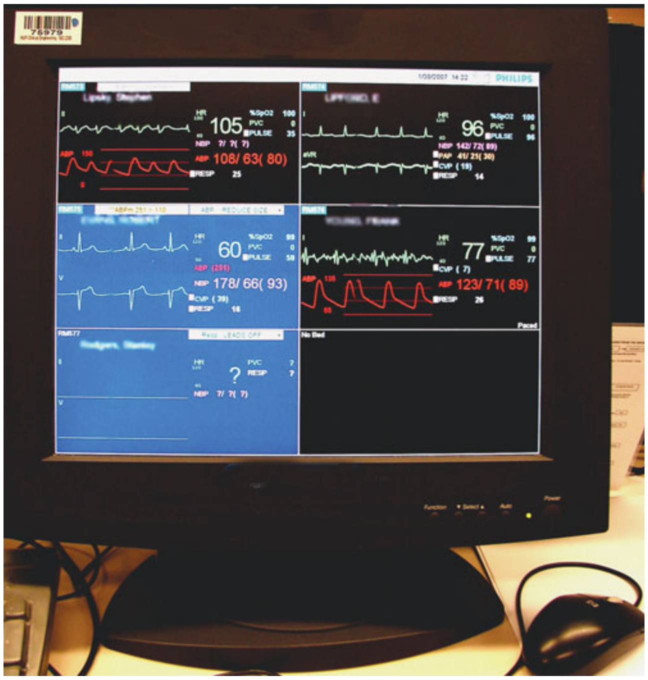

Figure 1-3. Central monitor on a nursing unit, where the key data from all of the patients on a unit are aggregated, and from which alarms are generated to all providers on a unit.

Figure 1-5. Pulse oximeter on a finger, with transillumination of the finger by light of a specific wavelength.

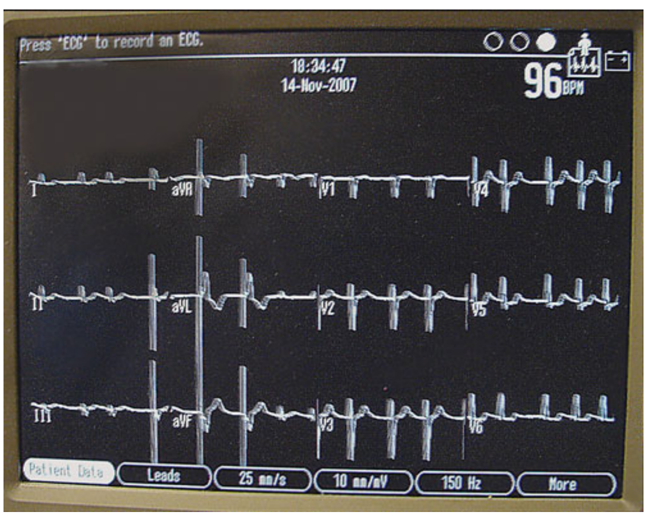

Figure 1-4. ECG acquired electronically, typically with preliminary automated analysis, which is then printed for the medical record.

Figure 1-6. Wall oxygen source, which is color-coded green (in the United States) and specifically fitted for oxygen connectors and tubing.

- Wall oxygen supply: Oxygen is piped into hospitals from a central supply source typically on the hospital grounds—gases are distributed to outlets throughout the hospital which are both color coded and distributed using gas specific connectors to mechanical ventilators and/or gas blenders. While colors for medical gases vary among countries, green (Figure 1-6) is used to indicate oxygen in the United States (whereas white is used in the United Kingdom). Wall oxygen is supplied at 50 pounds per square inch (psi) and distributed throughout the hospital from central liquid oxygen containers.

Figure 1-7. Wall air source, which is specifically color-coded yellow (in the United States) and specifically fitted for air (as distinct from oxygen) connectors and tubing.

