ANESTHESIA REVIEW

Blasting the Boards

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This book is dedicated to all of the trainees that demand the best teaching, challenge us to be paramount in our field, and continue to provide excellent care to all of the patients.

Preface

As each of us approached board certification and recertification exams in anesthesiology, we realized the need for a resource that was evidence-based, succinct, and composed of high-yield examination topics. This book is the compilation of hundreds of pages of handwritten notes from us (the three authors) that we took while we were studying for (and passed) our board exams. The content reflects topics that we thought were important, covered inadequately in other resources, or appeared in prior board certification exams.

Over the course of one year, we compiled, sorted, and fact-checked our notes into this book. We then added the most commonly encountered anesthesiology keywords (which are in bold face for easy recognition) to ensure that we covered the exams for certification and recertification to the fullest extent.

Our goal was to create a resource that was comprehensive, yet quick to read, and, most importantly, would enable you to understand and remember the information, with its bullet-point style. Furthermore, "In-training" scores are used for securing competitive fellowship positions. While there are a number of question and review books on the market, there are few that combine core content and questions in an easy-to-use format. The questions were designed to reinforce key concepts and simulate actual test questions. Blasting the Boards is intended to fill that unmet need and help you to succeed in "blasting" your board exam.

We hope this book can improve your knowledge base in anesthesiology, prepare you for examinations, and serve as a reference in the future.

SMB
EAB
KHZ

Acknowledgment

We would like to thank Dr. Archit Sharma for his brilliant editing skills.

Contents

CHAPTER 1 Equipment

ANESTHETIC BREATHING CIRCUITS

- Definition: an anesthetic breathing circuit must deliver gas and eliminate carbon dioxide (CO_2)
  - Circuits vary in components and organization
  - Rebreathing can be used to assess circuit efficiency by affecting the amount of fresh gas required and the amount of waste produced
- Circuit classification
  - On the basis of the rebreathing of CO_2, circuits can further be classified as
    - Open: no rebreathing
    - Semi-open: partial rebreathing
    - Closed: complete rebreathing
  - **Rebreathing** is dependent on
    - Circuit design
    - Fresh gas flow
    - Mode of ventilation
    - Mechanics of respiration including tidal volume, respiratory rate, inspiratory-to-expiratory ratio, and inspiratory flow rate
- **Mapleson breathing circuits** (Fig. 1.1)
  - Semi-open breathing circuits that are composed of a facemask, pop-off valve, reservoir tubing, fresh gas inflow tubing, and a reservoir bag
  - Designated by the letters A through F based on circuits construction
    - Mapleson A
      - Fresh gas flow (FGF) is opposite from the patient while the pop-off valve is adjacent to the patient
      - Best at eliminating CO_2 → most efficient for spontaneous breathing
        - FGF equal to minute ventilation prevents rebreathing during spontaneous breathing
        - FGF may need to be as high as 20 L/min to prevent rebreathing during

controlled ventilation

- Expiratory valve must be tightened to assist ventilation → least efficient for controlled ventilation

- Mapleson B and C
    - Both the FGF and pop-off valve are adjacent to the patient
- Mapleson D, E, and F
    - Fresh gas flow is adjacent to the patient while the pop-off valve is opposite the patient
    - Mapleson D is the most efficient for controlled ventilation, but least efficient for spontaneous ventilation

- Bain circuit
    - Modification of a Mapleson D where FGF enters through a narrow tube within the corrugated expiratory limb of the circuit

- **Circle breathing system** (**Fig. 1.2**)
    - A closed breathing circuit composed of an FGF inlet, reservoir bag, pop-off valve, two unidirectional valves, tubing, and a CO_2 absorber
        - FGF should enter proximal to the inspiratory unidirectional valve
        - The pop-off valve should be distal to the expiratory unidirectional valve

