Anesthesia for Plastic and Reconstructive Surgery

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We respectfully dedicate this book to noted anesthesiologist

E.A. Rovenstine

and to

John M. Converse

who pioneered and set important foundations in the field of plastic reconstructive surgery

Additionally, we dedicate our efforts to our parents

Victoria Abdel Sayed-El Nahal and Ramsey Abadir El Nahal

and Akhtar and Dr. A.C.S. Gilani

Preface

Reconstructive plastic surgery is a field of medicine that became most prominent in public awareness during World War II. Members of the armed forces who became victims of the conflict suffered multiple and various disabilities which required physical reconstruction. The demand on surgery was twofold. Initially the patient had to regain physical function; later, in many cases, the patient underwent further surgery for aesthetic improvement of face and limbs. The heightened demand for this type of surgery helped to generate new and important surgical techniques that ultimately led to tremendous improvements in the fields of congenital abnormalities, physical injury, and aesthetic surgery. Synthesis of current data combined with applied theory has been somewhat difficult to obtain without delving into massive tomes of literature in various disciplines.

The primary purpose of this book, therefore, is to summarize much of the data on rapid advances in this area. We have attempted to present a dissertation on the essentials of anesthesiology with the emphasis on plastic and reconstructive surgery. Our aim is to provide a textbook which shows the natural extension of the basics of anesthesiology applied to plastic reconstructive surgical procedures in several medical areas. The contributing authors have had many years of experience and have distinguished themselves in their respective disciplines in anesthesiology. Their exceptional and informative papers are presented in 20 chapters.

Chapters 1 through 4 are concerned with the preparative phases of anesthetic administration. Chapters 5 through 8 describe types of anesthesia administration and properties and actions of specific anesthetic agents. Chapter 9 deals with outpatient anesthesia for ambulatory surgery, under which the majority of aesthetic plastic surgical procedures take place. Specific medical conditions are discussed in the remaining chapters which include information on development, anesthesia administration, treatment, and postoperative care of the patient. Chapter 16 (Anesthesia for Cosmetic Surgery), written by Adel R. Abadir, especially reflects knowledge gleaned by the author while working with renowned plastic surgeons John M. Converse, Thomas Rees, Donald Wood-Smith, Philip Casson, and Joseph McCarthy. New techniques are also described along with the most current research reported in anesthesiology literature and journals.

In the preparation and editing of this collaborative publication, we soon realized that many people were involved in its creation and birth. Our

deepest appreciation is extended first to Dr. Benjamin Covino who so graciously provided input, advice, and review of Chapter 5 (Local Anesthesia). We also acknowledge with much gratitude Dr. Gertrude F. Marx who gave us insight and support throughout the developmental stages of the book.

We thank all our contributors for their thoughtful and masterful presentations, their willingness to include additional and current information that we thought might be potentially useful to students, residents, practicing anesthesiologists, and plastic surgeons, and for their work and rewriting after the galley proofs were reviewed.

Special thanks is extended to Rose De Luccio who worked on manuscript preparation and a variety of details associated with output of the chapters.

We also express our gratitude to all publishers and authors who granted permission for the use of reference citations, illustrations, and other materials contained in each chapter.

We further acknowledge the steadfast assistance of personnel at Brookdale Library and the Distinguished Library of New York Academy of Medicine for supplying us with the necessary literature, research journals, and other references that were required for our project.

Our immediate office staff must also be commended for their nonstop efforts in the day-to-day tasks performed in connection with the book, and their total loyalty and sustained encouragement throughout the book's progress.

Adel R. Abadir, M.D.
Shaesta G. Humayun, M.D.