- Wall air supply: Compressed air is piped to ICU headwalls using a separate and distinct piping system and is dispensed at the bedside through a specific color coded and connector specific gas outlet—air is blended with oxygen to dispense specific oxygen concentrations to the patient. In the United States, the color yellow (Figure 1-7) is used to indicate compressed air (whereas black and white are used in the United Kingdom). Wall air is typically supplied at 50 psi.
- Wall suction: A separate suction system is available at each ICU bedside and used for a variety of applications (Figure 1-8), including suction on drains (ie, chest tubes, gastric tubes, abdominal drains, etc.) and pulmonary secretion removal. Vacuum pressure is, approximately, 10 psi, and, as with medical gases, vacuum lines have specific connectors and are colored white in the United States (whereas they are yellow in the United Kingdom)
- Emergency power system: An electrical supply system in a hospital that is automatically set to convert to generator power in the event of loss of external electrical supply to a hospital—emergency outlets are red (Figure 1-9) to distinguish them from regular outlets (Figure 1-10).
- ICU rooms are often equipped with an emergency call button (Figure 1-11).

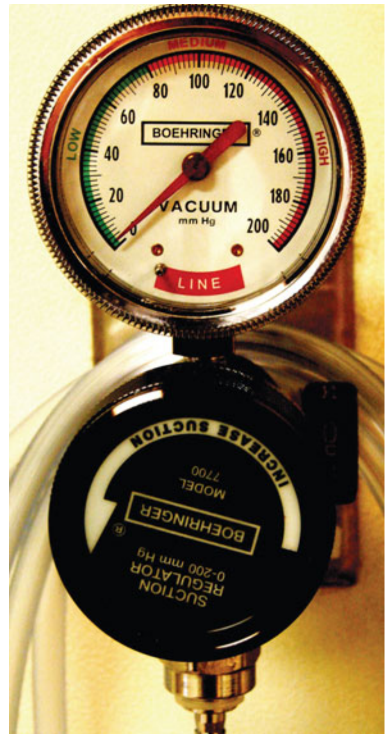

Figure 1-8. Wall suction, which is adjustable with an adjustable regulator. Suction tubing is color coded and fitted distinctly from air and oxygen fittings.

Figure 1-9. Emergency power supply outlet, which is color-coded red, and provides power attached to the backup electrical generator, which supplies power in the event of an interruption of supply from the utility company.

Figure 1-10. Standard power outlet.

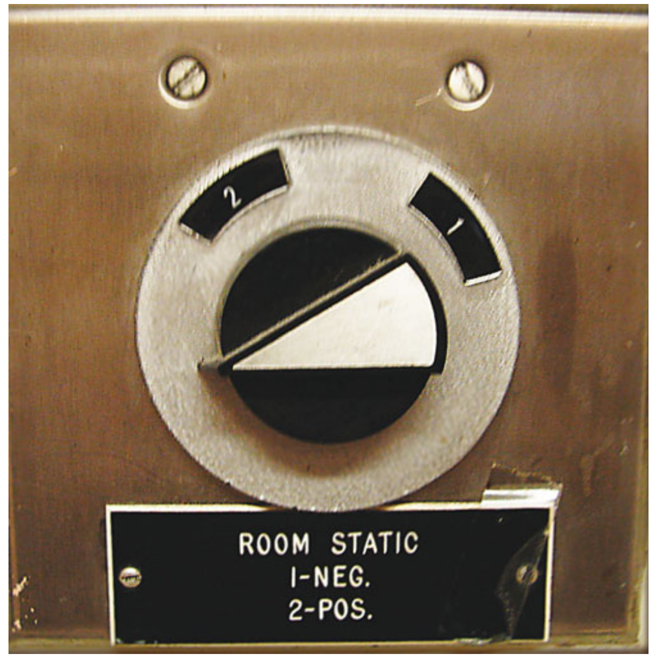

Figure 1-12. Room pressure regulator, which raises or lowers ICU room atmospheric pressure relative to the pressure outside of the room—used to partition the air in the room from the rest of the unit.

Figure 1-11. Emergency bedside "code" button which may be used to summon help in the event of an emergency.

- ICU room pressure may be adjustable to allow keep air outside of the room from coming in (positive pressure) in, for example, patients at risk for nosocomial infections, or to prevent air inside the room from leaving (negative pressure) in, for example, patients with highly contagious airborne organisms (Figure 1-12).
- Transducer: A device for converting energy from one form to another, typically a pressure wave to an electronic signal in the ICU, where fluid waves are measured and displayed (Figure 1-13).
- Infusion pump: A device that controls the administration of medications or fluids (Figure 1-14).