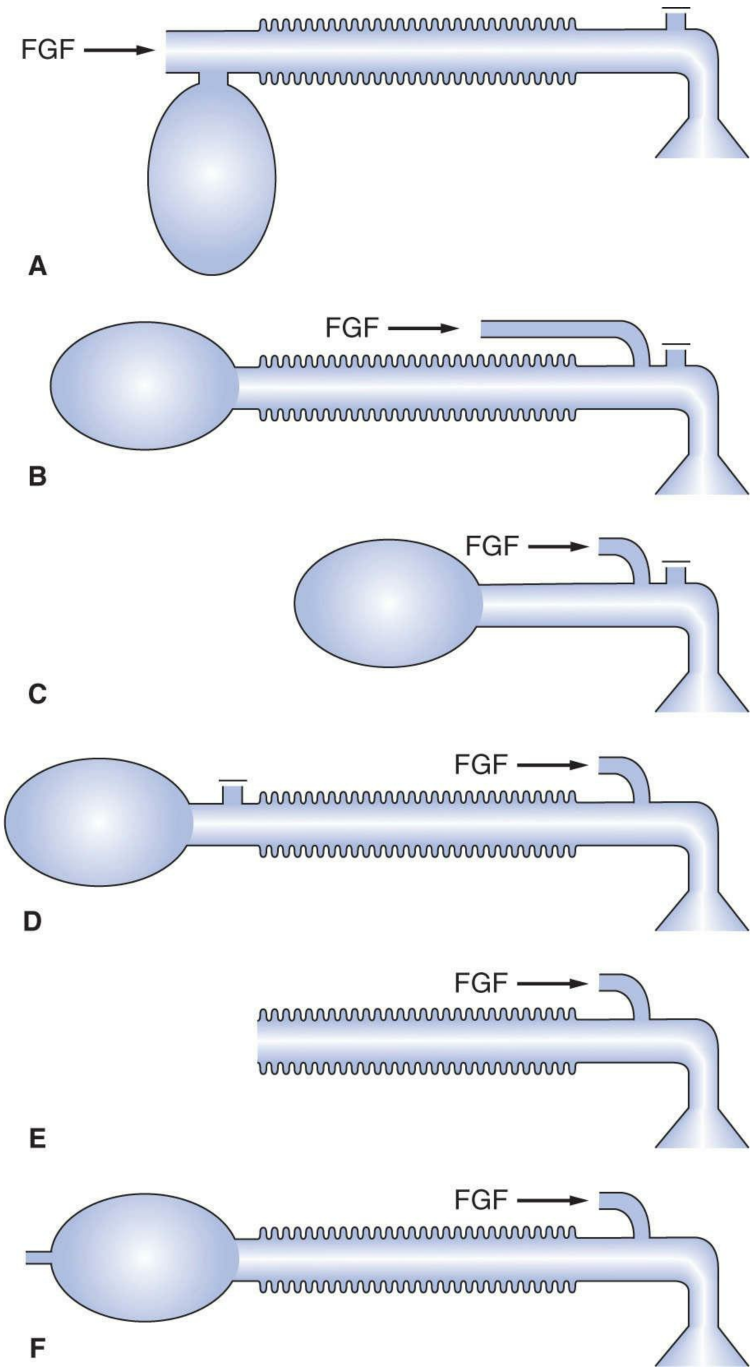


FIGURE 1.1 Mapleson Circuits. Mapleson circuits are semi-open circuits that vary by design. The Mapleson A circuit is the most efficient for spontaneous breathing and the Mapleson D circuit is the most efficient for controlled breathing. FGF, Fresh gas flow. (Reproduced from Riutort KT, Eisenkraft JB. The anesthesia workstation and delivery systems for inhaled anesthetics. In: Barash PG, Cullen BF, Stoelting RK, et al., eds. Clinical Anesthesia. 7th ed. Philadelphia, PA: Wolters Kluwer Health; 2013:663.)

- Benefits of a closed system
  - Reduced use of FGF
  - Decreased anesthetic pollution
  - Decreased heat loss
  - Humidification of gases
- **Bag valve mask**
  - Self-inflating bag often used in emergency settings to provide positive pressure ventilation
  - Composed of an FGF inlet, a reservoir bag, inflatable bag, and facemask
  - Function
    - Squeezing of the bag forces gas through a one-way valve to the patient
    - Release of the bag draws ambient air or gas from a wall source

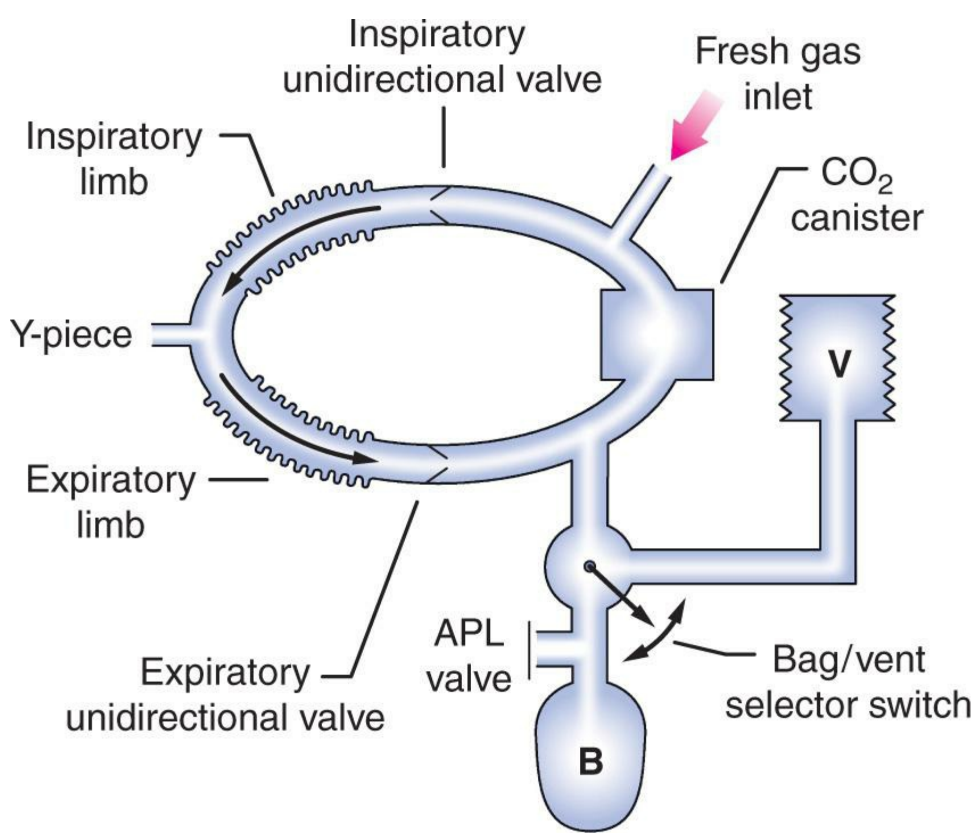


FIGURE 1.2 Circle Breathing System. A circle breathing system differs from open circuits through carbon dioxide removal. (Reproduced from Riutort KT, Eisenkraft JB. The anesthesia workstation and delivery systems for inhaled anesthetics. In: Barash PG, Cullen BF, Stoelting RK, et al., eds. Clinical Anesthesia. 7th ed. Philadelphia, PA: Wolters Kluwer Health; 2013:649.)

- Used primarily for resuscitation
    - Cannot be connected to anesthetic vaporizers
    - Self-inflating property distinguishes a bag valve mask from a Mapleson circuit

ANESTHESIA MACHINE

- Basic components for fresh gas delivery
  - **Inspiratory and expiratory limbs**
    - Each limb contains a one-way valve to control gas flow
    - Each limb is connected to a Y-piece adjacent to the patient
      - **Dead space ventilation** occurs distal to the Y-piece
      - Dead space includes bronchial tree, endotracheal tube or airway device, and tubing distal to the Y-piece
  - Access to oxygen, air, and nitrous oxide via **gas cylinders** or a **pipeline source** (**Fig. 1.3**)
    - Gas E-cylinders are attached to the anesthesia machine via a Pin Index Safety System
    - Pipeline source are attached to the anesthesia machine via Diameter Index Safety System
  - **Pressure regulators** and pressure-reduction valves
    - Pressures of up to 2,200 pounds per square inch (PSI) must be decreased prior to reaching the patient
    - Oxygen
      - First stage regulators reduce oxygen pressure to 45 PSI
      - Second stage regulators reduce pressure to about 14 to 16 PSI
      - Oxygen flush exists between the 1st and 2nd stage regulator
        - Does not require anesthesia machine to be turned on
        - Capable of flow rates up to 75 L/min
    - Nitrous
      - Nitrous pressure regulator reduces pressure of up to 745 to 45 PSI
  - **Pressure relief valves**
    - Ventilator pressure relief valve
      - During positive pressure ventilation, removes gas at a pressure greater than the setting of the relief valve to the scavenging system