Contents

CHAPTER 1

Anesthesia Equipment and Endotracheal Tubes, Laryngoscopes, Maintenance, and Safety

SHAESTA G. HUMAYUN
ADEL R. ABADIR

Anesthesia Equipment

■ ANESTHESIA MACHINES

The anesthesia machine prepares gas mixtures that are then delivered to a breathing system. Three divisions of power are involved. First, a high-pressure system receives the gases and decreases and regulates the pressure so that it is made more constant. Second, an intermediate-pressure system receives the gases from the hospital pipeline and delivers them to flowmeters. Third, a low-pressure system takes the gases from the vaporizer flowmeters to the machine or common gas outlet.

Anesthesia machines must conform to the performance and safety standards of the American National Standards Institute (ANSI).[4] These standards were developed after years of collaboration among engineers, anesthesiologists, and manufacturers. Two anesthesia machines that exemplify standards in performance and safety are the Ohmeda Modulus II and the Drager Narkomed 3, as illustrated in Fig. 1-1.

All anesthesia machines should possess the following essential components: (a) a source of compressed gas, either from a central pipeline or from an attached cylinder; (b) flowmeters to deliver gases to a breathing system; (c) a vaporizing system to deliver vapor of liquid anesthetics; (d) a breathing system; and (e) a mechanical ventilator.

In addition, all anesthesia machines should have fail-safe mechanisms to ensure that hypoxic gas mixtures will not be delivered to the patient if the oxygen supply should fail. Some machines have alarm devices that warn either audibly or visually of reduced oxygen pressure. Alarm devices are also part of breathing systems that alert the anesthesiologist to dysfunction and disconnections from the patient.[83]

Gas cylinder storage is subject to national standards and regulations. Cylinders must be stamped with symbol or name of the gas, owner identi-

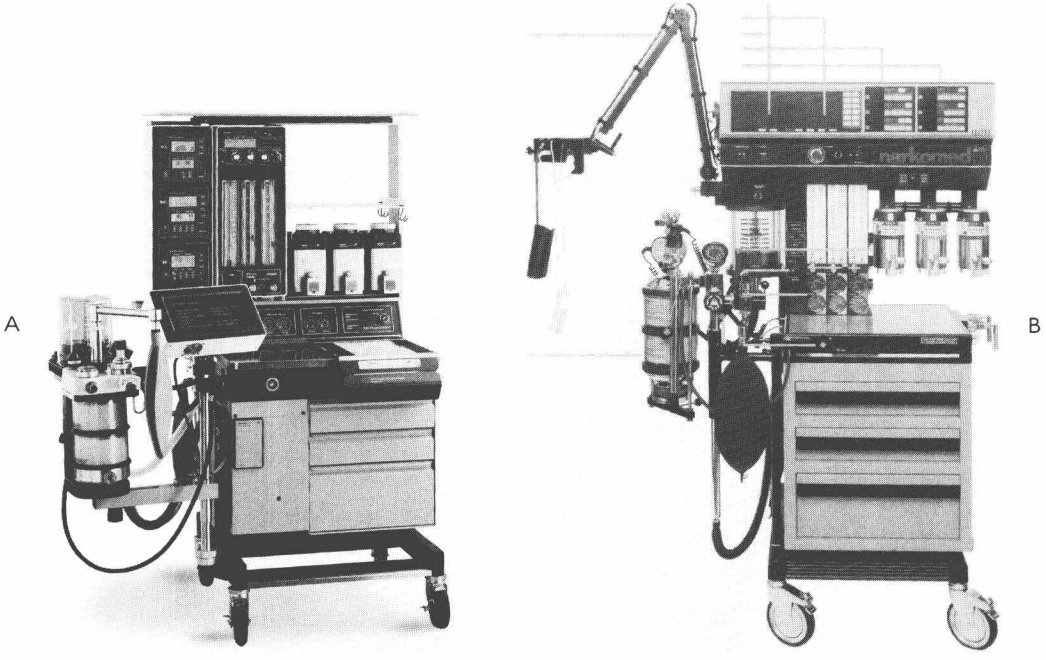

Fig. 1-1 Two anesthesia machines. **A,** Ohmeda Modulus II. **B,** Dräger Narkomed 3. *(Reprinted with permission from Ohmeda, The BOC Group, Madison, Wisconsin and North America Dräger, Telford, Pennsylvania.)*

fication, manufacturer identification, maximum filling pressure, capacity of the cylinder, and weight of the empty cylinder. Cylinders should not be stored at temperatures above 52° C. They should be kept clean; explosions can occur if oxygen or nitrous oxide combines with oil or grease. Cylinders are filled and emptied through a cylinder valve, which must be equipped with a safety relief device that can be activated if the cylinder is in danger of rupturing.[74]