Techniques

- Standard vital signs in an ICU
  - —Continuous electrocardiography using one or more leads, typically leads II and V_5 (lead II is preferred for arrhythmia analysis because it is best for showing the P wave, whereas V_5 is preferred to detect ischemia).
  - —Blood pressure using noninvasive or continuous intra-arterial measurement (Figure 1-15).
  - —Pulse oximetry in patients receiving supplemental oxygen.

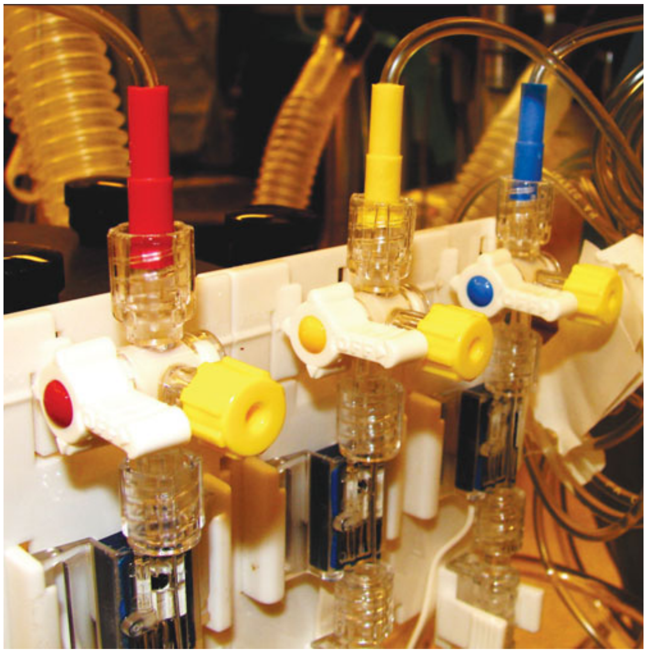

Figure 1-13. Electronic transducer which converts fluid pressures and waveforms into an electrical signal that is interpretable by bedside physiologic monitor.

Figure 1-14. Infusion pumps, used to control the rate of delivery of fluids or medications to a patient, and prevent infusion of air or debris.

—Respiratory rate using impedance pneumography.

—Temperature can be measured intermittently (Figure 1-16) or continuously through indwelling devices such as the pulmonary artery catheter or a thermistor-equipped urinary catheter.

Figure 1-15. Disposable blood pressure cuff for automated measurement.

Figure 1-16. Digital thermometer.

- Additional discretionary ICU monitoring
  - —Automatic, continuous arrhythmia detection may be indicated in certain patient populations at high risk for rhythm abnormalities (Figure 1-17).
  - —Fluid waveform and pressure are used to analyze intravascular and other intracompartmental pressure (ie, pulmonary artery, cerebrospinal fluid [CSF]) in patients undergoing advanced monitoring.

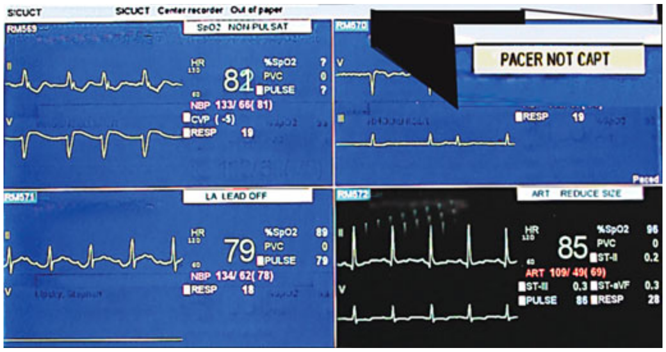

Figure 1-17. Central nursing unit monitor with automated rhythm detection.

—Tissue and blood oxygen saturation may be displayed continuously from a variety of sources including central vascular sites (ie, mixed venous oxygen saturation), brain (ie, cerebral oximetry).