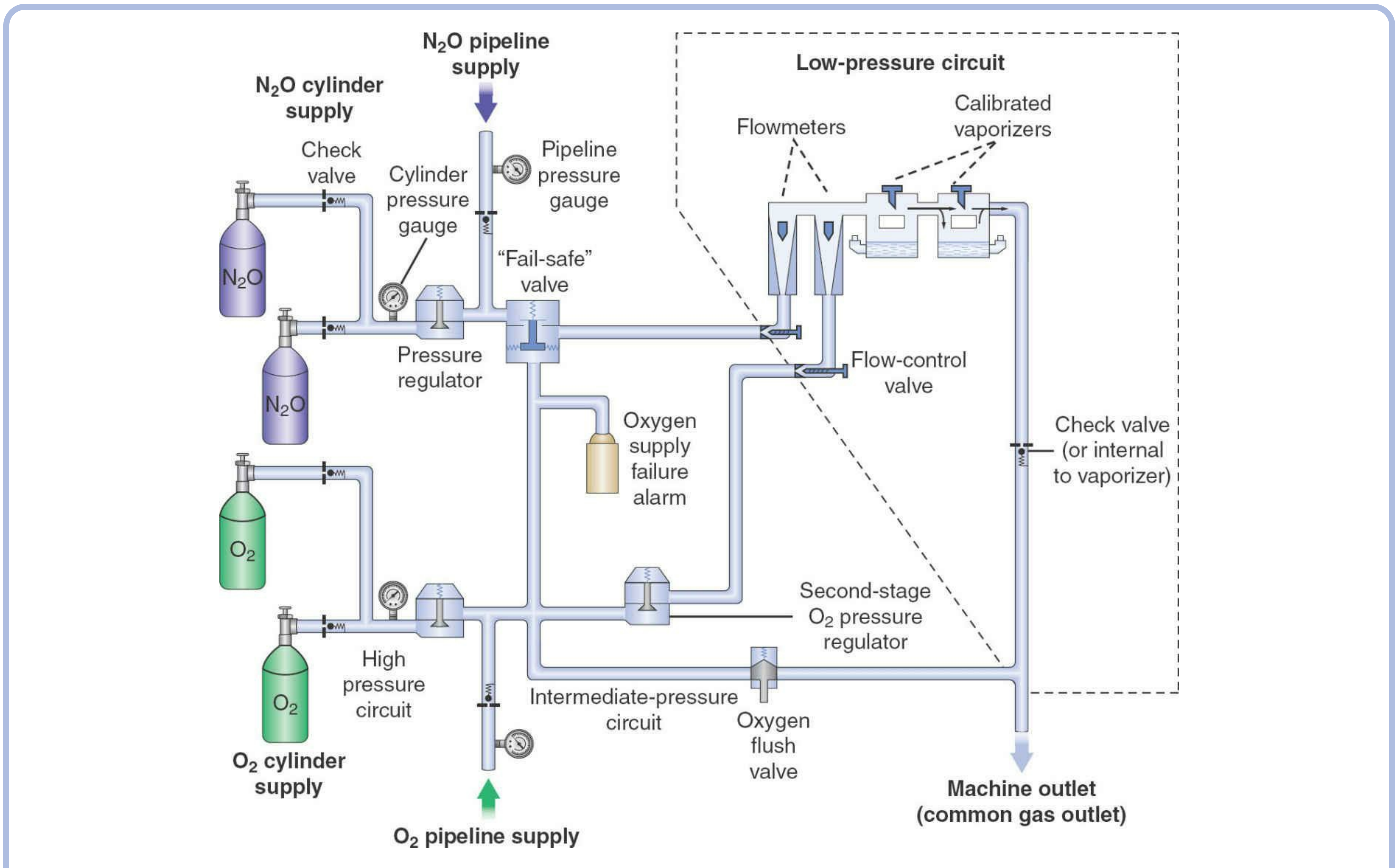


FIGURE 1.3 Anesthesia Machine Pipeline. Circuitry of wall gases connections to an anesthesia machine. (Reproduced from Riutort KT, Eisenkraft JB. The anesthesia workstation and delivery systems for inhaled anesthetics. In: Barash PG, Cullen BF, Stoelting RK, et al., eds. Clinical Anesthesia. 7th ed. Philadelphia, PA: Wolters Kluwer Health; 2013:647.)

- **Adjustable pressure limiting valve**
  - During spontaneous ventilation, removes gas at a pressure greater than the pressure setting
- **Gas analyzers**
  - Two types of oxygen analyzers
    - Clark electrode
      - Increased oxygen tension generates increased current across two electrodes in a gel
      - Clark electrodes require calibration and eventual replacement when electrodes are consumed
    - Paramagnetic device
      - Increased oxygen tension generates increased magnetic attraction
      - Paramagnetic devices have a faster response time, are self-calibrating,

and have no consumable parts

- **Flow meters**
  - Measures gas flow to the common gas outlet
    - Upward force provided through gas flow
    - Downward force provided by gravity
  - Oxygen flowmeter is downstream of other flow meters to prevent a hypoxic mixture from reaching the patient
- Power source and bellows
  - Ventilators can be powered by electricity or compressed gas
    - Piston ventilators are driven by an electric motor
    - Pneumatic ventilators are driven by compressed gas
  - Bellows
    - Descending bellows (descend during expiration)
      - During inspiration, driving gas pressurizes the bellows → bellows rise and delivers gas to patient
    - Ascending bellows (ascend during expiration)
      - During exhalation, depressurization of the bellows allows exhaled gas to fill the bellows
      - Considered safer because during a disconnect, the ascending bellows will fail to fill
  - Tidal volume measurements
    - Some older mechanical ventilators will deliver additional tidal volume based on FGF
      - (FGF × percentage of inspiratory time)/respiratory rate = additional volume delivered per breath
    - Compression volume
      - Compression volume is the volume absorbed by the circuit
      - Compression volume = (respiratory rate × set tidal volume) − minute ventilation
- **Reservoir bag**
  - Used to collect gases and squeezed to assist ventilation
  - Bag size should be selected based on the expected tidal volume of the patient