Even with a piped-in gas supply, cylinders of oxygen and nitrous oxide should be attached to the anesthesia machine by hanger yokes in case the central oxygen supply fails. The gas cylinders are usually color-coded: green for oxygen and blue for nitrous oxide, with corresponding color-coded pressure gauges on the anesthesia machine.

When it leaves the cylinder, gas enters a metal tube and goes through a pressure-reducing valve that regulates the pressure to a constant 50 psig (per square inch gauge) before it is delivered to the flowmeters.[83] Pressure regulators must also have relief valves to protect the rest of the machine from excessive pressure.[23]

The intermediate-pressure system—which includes pipeline inlet

connections, pipeline pressure gauges, ventilator power outlets, oxygen pressure failure devices, flowmeter assembly, and oxygen flush—receives gases at lower pressures than the high-pressure system. Generally the pressures are between 37 and 55 psig. All components of the intermediate-pressure system are equipped with safety valves, check valves, and low-pressure alarm devices and/or shutoff systems that protect against malfunction of pressure or gas flow, disconnection, and inadvertent delivery of hypoxic gas mixtures.

The flowmeter assembly measures and controls the rate of gas flow. A variable orifice flowmeter, generally of the Thorpe type tube which tapers to the bottom and has a floating indicator, is the instrument that measures the rate of flow. As indicated in Fig. 1-2, gas enters the flowmeter and pushes the indicator float upward; when gas is decreased, the float descends. The position of the float indicates gas flow by a scale marked on the tube. The accuracy of the measured flowrate may be influenced by temperature and pressure changes, which affect the viscosity and density of gases.[23]

The anesthesia machine usually has a number of flowmeters for different gases. In some cases there are two flowmeters for one gas, with one flowmeter assigned to low flows and the other to high flows.

It has been found that the sequence of flowmeters may be a cause of hypoxia if a leak occurs.[27] In the United States and Canada, the oxygen flowmeter is always on the right. The correct location according to anesthesia machine standards is that the oxygen is delivered downstream of all other gases when a common manifold is used.[23]

To prevent setting the flows incorrectly and thereby incurring hypoxic delivery, several safety devices have been developed. Touch-coded oxygen control knobs that are fluted and larger than all other control knobs are available[16] and lessen the possibility that the wrong flow control knob will be used. Some anesthesia machines have another safety measure that allows for the presetting of minimal oxygen flows before other gases will flow. Proportioning devices combine oxygen and nitrous oxide flowmeter assemblies, and the oxygen concentration is dialed directly.[23] Although proportioning devices are convenient to use, they make it impossible to obtain low fresh gas flows. Flowmeters are also susceptible to leakage, and glass flowtubes are the most delicate components of the anesthesia machine and the easiest to damage. Additional problems with flowmeters that contribute to inaccurate measurement and readings are improper calibration, improper alignment (from the vertical position), static electricity (charges build up causing the indicator to stick), and float damage.