—Intermittent or continuous cardiac output can be displayed on dedicated bedside devices or through a suitably interfaced physiologic monitoring system (Figure 1-18).

Figure 1-18. Physiologic monitor dedicated to the display of cardiac output and central vascular oxygen saturation—these data may also be sent directly to the main bedside physiologic monitor.

Figure 1-19. Bedside ventilator readout showing a variety of ventilator settings and patient measurements.

—A variety of respiratory parameters can be measured through a mechanical ventilator in a mechanically ventilated patient, including respiratory rate, tidal volume, minute ventilation, compliance, autopeep, and so on (Figure 1-19).

Suggested Reading

Guidelines/Practice Parameters Committee of the American College of Critical Care Medicine, Society of Critical Care Medicine. Guidelines for intensive care unit design. *Cri Care Med*. 1995;23:582–88.

CHAPTER 2

The ICU Bed

Introduction

Intensive care unit (ICU) patients can develop a variety of complications related to prolonged immobilization and recumbent positioning while in the ICU, and, increasingly, obese patients present a number of specific challenges. ICU beds have a common set of capabilities, and a variety of specialty ICU beds have been developed for specific patient populations (Figure 2-1) including patients at risk for decubitus ulcers, obese patients, patients with fractures. A standard ICU bed typically has electric and manual controls, side rails, wheels and a brake, a removable headboard to allow procedures (ie, endotracheal intubation, vascular access) from the head of the bed, and intravenous (IV) pole mounts.

Definitions and Terms

- Trendelenburg position: Bed position in which the head is lower than the feet—typically used to increase venous return to the heart in hypovolemic shock or to distend blood vessels superior to the heart during venous access procedures (Figure 2-2).
- Reverse Trendelenburg position: Used in the ICU to elevate the head above the heart to diminish venous return, or to decrease the likelihood of passive regurgitation of gastric contents in patient in whom leg flexion is contraindicated (ie, following femoral arterial cannulation).
- Elevated head of bed (also known as Fowler or semi-Fowler position): Standard nursing position in an ICU patient, where not otherwise contraindicated—used as one element of the "bundle" of interventions designed to reduce the incidence of ventilator associated pneumonia, by lowering the risk of passive aspiration of gastric contents (Figure 2-3).
- Decubitus ulcer: Skin ulceration caused by prolonged pressure on a vulnerable area (ie, sacrum, occiput), typically in a bed-ridden patient.
- Rotation therapy: An approach to the prevention of pulmonary complications and decubitus ulcers by continuously rotating the entire patient.
- Percussion therapy: An approach to the prevention of ICU complications by continuous bed vibration intended to facilitate the mobilization of pulmonary secretions.
- Pressure relief therapy: A variety of approaches to the redistribution of weight away from vulnerable pressure points—designed to prevent or treat decubitus ulcers (Figure 2-4).

Techniques

- A standard ICU bed is suitable for the care of most ICU patients and may be equipped with a pressure relief mattress designed to prevent the formation of decubitus ulcers.
- A bariatric bed is designed to accommodate and facilitate the care of the obese patient, having a larger surface area and greater hydraulic lifting power.
- A fall prevention bed can be lowered to the floor to limit the potential of injury in patients at risk for falls.
- Pressure relief beds may include automatic patient rotation, air/fluid mattress technology.
- A kinetic therapy bed allows the patient with adult respiratory distress syndrome (ARDS) and/or spinal cord injury to undergo continuous rotation and percussion to facilitate secretion mobilization and drainage without the need for manual mobilization of the patient.

Clinical Pearls and Pitfalls

- ICU specialty beds are expensive and specific indications should be developed for individual bed usage.
- The choice of specialty beds is usually made collaboratively between the physician and nursing members of the critical care time.
- Individual hospitals often have a resource person with specific expertise in specialty beds.
- The increasing number of obese patients in the healthcare system has led to the development of new technologies such as bed scales, specialty (ie, ceiling) lifts, and bariatric chairs for early mobilization of these patients.

Vac ats

- Negative Pressure Wound Therapy
- Chronic open wounds
- Diabetic ulcers
- Acute and traumatic wounds
- Flaps and grafts
- Surgical wounds
- Partial thickness burns, and pressure ulcers.

