Respiratory Therapy

Respiratory Therapy

An Open Workbook for the Entry-to-Practice Student

KIRSTEN HOLBROOK, BA, RRT, RRT-ACCS

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Overview

About Respiratory Therapy: An Open Workbook for the Entry-to-Practice Student

Respiratory Therapy: An Open Workbook for the Entry-to-Practice Student is a practical and interactive resource designed to support students entering the field of respiratory therapy. This workbook provides foundational knowledge and hands-on exercises covering key topics such as respiratory anatomy and physiology, diagnostic techniques, therapeutic interventions, and patient care strategies. With a focus on real-world application, it includes case studies, practice questions, and activities to reinforce learning and build clinical skills. Ideal for entry-level students, this workbook serves as a valuable tool for mastering the essentials of respiratory therapy and preparing for professional practice.

Respiratory Therapy: An Open Workbook for the Entry-to-Practice Student is an open educational resource with CC-BY 4.0 licensing developed for entry-to-practice level respiratory therapy students. Content is based on the Wisconsin Technical College System (WTCS) statewide respiratory curriculum for the Respiratory courses (10-515-111, 10-515-171, 10-515-172, 10-515-112, 10-515-113).

Using the Digital Textbook

The following video provides a quick overview of how to navigate the digital version of the textbook:

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://wtcs.pressbooks.pub/respiratorysurvey/?p=4#oembed-1

Acknowledgment of Support and Disclaimer

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Preface

About this Book

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Reviewers

Peer reviewers of the first edition of this textbook included respiratory therapy faculty from Wisconsin Technical Colleges:

- Anja Dreps MS, RRT, RPFT, RRT-ACCS, RRT-NPS, Program Director Moraine Park Technical College
- Jim Coutley, BSRT, RRT, Director of Clinical Education, Moraine Park Technical College
- Lauren Kante, RRT, RRT-ACCS, Madison College
- Joe Punzel, BS, RRT, Respiratory Therapy Instructor, Madison College
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- Holbrook, K. (2025). *Respiratory therapy*. WisTech Open. https://wtcs.pressbooks.pub/respiratorysurvey/

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If you've adopted this book for a course or would like to suggest a correction, please let us know by filling out the form at wistechopen.org/contact. Your feedback helps us improve and advocate for WisTech Open—we appreciate your support!

Acknowledgements

I would like to express my gratitude to those who have supported and influenced me throughout the process of writing this book. To my family and friends, thank you for your encouragement and support throughout this journey.

A special thank you to my mentors, Don Raymond and Theresa Meinen, for their guidance and leadership throughout my career. I am forever grateful for the knowledge you have shared and the example you have set.

To my Respiratory Therapy students—past, present, and future—your dedication, curiosity, and drive inspire me every day. You are the reason I continue to teach, learn, and advocate for excellence in our field. This book is, in many ways, a reflection of my commitment to your success.

Finally, I want to extend my appreciation to the Chippewa Valley Technical College WisTech Open team and the reviewers that helped put this book together. Your hard work and contributions were invaluable in bringing this project to life.

Standards and Conceptual Approach

Standards

Respiratory Therapy: An Open Workbook for the Entry-to-Practice Student is based on external standards and uses a conceptual approach.

External Standard

NBRC Therapist Content Outline 2020 Sponsoring Organization:

The National Board for Respiratory Care (NBRC) Therapist Multiple-Choice (TMC) Examination objectively measures essential knowledge, skills, and abilities required of respiratory therapists at entry into practice.[1] Passing the TMC Examination and the CSE Examination and wearing the Registered Respiratory Therapist (RRT) badge of distinction signals to employers, colleagues, and patients that you are committed to excellence in respiratory care. Additionally, all 49 states that regulate the practice of respiratory care use the CRT (Certified Respiratory Therapist) or RRT (Registered Respiratory Therapist) credential as the basis for state licensure.

Conceptual Approach

Respiratory Therapy: An Open Workbook for the Entry-to-Practice Student incorporates the following concepts:

- **Evidence-Based Practice (EBP).** Evidence-based practices are referenced by footnotes throughout the textbook. To promote the development of digital literacy, links are provided to credible, free online resources that supplement content. *Respiratory Therapy: An Open Workbook for the Entry-to-Practice Student* will be updated as new EBPs are established.
- **Clinical Judgment.** Laboratory activities, critical thinking assessments, and skill competency are incorporated. Formative assessments encourage students to recognize cues, analyze cues, generate solutions, take action, and evaluate outcomes.
- **Safe, Quality, Patient-Centered Care.** Content reflects the priorities of safe, quality, patient-centered care.
- **Open-Source Images and Fair Use.** Images are included to promote visual learning. Students and faculty can reuse open-source images by following the terms of their associated Creative Commons licensing. Some images are included based on Fair Use as described in the "Code of Best Practices for Fair Use and Fair Dealing in Open Education" presented at the OpenEd 2020 conference. Refer to the citations.