The low-pressure system components of the anesthesia machine receive gases at slightly above atmospheric pressure. They are located downstream of the flowmeters. The low-pressure components are the vaporizers, vaporizer circuit control valves, back pressure safety devices, and common gas outlet.[23]

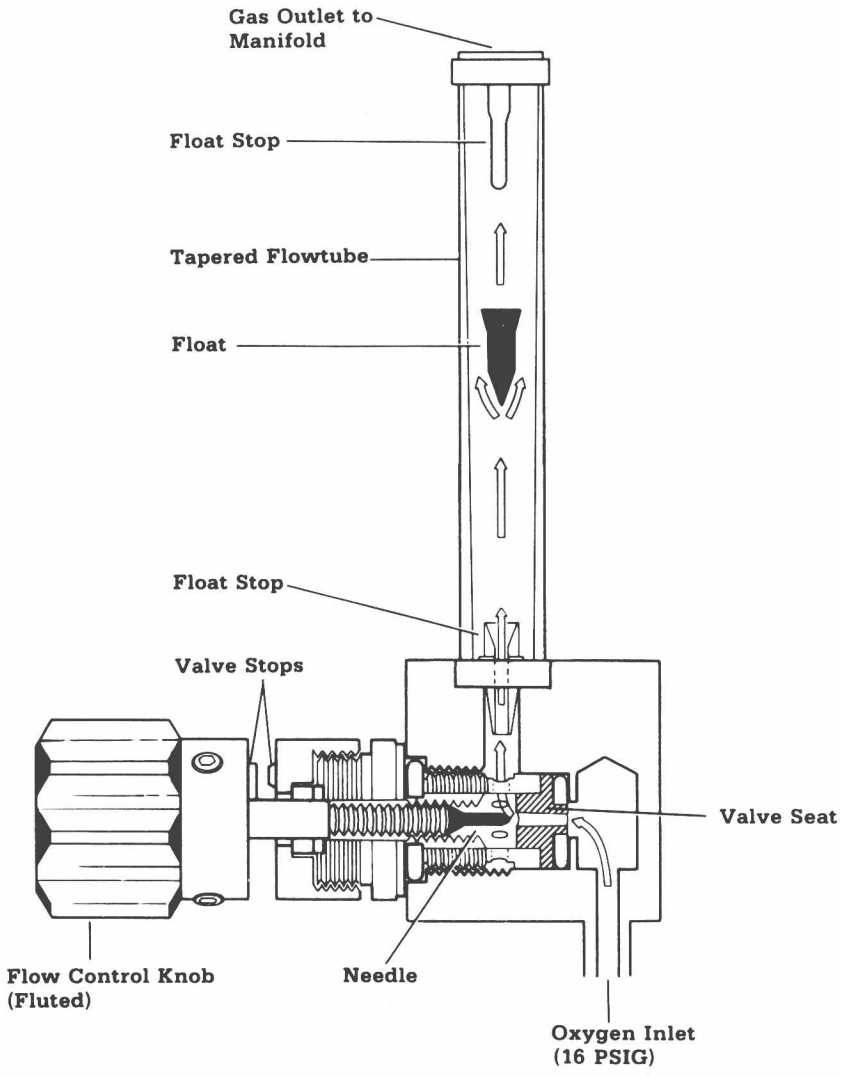

Fig. 1-2 Oxygen flowmeter assembly. *(Reprinted with permission from Bowie F and Huffman LM: The anesthesia machine: essentials for understanding, Madison, Wisconsin, 1985, Ohmeda, The BOC Group.)*

■ VAPORIZERS

The process of vaporization occurs when a liquid is converted to a vapor. A vaporizer is the instrument used to convert volatile liquid anesthetic agents to vapors, which are added to the gas flow that goes to the patient. The vaporizer may be placed in the fresh gas line outside the breathing system (out-of-circuit) or it may be inserted directly into the breathing system (in-circuit).