CO^2 elimination

- Absorber collects exhaled CO_2 through soda lime or Baralyme
  - Soda lime: 75% $Ca(OH)_2$, 3% NaOH, 1% KOH, 20% H_2O
  - Baralyme: 80% $Ca(OH)_2$ + $Ba(OH)_2$
- Exhausted soda changes color from white to purple, which can revert to white with time

- Absorbent can create **carbon monoxide (CO)**
  - Factors associated with CO production
    - Degree of absorbent dryness
      - Absorbents not used for several days (over the weekend) commonly implicated in CO case reports
      - Low FGF rates can dry absorbent
    - High concentrations of volatile
    - Higher temperatures
    - Volatile used (desflurane > enflurane > isoflurane > halothane and sevoflurane)
    - Use of Baralyme over soda lime
- Absorbent can create **compound A**
  - Sevoflurane + CO_2 absorbents → vinyl ether (compound A)
    - Nephrotoxic to rats at high concentrations
    - Implications on humans is less clear
  - Gas flows at >2 L/min prevents rebreathing of compound A, but not its formation
  - Factors increasing compound A
    - Low FGF
    - High absorbent temperatures
    - Fresh absorbent
    - Higher concentrates of sevoflurane
    - Use of Baralyme over soda lime
      - Dehydration of Baralyme increases compound A
      - Dehydration of soda lime decreases compound A

Heat and moisture exchangers

- Used in ventilators to prevent drying of the respiratory tract
  - Minimal clinical effect because only 10% of heat loss is through respiratory tract
- Heat and moisture exchangers are hydrophobic or hygroscopic
  - Hydrophobic
    - Better at filtering infectious agents
    - Long-term use associated with tube occlusion due to inadequate humidity to break secretions
  - Hygroscopic
    - Better at providing humidity
    - Increases circuit resistance

VAPORIZERS AND GAS CYLINDERS

- Vaporizers
  - Volatile anesthetics exist in a liquid state
    - The amount of liquid vaporized is dependent on the saturated vapor pressure of the volatile and the temperature
  - Contemporary vaporizers are variable-bypass (**Fig. 1.4**)
    - Gas enters through a common inlet
    - Concentration control dial alters the ratio of flow between the bypass chamber and vaporizing chamber
    - Gas from both chambers merge at a common outlet
  - Factors affecting vaporizer output
    - Flow rate
    - Gas concentration
    - Temperature
  - Altitude
    - Higher altitude → greater vaporizer output
    - Vapors are at constant potency at constant temperature irrespective of altitude
      - Except desflurane, which has decreased anesthetic potency with increased altitude because of its partial pressure
  - Problems that may occur with vaporizers
    - Vaporizer tipped
      - Anesthetic liquid in vaporizing chamber may enter the bypass chamber and increase the concentration of delivered anesthetic gas
        - The transport dial prevents this bypass
      - If tipped, the vaporizer should be flushed at high flows with the vaporizer set to low concentrations for 30 minutes
    - Wrong volatile is filled into the vaporizer
      - If a volatile of higher saturated vapor pressure is used → higher concentration of gas administered to patient

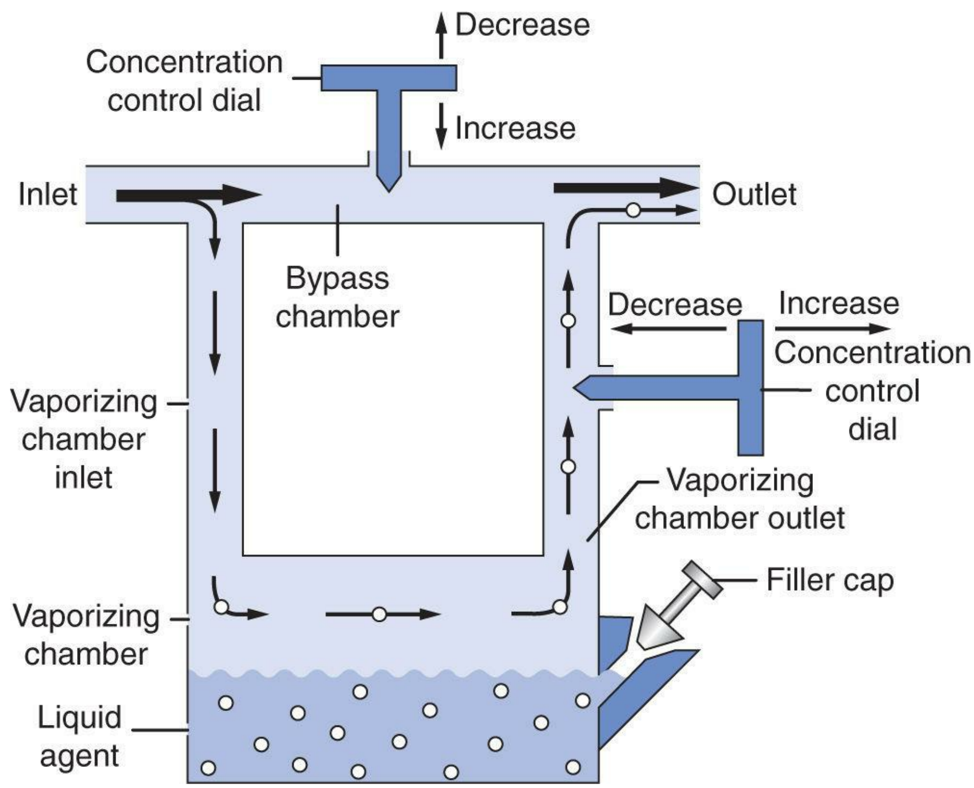


FIGURE 1.4 Variable-Bypass Vaporizer. A variable bypass vaporizer splits fresh gas flow between the mixing and bypass chamber to deliver a specific volatile gas concentration. (Reproduced from Riutort KT, Eisenkraft JB. The anesthesia workstation and delivery systems for inhaled anesthetics. In: Barash PG, Cullen BF, Stoelting RK, et al., eds. Clinical Anesthesia. 7th ed. Philadelphia, PA: Wolters Kluwer Health; 2013:663.)