1. National Board for Respiratory Care. (2020). *Certified respiratory therapist (CRT).* https://www.nbrc.org/examinations/crt/

- **Open Pedagogy.** Students are encouraged to contribute to the *Respiratory Therapy: An Open Workbook for the Entry-to-Practice Student* project in meaningful ways by reviewing content for clarity and assisting in the creation of open-source images.[2]

2. Wagstaff, S. (2023). Open Pedagogy Notebook. https://openpedagogy.org/

Introduction to Respiratory Therapy: An Open Workbook for the Entry-to-Practice Student

When Taylor's grandfather was hospitalized with pneumonia, she spent long hours by his bedside. One afternoon, a respiratory therapist entered the room with a calm presence and a portable ventilator. Within minutes, the therapist assessed his breathing, adjusted his oxygen, and patiently explained each step to the family. The change was almost immediate—her grandfather relaxed, and so did Taylor. That moment sparked a question in her mind: "What exactly does a respiratory therapist do?" It wasn't long before Taylor enrolled in a respiratory therapy program, ready to be that same reassuring presence for someone else's loved one.

This *Respiratory Therapy* workbook is your gateway into the dynamic, life-saving world of respiratory care. Designed to give you a broad overview of the field, it will introduce you to essential roles, responsibilities, tools, and treatment methods that respiratory therapists use in hospitals, clinics, and home care settings. You'll explore key concepts in pulmonary anatomy and physiology, medical gas therapy, airway management, and the critical thinking skills that define the profession. Whether you've already seen the impact of this career firsthand or are just beginning to explore it, this book will lay the foundation for your success—and your future patients' breath of relief.

PART I

RESPIRATORY SURVEY

Learning Objectives

- Define the role of a respiratory therapist and describe their scope of practice.
- Identify key professional organizations (e.g., AARC, NBRC) and explain their role in advancing the respiratory care profession.
- Demonstrate knowledge of state licensure and certification requirements for respiratory care practitioners.
- Explain the importance of ethical and legal standards in clinical practice, including patient confidentiality and other legal implications.
- Describe the principles of infection control and their application in respiratory care settings.
- Differentiate between cleaning, disinfection, and sterilization methods for respiratory equipment.
- Identify modes of pathogen transmission and implement appropriate protective measures to prevent health care-associated infections.
- Demonstrate proper donning and doffing of personal protective equipment (PPE) following CDC guidelines.
- Identify and mitigate common patient safety risks.
- Explain the principles of fire safety in health care settings.
- Apply safety protocols during emergency situations, including evacuation procedures.
- Describe the benefits and risks of certain patient positions such as Fowlers, Trendelenburg, etc.
- Use effective communication strategies to build rapport with patients and health care teams.
- Obtain a comprehensive respiratory history from patients, including past medical history, family history, and social history.
- Perform a physical examination, including vital signs, along with a focus on the respiratory system, identifying key findings such as breath sounds and chest expansion.
- Document patient assessments and findings using the SOAP (Subjective, Objective, Assessment, Plan) format.
- Explain the principles of pulse oximetry, including its limitations and potential sources of error.
- Demonstrate the correct technique for measuring oxygen saturation using a pulse oximeter.
- Conduct a thorough pulmonary examination, including inspection, palpation, percussion, and auscultation.

1.1 The Profession, Organizations, and Legal Considerations

Respiratory therapists are members of a multidisciplinary healthcare team. Respiratory therapists are specialized clinicians who are involved in all aspects of respiratory care including managing oxygen therapy; drawing arterial blood gasses; managing patients on specialized oxygenation devices such as mechanical ventilators and non-invasive machines; administering respiratory medications like inhalers and nebulizers; intubating patients; assisting with bronchoscopy and other respiratory-related diagnostic tests; performing pulmonary hygiene measures like chest physiotherapy; and serving an integral role during rapid responses, cardiac and respiratory arrests, traumas, and codes.[1]

A Brief Overview of Respiratory Care

Respiratory care, also known as respiratory therapy, has been defined as the health care discipline that specializes in the promotion of optimal cardiopulmonary function and health. Respiratory therapists (RTs) apply scientific principles to prevent, identify, and treat acute or chronic dysfunction of the cardiopulmonary system. Respiratory care includes the assessment, treatment, management, control, diagnostic evaluation, education, and care of patients with deficiencies and abnormalities of the cardiopulmonary system. Respiratory care is increasingly involved in the prevention of respiratory disease, the management of patients with chronic respiratory disease, and the promotion of health and wellness.

The role of respiratory therapists has significantly evolved over time. Figure 1[2] shows a technician fixing an iron lung from the 1950s. Once primarily considered technical support personnel or technicians, respiratory therapists have transitioned into highly skilled clinical practitioners. This transformation has been driven by advancements in medical technology, increased complexity in patient care, and the growing recognition of respiratory therapists as essential members of the healthcare team. Today, respiratory therapists play a critical role in assessing, diagnosing, and managing cardiopulmonary conditions, collaborating with physicians, and making independent clinical decisions to optimize patient outcomes.