Contraindications:

- Malignancy in the wound
- Untreated osteomyelitis
- Nonenteric and unexplored fistula
- Necrotic tissue with eschar present

**Do not place VAC dressing over exposed blood vessels or organs.

- **Vac ATS Accessories** →

Item	Lawson #
Vac Canister	129259
1 Liter Canister	146636
Sml Dressing	129256
Med Dressing	129257
Lg Dressing	129258
X-Lg Dressing	129261
Ab Dressing	129262
White Foam	130109
T.R.A.C. Foam	130807
"Y" Connector	129260

Bariatric

- Built in scale
- Intellidrive power transport

Contraindications:

- Not for patient's with pressure ulcers
- Bariatric Patient's with pressure ulcers consult your Clinical Specialist
- **Weight limit: 500 lbs**

- Extra wide 42' bariatric Bed
- Built in scale
- IntelliDrive power transport
- Full Chair positioning
- Full Egress Position
- Retractable Foot

Contraindications:

- Not for patient's with pressure ulcers
- Bariatric Patient's with pressure ulcers consult your Clinical Specialist

- **Weight limit: 460 lbs**
- **Height limit: 7 feet**

- Expandable bariatric bed from 39", 48" or 54"
- Basic Mattress included

Accessories:

- Trapeze
- RS Bariatric

- **Weight limit: 1000 lbs**

Fall prevention

- Fall Prevention and risk mitigation
- Electric Hi-Lo bed
- Lock out functions
- Raised border mattress included
- **Can Order second floor mat through Sunrise**

- **Weight Limit: 500 lbs**

Kinetic therapy

- Kinetic Therapy for the critically ill, immobilized patient
- Specifically for spinal injuries or ARDS patients

Indications:

- Treatment and prevention of pulmonary complications
- Thoracic or lumbar fracture
- Cervical Traction
- Skeletal Traction

Contraindications:

- Patients that do not tolerate rotation.

- **Weight limit: 500lbs**

Pressure relief

- Pressure relief overlay
- Anti shear layer

Indications:

- Patients at high risk of pressure ulcers
- Management of Stage I, II, III and IV pressure ulcers

Contraindications:

- Unstable cervical, thoracic and/or lumbar fracture
- Cervical Traction

- **Weight limit: 350 Lbs**

- Use on Care 1000 Beds.
- An Aggressive Therapeutic mattress
- Alternating pressure therapy with low air-loss
- Maximum inflate mode for immediate firm surface
- 1 in 3 alternating variable time cycles

- **Weight Limit: 1000 lbs**

- Placed on Regular or HiLo Beds
- An Aggressive Therapeutic mattress
- Alternating pressure therapy with low air-loss
- Maximum inflate mode for immediate firm surface
- 1 in 3 alternating variable time cycles

- **Weight Limit: 350 lbs**

Adv pressure relief

- Air Fluidized Therapy Unit
- Provides combination of air fluidized therapy and low air loss therapy
- Prevention/treatment to Stage IV pressure ulcers.
- When mobility and HOB elevation is the goal of therapy
- Post op flap and graft surgery.

Contraindications:

- Unstable spinal cord injuries, long bone traction

- **Weight limit: 350 lbs**

Other

- Bariatric Mobile Chair Recliner
- Switches from full seat to supine position
- Side rails raise or lower for transfer or safety

- **Weight Limits: 850lbs**
- Must Provide Patient's Actual Weight
- Models:
- 400lbs - 24" seat width
- 600lbs - 27" seat width
- 850lbs - 31" seat width

- Patient Transfer Device
- Inflatable mattress with detachable air supply unit
- Transfer from bed to bed or bed to litter
- Can remain un-inflated under the patient
- Models: 34", 39", and 50" mattresses
- **Weight Limit: 900lbs**
- Must Provide Patient's Actual Weight

Bariatric Commodes

- Swing-away arms, easy transfers, 26" or 30" width
- Must Provide Patient's Actual Weight
- **Weight Limit: 1000lbs**

Bariatric Walker

- Swing-away arms, easy transfers, 26" or 30" width
- Must Provide Patient's Actual Weight
- **Weight Limit:1000lbs**

Shower Commode

- Used for Rehab Pts
- 26" or 30" weight, Padded
- Must Provide Patient's Actual Weight
- **Weight Limit: 1000lbs**

Figure 2-1. Chart of various specialty beds with applications, costs, and additional details. *Copyright Trustees of the University of Pennsylvania, with permission.*

Figure 2-2. ICU bed with pressure relief mattress and standard controls in Trendelenburg (head down) position.