    - If a volatile of lower saturated pressure vapor is used → lower concentration of gas administered to patient
- Overfilling vaporizer
    - Volatile liquid can enter the bypass chamber → an elevated concentration of gas is delivered to the patient
    - Side-fill design of modern vaporizers minimizes the likelihood of overfilling
- Pumping effect and back pressure
    - Pumping effect
        - Intermittent back pressure from circuit prevents outflow of gases from vaporizing chamber and bypass
        - More anesthetic is vaporized
    - Back pressure effect

        - Back pressure may decrease concentration of gas
        - Compresses the carrier gas, but the anesthetic agent in chamber is unchanged because the amount of agent vaporized depends on saturated vapor pressure of the drug and not the drug in the chamber
- **Anesthetic gas vapor pressures**
    - Methoxyflurane: 23 mm Hg
    - Sevoflurane: 160 mm Hg
    - Enflurane: 172 mm Hg
    - Isoflurane: 240 mm Hg
    - Halothane: 243 mm Hg
    - Desflurane: 669 mm Hg
- **Calculating anesthetic gas output**
    - Vapor output (mL) = (carrier gas flow × saturated vapor pressure of gas)/(barometric pressure − saturated vapor pressure of gas)
        - At low flow rates (<250 cc/min), insufficient pressure to advance molecules of volatile upward
        - At high flow rates (>15 L/min), insufficient mixing in vaporizing chamber
    - Volatile uptake
        - Amount of uptake in the first minute is equal to the amount taken up between the squares of any two consecutive minutes
        - Example: between the 16th and 25th minute, the amount taken up is equal to the 1st minute
- Gas cylinders
    - **Oxygen**
        - Green canister
        - Compressed gas cylinder holds 625 L at 2,000 PSI
    - Air
        - Yellow canister
        - Compressed gas cylinder holds 625 L at 2,000 PSI
    - **Nitrous oxide**
        - Blue canister
        - Compressed gas cylinder holds 1,590 L at 750 PSI
            - When pressure drops from 750 PSI, only 400 L of nitrous oxide remain
    - Helium
        - Brown canister
        - Helium has a lower density than nitrogen and oxygen, so it can decrease the density of a gas mixture by as much as a 3×
            - In laminar flow, gas flow is dependent on viscosity

        - In turbulent flow, gas flow is dependent on density
        - Reynolds number = 2 × radius × velocity × density/viscosity
            - Reynolds <2,000 = laminar flow
            - Reynolds >4,000 = turbulent flow
            - Reynolds between 2,000 and 4,000 = both flows
    - Helium–oxygen combination (heliox) can be used to decrease the work of breathing and improve gas flow through a stenotic lesion
- Carbon dioxide
    - Gray canister
- Nitrogen
    - Black canister

ANESTHESIA MACHINE SAFETY DEVICES

- **Fail-safe device**
    - Shuts off nitrous oxide if there is a loss of oxygen supply pressure
    - Does not allow oxygen concentration to fall below 19%
        - Fail-safe device checks only pressure and not flow
        - A hypoxic mixture can still be delivered if low flows are used
- Positive pressure and negative pressure relief valves
    - Exist in the scavenging system to prevent positive or negative pressure from being transmitted to the breathing circuit
    - The positive pressure valve opens if positive pressure accumulates in the scavenging system
    - The negative pressure valve opens and entrains room air if a vacuum develops in the scavenging system
- Common gas outlet check valve
    - Prevents expired gas from transmitting back to the vaporizers or flowmeters
- Interlock device
    - Prevents two vaporizers from working simultaneously
    - Two volatiles being administered together is referred to as an azeotrope

ANESTHETIC GAS POLLUTION

- **Anesthetic pollution**
    - Volatiles are allowed at 0.5 parts per million
    - Nitrous is allowed at 25 parts per million

        - Dental facilities permit up to 50 parts per million
- Anesthesia machine sterilization
    - Methods for anesthesia machines to kill bacteria
        - Shifts in humidity
        - Shifts in temperature
        - High oxygen concentration
        - Metallic ions in machine
    - Bacterial filter on breathing circuit is not effective at preventing cross-infection
- **Environmental risk**
    - Historical reports suggested that anesthesiologists and those working in the operating room had increased risks of liver disease, memory deficits, and miscarriages
        - Reports were done before effective scavenging systems
        - Studies were poor qualities (retrospective surveys)
    - Recent investigations into historical reports suggest that the fears are exaggerated and largely unfounded

ULTRASOUND

- Ultrasound imaging utilizes a sound wave at a frequency greater than the upper limit of human hearing
    - Ultrasound frequencies are >20 kHz
    - Ultrasound imaging is done at 2.5 to 10 MHz
- Frequency and image quality (**Fig. 1.5**)
    - Relationships
        - Wavelength and frequency are inversely related
            - Increased frequency → lower wavelength
        - Resolution is 2× wavelength
            - Lower resolution → improved image quality

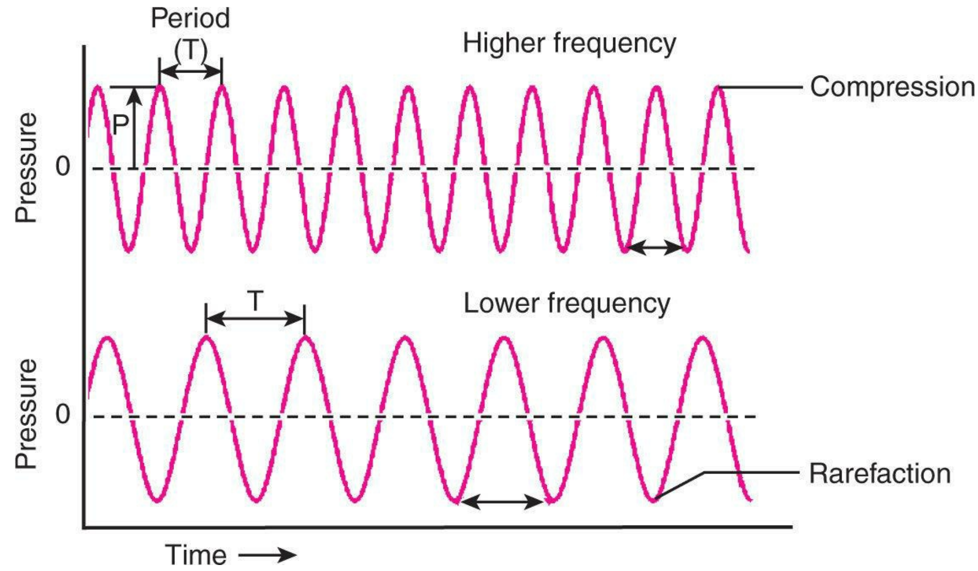


FIGURE 1.5 Ultrasound Physics.