Understanding the conversion of a liquid to its gaseous phase requires some knowledge of the physics of heat and vaporization. In a closed container (vaporizer) of liquid and air, two types of molecular motion exist. The bulk of the liquid molecules are in constant random motion; the symmetrical arrangement between molecules tends to cancel out attractive forces. At the liquid-air interface there are fewer molecules in the air than in the liquid. The asymmetrical arrangement of intermolecular forces at the surface results in a net attractive force that draws the surface molecules into the liquid. In order to transcend this force, energy is required. Energy must originate in the liquid itself or come from an external source. The surface molecules must enter the air for the creation of vapor.[57] Heat is the energy that brings about the conversion of the molecules from the liquid to the gaseous state. The latent heat of vaporization of a liquid is the number of calories required to transform 1 g of liquid into a vapor without a change in temperature.[6] Latent heat energy allows the surface molecules in the container to overcome the intermolecular attractive force and rise into the atmosphere to become vapor.[65] Vaporization is concluded when the number of molecules in the vapor phase is constant. This state of equilibrium occurs when the same number of molecules leave the liquid phase as reenter it.[57]

More energy is required for vaporization when liquid is at low temperatures. As energy is expended during vaporization, there is additional loss of energy from the remaining liquid, resulting in considerable temperature decreases.[83] Vapor pressure, depicted in Fig. 1-3, is created when molecules collide with each other and against the walls of the container. If external heat is applied to the container, more molecules will enter the vapor phase, thereby increasing vapor pressure. Alternatively, vapor pressure will decrease with reduced heating.[23] The vapor pressure for a volatile anesthetic depends on the temperature and unique characteristics of the liquid. Heat loss affects vapor pressure and vapor concentration.

Manufacturers of vaporizers have given much attention to the problem of heat loss. The materials used in constructing vaporizers are high in thermal conductivity. Platinum and silver are good conductors, but their high cost prohibits their use. Older vaporizer models often used copper, which has high conductivity and relatively low cost.[47,48] Newer models use combinations of brass, copper, nickel, and chromium.[60]

Dorsch and Dorsch[23] classify vaporizers according to the following important features: (a) method of regulating output concentration; (b)

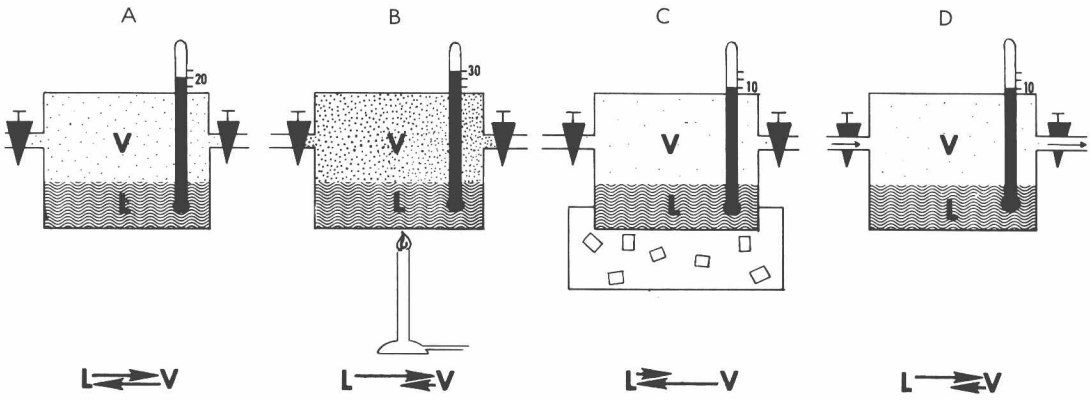

Fig. 1-3 Altering vapor pressure by increasing and decreasing temperature. **A** to **C**, Vapor pressure changes with varying temperature. **A**, The liquid and vapor are in equilibrium. **B**, The application of heat causes the equilibrium to shift so that more molecules enter the vapor phase, as illustrated by the increased density of dots above the liquid. **C**, Lowering the temperature causes a shift toward the liquid phase and a decrease in vapor pressure. **D**, Effect of carrier gas flow. Passing a carrier gas over the liquid shifts the equilibrium toward the vapor phase because vapor is carried away from the system. The temperature falls as heat is lost during vaporization. *(From Dorsch JA and Dorsch SE: Understanding anesthesia equipment: construction, care and complications, ed 2, Baltimore, 1984, Williams & Wilkins.)*

method of vaporization; (c) location; and (d) temperature compensation.