Figure 2-3. ICU bed in Fowler position.

Figure 2-4. Specialty pressure relief air/fluid mattress, in which warmed air passes continuously through beads and the mattress surface, minimizing local skin pressure.

Suggested Reading

Gebhardt KS, Bliss MR, Winright PL, Thomas J. Pressure relieving supports in ICU. *J Wound Care*. 1996;5:116–121.

Ryan DW. The fluidized bed. *Intensive Care Med*. 1995;21:270–276.

The Universal Protocol in the ICU

Introduction

The universal protocol was designed to prevent wrong site, wrong procedure, and wrong person surgery and has evolved from collaboration among accreditation organizations and professional societies. It was introduced as a standard in 2004.

Definitions and Terms

The protocol is a three-step process including (1) preprocedure identification and verification, (2) site marking, and (3) performance of a "time-out" prior to initiation of the procedure. A mnemonic is "Correct Person, Correct Procedure, and Correct Site."

Techniques

- Indications in the ICU
  —Surgical/invasive procedures falling within the scope of universal protocol guidelines include, but are not limited to, cardioversions, cardiac and vascular catheterizations (ie, pulmonary artery catheter placement and vasculare cannulation), transesophageal echocardiography, endoscopies, thoracentesis, chest tube insertions, paracentesis, lumbar puncture, incisions and drainage of wounds, and so on.
- Preprocedure patient identification elements
  —Patient name and date of birth
  —Medical record number
  —Verbal identification with patient and/or family member
- Preprocedure verification (Figure 3-1)
  —Procedure confirmation with patient or family/designee
  —Consent obtained for procedure
  —Relevant documentation performed
  —Indications for procedure
- Site marking (Figure 3-2)
  —Marking of the site is required for procedures involving left/right distinction, multiple structures (ie, fingers and toes) or multiple levels (ie, spinal levels).
  —Site marking is not required for interventional procedures for which the site is not predetermined, such as arterial line placement, or when procedure is performed under urgent or emergency conditions.

Universal Protocol

Patient identification (need 2):	Procedure verification:	Site marked (operative site):	Time-out with all members of procedure team immediately prior to procedure:
☐ Name/DOB	☐ Procedure confirmed with patient or family/designee	☐ Yes	☐ Correct patient identified
☐ Verbal with patient and/or family	☐ Consent for procedure signed	☐ N/A	☐ Agreement on procedure
☐ Other (MRN)-Use when there are 2 patients with same name and DOB	☐ Relevant documentation completed, reviewed and signed		☐ Correct side and site ☐ N/A
	☐ Clinical indications for procedure		☐ Correct patient position
			☐ Availability of correct implant/equip. ☐ N/A
Completed by: Name (Print) ______	Signature ______	Date ______	Time ______

Figure 3-1. A sample universal protocol checklist.

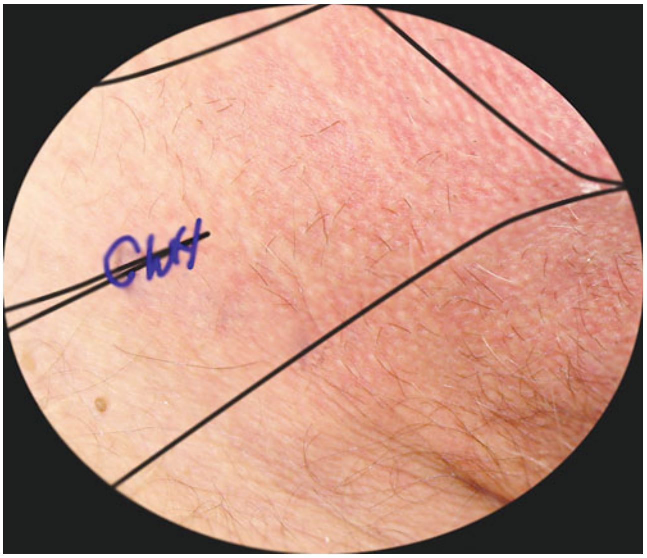

Figure 3-2. Example of site marking with operator's initials at the site of left internal jugular, as viewed from the left side of patient's neck.