- Penetration is 200× to 400× wavelength
  - Increased frequency → lower penetration, improved resolution
- Image acquisition
  - A sound wave is emitted from a piezoelectric transducer and received after bouncing off an object
    - Time and strength of sound wave return determines image formation
  - Water based–gel improves coupling between transducer and patient
    - Air–tissue interface loses 99% of ultrasound beam
    - Gel has similar acoustic impedance between transducer and the patient
  - Speed of propagation
    - Fastest in bone, slowest in air (denser = faster)
    - Very rapid
      - 1,540 m/sec in soft tissue
- Application
  - Ultrasound is used for vascular access, regional anesthesia, echocardiography, and focused assessment with sonography for trauma (FAST) exams
  - Probe selection
    - Linear
      - Used in **line placement** and regional anesthesia
    - Phased array (cardiac)
      - Used for transthoracic echocardiography
    - Curvilinear (abdominal)

        - Used for abdominal and obstetric exams
    - Transesophageal (matrix array)
        - Used for transesophageal echocardiography
- **Doppler**
    - Uses the Doppler effect to assess blood flow
        - Doppler effect: a wave changes in frequency based on whether the wave is moving away or toward a focal point
    - Color interpretation during ultrasonography (BART = Blue Away, Red Toward)
        - Red color = flow toward the probe
        - Blue color = flow away from the probe
- **Transthoracic echocardiogram**
    - Parasternal long-axis views
        - Offers views of the left atrium, mitral valve, left ventricle, right ventricular outflow tract, aortic valve, and descending aorta
    - Parasternal short-axis views
        - Offers five cross-sectional levels that include the pulmonary artery, aortic valve, mitral valve, mid-papillary, and apex
    - Apical views
        - Offers a four- or five-chamber view of the heart
    - Subcostal views
        - Provides a four-chamber view of the heart as well as clear views of the pericardium and inferior vena cava
- **Transesophageal echocardiogram**
    - Mid-esophageal views
        - The mid-esophagus offers numerous views through the left atrium including the four-chamber view, two-chamber view (left atrium and left ventricle), bicaval view, and views of the left ventricular outflow tract and aortic valve
        - The four-chamber view displays the anterolateral (supplied by the left anterior descending and circumflex) and inferoseptal (supplied by the left anterior descending and right coronary artery) walls
        - The two-chamber view displays the anterior (supplied by the left anterior descending) and inferior (supplied by the right coronary artery) walls
    - Transgastric views
        - The transgastric and deep transgastric views transmit through the stomach to offer important information about left and right ventricular function as well as valvular function

      - Offers views of all three major coronary arteries
    - High esophageal views
      - Offers views of the great vessels, coronary vessels, and aorta
  - **Transesophageal echocardiogram contraindications**
    - Patient refusal
    - Esophageal obstruction or tracheoesophageal fistula
    - History of an esophagectomy
    - Perforated viscus
    - Active gastrointestinal bleed
    - Coagulopathy and varices are relative contraindications

ELECTRICITY

- Pacemakers
  - Types
    - **Transcutaneous**
      - Two pacing pads and ECG leads are placed on the chest or back
      - Used for temporary stabilization of hemodynamically unstable bradycardias before a more permanent modality is established
    - **Transvenous**
      - Pacing wires are placed into the right atrium or ventricle through an introducer in a central vein
    - **Epicardial**
      - Pacing wires are placed during open heart surgery in the epicardium
    - **Permanent**
      - Pacing wires are placed in the right atrium and/or right ventricle and an electronic pacemaker is implanted under the skin
      - Electrodes require an implantation time of up to 4 weeks to avoid dislodgement
  - **Nomenclature**
    - First letter: chamber paced
    - Second letter: chamber sensed
    - Third letter: response to sensing
    - Fourth letter: programmability
      - Example: rate modulation
        - An increase in vibration, motion, or minute ventilation is sensed → pacing rate increases
    - Fifth letter: multistate pacing

- **Interrogation**
  - Recommended 30 days prior to surgery
  - Routine follow-up recommended every 3 to 4 months
- **Preoperative considerations**
  - Determine pacer type
  - Determine setup (e.g., DDD, VOO)
  - Determine what happens when a magnet is applied
  - Discontinue rate modulation, if applicable
  - Consider programming to an asynchronous mode
- **Intraoperative considerations**
  - Disable artifact filter on monitor
  - Avoid **R on T phenomenon**
    - R on T occurs if a pacemaker paces during the heart's refractory period
- Risk exists if the native HR exceeds the programmed rate in an asynchronous mode → the native sinus node and the pacemaker will both fire
  - If the native rate is faster than the pacemaker, consider administering β-blockade to allow the pacemaker to lead
  - Encourage the use of bipolar, not monopolar, cautery
    - Bipolar transmits across only the distance between the two leads
    - Monopolar transmits to the grounding pad and can go a longer direction
    - Use short bursts of cautery at low settings
  - Consider whether magnet should be used
- **Postoperative considerations**
  - Re-interrogate pacemaker
  - Reprogram if needed

- Defibrillators
  - Function
    - Treatment for life-threatening dysrhythmias such as ventricular fibrillation and tachycardia
      - Depolarizes heart muscle and allows normal sinus rhythm to take over pacing function
    - Can be monophasic or biphasic
      - Monophasic delivers current in one direction
      - Biphasic delivers current in two directions and allows a measure of impedance
        - Higher efficacy at terminating ventricular fibrillation
        - Less postresuscitation myocardial dysfunction
        - Fewer skin burns

- Types
  - **External**
    - Deliver a shock through paddles or pads placed on a patient's chest
    - **Paddle placement**
      - One below the right clavicle in the midclavicular line
      - One over the left lower ribs in the mid/anterior axillary line
    - **Energy**
      - Biphasic 200 J or monophasic 360 J should be used
    - Automated external defibrillators (AEDs) utilize a computer to read the patient's heart rhythm to determine if a shock is warranted
      - Delay for AED to read the heart rhythm can delay chest compressions and defibrillation
      - If trained health-care providers are available, the monitor should be read by the providers to expedite decision making
  - **Internal**
    - An internal cardiac defibrillator monitors a patient's heart rhythm and shocks during life-threatening dysrhythmias
      - Can remodel the left ventricle over time and increase cardiac output
    - Lead placement
      - One at right atrium, one at right ventricle, and one at the coronary sinus
    - Indications
      - Ejection fraction <35% or New York Heart Association class II or III
    - Nomenclature
      - First letter: chamber shocked
      - Second letter: chamber stimulated for overdrive packing
      - Third letter: chamber where rhythm is sensed
    - Magnet inhibits the cardioverter-defibrillator, but does not reprogram the pacer to an asynchronous mode
- **Cardioversion**
  - Used to convert an arrhythmia with a pulse into a sinus rhythm
  - Example: atrial fibrillation or ventricular tachycardia with a pulse