The method of regulating output concentration refers to the method used to dilute saturated carrier gas in a controlled manner. In the variable-bypass model, the entire flow from the anesthesia machine goes to the vaporizer and is divided; some enters the vaporizing chamber, and the excess goes to a bypass vaporizer outlet. The measured flow model requires the input of a measured amount of gas, all of which goes through the vaporizing chamber. The machine then dilutes the gas with additional flow.[23]

The method of vaporization is either flow-over, as shown in Fig. 1-3, or bubble-through, as shown in Fig. 1-4. In the bubble-through method, oxygen is passed through a porous plate beneath the liquid, creating bubbles so as to increase the surface area for more efficient vaporization.[57] These machines present the danger of foaming of the bubbles,[84] and in addition they are inconvenient to use because they are usually not calibrated. Although still in use, the bubble-through copper kettle vaporizer is no longer manufactured.[6]

Vaporizers are located either inside or outside the breathing system. Both measured-flow and variable-bypass vaporizers are located outside the breathing system. Measured-flow vaporizers have their own flowmeter assemblies and are connected upstream of the common gas outlet. The variable-bypass models are located between the common gas outlet and the

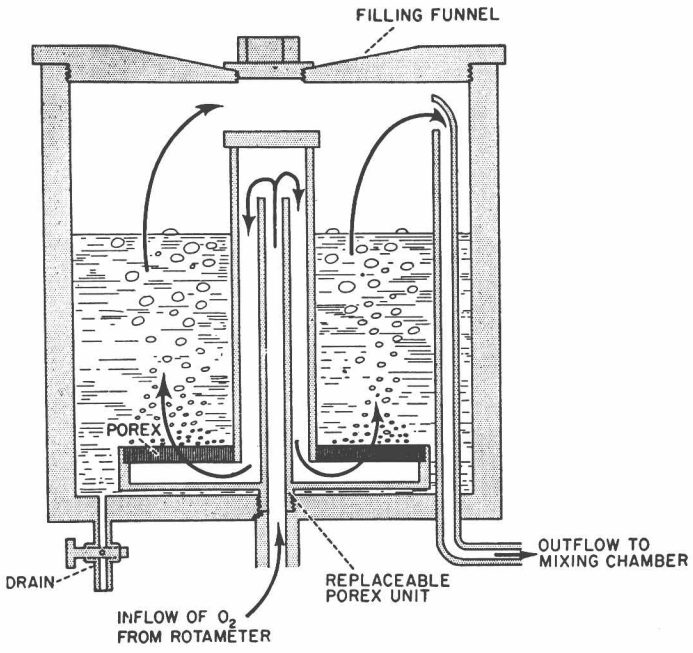

Fig. 1-4 The copper kettle bubble-through vaporizer. *(From Morris LE: A new vaporizer for liquid anesthetic agents, Anesthesiology 13: 587, 1952.)*

breathing system (the delivery hose). This location presents potential problems, such as tipping if the vaporizer is not well secured and an improper connection resulting in reversed gas flow.[23]

In-system vaporizers are located in the breathing system and may be used as inhalers for spontaneous breathing. The movement of gas inside the circle system depends on the rate and depth of ventilation.

Temperature compensation involves the replacement of heat loss due to the vaporization process. Although heat is supplied to copper kettle models by the copper that is used to conduct heat, these are often termed non–temperature-compensating vaporizers. Another way to compensate for heat loss is by altering the flow of carrier gas. The percentage of gas flow is increased automatically on most variable-bypass vaporizers.

Some vaporizers can be used with only one agent; they are called agent-specific models. Other vaporizers can be used with several agents; they are called multiple-agent models. Gas concentrations may be affected through use of a container for one anesthetic agent that was designed for a different agent, resulting in the inadvertent increase or decrease of delivered anesthetic agent.[39,77,81] The name, type, and manufacturer of several vaporizer models are shown in the box on pp. 8-9.