—Marking should be unambiguous (ie, use initials of operator or YES).

—Marking should be made with ink that remains visible after skin preprocedure.

—Marking should remain visible after draping.

- Time-out elements checked with all members of procedure team immediately prior to performance of procedure
  —Verify correct patient identified
  —Ensure agreement on planned procedure
  —Verify correct side and site
  —Verify correct patient position for procedure
  —Ensure availability of all required equipment

Clinical Pearls and Pitfalls

- Marking a site with an X is ambiguous—this could be interpreted as "this *is* the site" or "this is *not* the site."
- Certain sites (ie, teeth) need not be marked directly, but radiographs should be marked correctly.
- Single organ sites need not necessarily be marked (ie, cardiac surgery, caesarian section).

Suggested Reading

The Joint Commission. Universal protocol. http://www.jointcommission.org/PatientSafety/UniversalProtocol. (Accessed on May 11, 2008.)

CHAPTER 4

Hand Washing in the ICU

Introduction

Hand washing has been shown to reduce nosocomial infection dating back to Semmelweis' historic research on obstetric infections in the 1800s. Hand washing is now the focus of recommendations and requirements from the Centers for Disease Control and the Joint Commission for Accreditation of Healthcare Organizations. It is also widely felt to be the best measure to prevent the emergence and transmission of drug-resistant nosocomial infections, such as Methicillin Resistant Staphylococcus Aureus (MRSA).

Definitions and Terms

- Plain (detergent) soaps: Used for cleansing but lack intrinsic antimicrobial properties.
- Antimicrobial soaps Detergent plus an antimicrobial such as alcohol, chlorhexidine, or povidone-iodine.
- Alcohol-based hand rub: Contain ethanol or isopropanol and denature proteins when used in water-containing solutions; rapidly active against bacteria, mycobacteria, fungi, and viruses; typically combined with moisturizer to prevent hand chapping.
- Chlorhexidine and iodophors: Alternative antiseptic agents with intermediate speed of action and variable activity against infectious agents, chlorhexidine has good persistence (*see below*).
- Visibly soiled hands: Show visible dirt or proteinaceous material, blood, or body fluids.
- Persistent (antimicrobial) activity: The property of certain hand-cleansing agents having extended antimicrobial action.

Techniques

- Visibly soiled hands: Wash with soap and water.
- Before eating or after using the restroom: Wash with soap and water.
- Not visibly soiled hands: Use an alcohol-based hand rub under the following circumstances:
  - —Before direct patient contact
  - —Before donning sterile gloves for a procedure
  - —Before insertion of urinary catheters, intravascular devices, or other invasive devices
  - —After contact with a patient's skin
  - —After contact with bodily fluids, excretions, or dressings
  - —After contact with inanimate objects in the immediate vicinity of a patient (ie, ventilator, bed rail)
  - —After removing gloves
- Remove visible debris from beneath fingernails.
- Routine hand washing: Wet hands with water, apply recommended amount of soap, and rub hands together vigorously for at least 15 seconds covering all surfaces of hands and fingers. Dry with disposable paper towel and turn water off with towel.
- Decontamination with alcohol-based hand rub: Apply product to palm of one hand and rub hands together covering all surfaces of hands and fingers until hands are dry (Figure 4-1).
- Additional recommendations for healthcare workers
  - —Remove rings, watches, and bracelets before hand scrub.
  - —Do not wear artificial fingernails.
  - —Keep natural fingernail length less than $^1/_4$ in long.
  - —Wear gloves when in contact with blood or other infectious agents.
  - —Remove gloves after patient care.