OPERATING ROOM ELECTRICITY AND FIRES

- Operating room electricity
  - A **transformer** connects the **grounded** hospital to ungrounded electricity in the operating room
  - Operating rooms use an isolation transformer to convert grounded power to an

ungrounded or isolated power system to avoid macroshocks

- **Line-isolation monitor**
  - Measures total amount of current leakage in an isolated power system by monitoring the integrity of the isolated power system
    - Intact equipment ground wires key to function
    - Detects 2 to 5 mA
      - Prevents macroshocks, not microshocks
      - Understanding shocks
        - 1 mA = perceived
        - 10 to 2 mA = muscle contractions
        - 100 mA to 4 A = ventricular fibrillation
    - Does not suggest current is actively leaking, but suggests the potential for leaking
  - If line isolation monitor alarm goes off → unplug unneeded equipment or the last piece of equipment plugged in
- Electrocautery
  - A metal probe is heated by an electric current
    - Used to stop bleeding or cut through tissue
  - Monopolar vs. bipolar
    - Monopolar: a small electrode contacts the tissue → current exits through grounding pad
    - Bipolar: circuit established between two tips of forceps → does not require a grounding pad
  - Grounding pads should have large surface area and be placed away from the heart
- **Lasers**
  - Frequently used in otolaryngology, urological, and gynecological surgery
  - Greatest safety concern with laser usage is corneal and retinal damage
    - Milliseconds of exposure can cause permanent damage
  - Types of lasers
    - KTP-Nd: YAG (potassium, titanyl, phosphate-neodymium: ytrium, aluminum, garnet)
      - Light passes through cornea without causing damage → absorbed by pigment tissue → burns retina
    - Ruby lasers
      - Higher frequency light penetrates corneas → risk to retina
    - CO_2 lasers
      - Highest wavelength in the infrared range
      - Energy absorbed at water and tissue → increases corneal damage risk

            - Any clear glass or plastic is opaque to CO_2 energy, making this protective
                - Contact lenses fail due to high moisture
                - Patients can have water/saline soaked gauzes or metal shields at eyes

- Operating room and airway fires
    - **National Fire Protection Association (NFPA)** governs and regulates operating room fire safety
    - **Triad for fire**
        - Ignition
        - Fuel
        - Oxidizer
    - Skin antiseptic solutions contain flammable isopropyl alcohol
        - Must be allowed to dry prior to surgical draping
    - Airway fires
        - Airway fires typically begin on the outside of tube, but it can have a devastating blowtorch effect if it reaches the inside of the tube
        - Immediate interventions in the event of an airway fire
            - Remove the endotracheal tube
            - Stop flow of all gases, especially oxygen
            - Remove burning material from the patient
            - Pour saline on airway
            - Mask ventilate with minimal inspired oxygen
            - Examine endotracheal tube for fragments
            - Perform a bronchoscopy to assess for debris, fragments, and degree of injury

RADIATION

- Radiation exposure
    - Radiation use is increasing in the medical field and in anesthetic locations
        - Locations and methods include interventional radiology, vascular operating rooms, cardiac catheterization suits, computerized tomography, and x-rays
    - Radiation exposure is permanent and cumulative
        - Radiation impart energy that can dislodge electrons and result in free radicals → adverse biological effects
- Radiation doses and safety
    - Maximum recommended annual accumulation is 50 mSv
    - Non–blood-forming agents, gonads, and lens should have maximum annual accumulation of 150 mSv

            - Cover eyes to prevent cataract formation
    - Total recommended dose of pregnancy should be <5 mSv
- Examples of radiation from typical medical equipment
    - Single x-ray
        - Chest x-ray: 0.1 mSv
        - Hip x-ray: 5 to 6 mSv
        - Fluoroscopy: 12 to 40 mSv/min
    - CT = 5 to 10 mSV
    - Interventional radiology or catheterization lab = 20 to 80 mSv
- Strategies to avoid radiation exposure
    - Minimize time near radiation source
    - Maintain distance from radiation source
        - Relationship of radiation and distance is the inverse of distance squared
            - Doubling distance → one-quarter of radiation
        - 1 m distance = 0.1% of patient's dose
        - 5 m distance = background radiation levels
    - Shielding
        - Lead aprons that contain 0.5-mm thick lead reduce 75% of radiation dose
        - Use barriers, such as a leaded glass, when possible
    - Be perpendicular to beam

MAGNETIC RESONANCE IMAGING (MRI)

- MRI mechanism
    - A magnetic field aligns nuclei in a patient
    - Radiofrequency pulses are emitted by the MRI machine and absorbed by the patient's cells
        - Different tissues emit a different response to radiofrequency
        - The various signals are compiled to form an image
- Equipment selection
    - All equipment used in an MRI suite must not interfere with the magnetic field
    - All equipment must function properly in the setting of a strong magnet
- Positioning
    - Careful attention must be made to avoid any metal objects being on, in, or near the patient
    - Prevent burns by avoiding loops in leads and cables
- Monitoring
    - ST-segment and T wave interpretation may not be possible during MRI

acquisition
        - If a patient is at high risk of a cardiac event, a 12-lead ECG before and after the MRI may be advisable
    - Temperature
        - Body temperature can increase from heat created by the radiofrequency pulses
        - Body temperature can decrease due to the cold temperature in the scanner
- Quench
    - Termination of magnet operation
        - Can be done intentionally for a life-threatening emergency
    - Magnet turns resistive and all stored energy is released
        - Coolant evaporates → oxygen supply in the room can drop rapidly if venting does not occur
    - Procedures
        - Remove patient from scanner immediately
        - Oxygen should be administered to the patient
        - Oxygen should be available for all personnel in the room

MEDICAL INFORMATICS

- Computer hardware and software
    - **Central processing unit**
        - Receives input from various sources, integrates information, and responds with output
        - Conduit for information transmission
    - **Operating system**
        - Coordinates activity between hardware and software programs
        - Sets up the framework for software to operate (e.g., Apple, Windows)
        - Responsible for management of storage, memory, and user interfacing
- **Anesthesia information management system (AIMS)**
    - Electronic version of the anesthesia record
        - Captures information from monitors and laboratory services
        - Integrates record into hospital system for documentation and billing
        - Largely replaced paper charting
            - Up to 40% of operating room time can be spent charting
    - Benefits
        - Increased accuracy of data from monitoring
        - Increased legibility
        - Allowing the anesthesiologist to focus more on patient care than documentation

    - Patients that require the most charting are usually also the most unstable
- Ability to program reminders such as antibiotic dosing and missing documentation
- Data can be collected for research and quality improvement

QUESTIONS

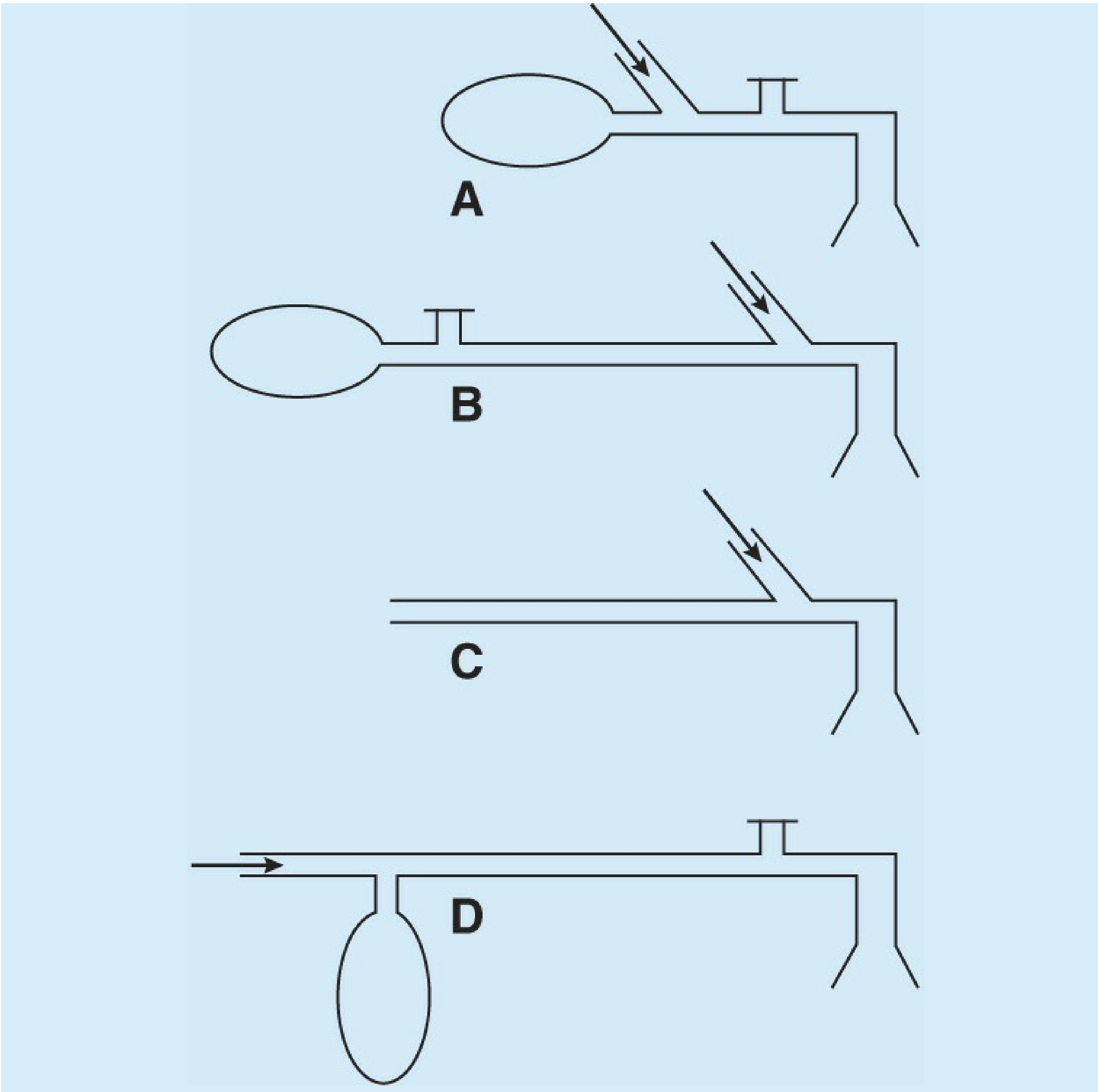
1. **W**hich of the following statements regarding the sensitivity setting of a temporary pacemaker is most correct?
   A. Increasing the sensitivity setting will reduce the occurrence of "R on T" phenomenon
   B. Increasing the sensitivity setting will result in an asynchronous pacing
   C. Decreasing the sensitivity setting will make the pacemaker more sensitive is to intracardiac signals
   D. Once the sensitivity threshold is determined, the sensitivity setting should be set 1–2 times higher

2. **D**uring an MRI scan for a patient, an unintentional shutdown of the magnet (quench) occurs. Which of the following statements regarding emergency management is most correct?
   A. Emergency personnel can safely enter the scanner
   B. Oxygen can safely be administered in the scanner
   C. The patient should be cared for in Zone IV if possible
   D. Ferromagnetic materials can safely enter the scanner

3. **T**he annual whole-body effective dose limit for an occupational worker is 50 mSv. The average effective dose of radiation from a CT scan is:
   A. 0.05–0.25 mSv
   B. 0.5–1 mSv
   C. 2–20 mSv
   D. 5–70 mSv

4. **W**hich of the following factors reduces the production of CO during the degradation of volatile anesthetics and CO_2 absorbers?
   A. Use of Baralyme instead of soda lime
   B. Increasing FGF
   C. Use of sevoflurane instead of desflurane
   D. Flushing the breathing circuit with fresh gas before use

5. **W**hich of the following circuits is most efficient for spontaneous respiration?


A
B
C
D