1. Ernstmeyer, K., & Christman, E. (Eds.). (2024). *Nursing fundamentals 2E*. Open RN | WisTech Open. https://wtcs.pressbooks.pub/nursingfundamentals/

2. "An_unidentified_man_makes_adjustments_to_an_iron_lung_(12618013383)" by City of Boston Archives is licensed under CC BY 2.0

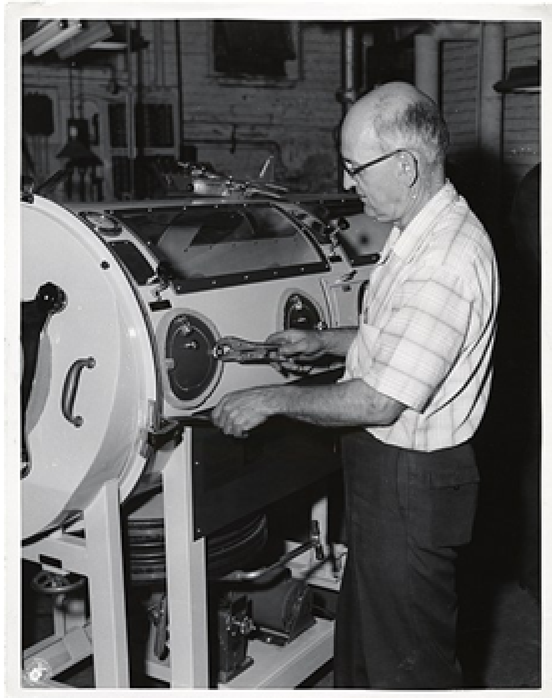

Figure 1. Technician fixing an iron lung.

Respiratory therapists, also be known as respiratory care practitioners, are health care professionals who are educated and trained to provide respiratory care to patients. About 75% of all respiratory therapists work in hospitals or other acute care settings. However, many respiratory therapists are employed in clinics, physicians' offices, skilled nursing facilities, cardiopulmonary diagnostic laboratories, and public schools. Others work in research, disease-management programs, home care, and the sales industry. Some respiratory therapists work in colleges and universities, teaching students the skills they need to become respiratory therapists. Regardless of the practice setting, all direct patient care services provided by respiratory therapists must be done under the direction of a qualified physician. Medical directors are usually physicians who are specialists in pulmonary or critical care medicine.

There are approximately 200,000 respiratory therapists practicing in the United States. As the incidence of chronic respiratory diseases continues to increase, the demand for respiratory therapists is expected to be even greater in the years ahead. Although the respiratory therapist as a distinct health care provider was originally a uniquely North American phenomenon, since the 1990s there has been a steady increase in interest of other countries in having specially trained professionals provide respiratory care. This trend is referred to as the "globalization of respiratory care."[3]

3. Dunne, P. J. (2017). History of Respiratory Care. In *Eagan's Fundamentals of Respiratory Care* (11th ed., p. 2). Elsevier.

Professional Organizations

American Association for Respiratory Care (AARC)

The American Association for Respiratory Care (AARC) is the leading national and international professional association for respiratory care. The AARC encourages and promotes professional excellence, advances the science and practice of respiratory care, and serves as an advocate for patients and their families, the public, the profession, and the respiratory therapist.[4]

Chartered Affiliates

All 50 states are known as chartered affiliates of the AARC. The chartered affiliates work hard to represent and protect the interests of respiratory therapists within their state. Chartered affiliates represent a great way for you to network with RT colleagues who live in your state and, by doing so, can boost your career potential. Chartered affiliates do much more than just serve as a way for therapists to get together. They provide RTs with the continuing education they need to maintain their license to practice and also advocate for legislation important to patients and the professional interests of RTs.[5]

National Board for Respiratory Care (NBRC)

The mission of the National Board for Respiratory Care (NBRC) is to promote excellence in respiratory care by awarding credentials based on high-competency standards. The NBRC shares the RT's goal of protecting and enhancing patient lives. Nearly 40,000 candidates test for NBRC credentials each year, seeking to demonstrate how excellence defines them across seven specific areas of respiratory care. These include Certified Respiratory Therapist (CRT), Registered Respiratory Therapist (RRT), Adult Critical Care (RRT-ACCS), Neonatal/Pediatric Respiratory Care (RRT-NPS), Certified or Registered Sleep Disorders Testing and Therapeutic Intervention (CRT-SDS or RRT-SDS), Certified or Registered Pulmonary Function Technology (CPFT or RPFT), and Asthma Education (AE-C).

NBRC credentials provide recognition for hard work and dedication to quality. Success on the exams brings respect among colleagues and instills a sense of pride in those who earn the NBRC badges of distinction. The NBRC accredited examinations, which are developed by respiratory care professionals and predictive of job performance, provide the opportunity to prove readiness for excellence in patient care.[6]

In 1960, Sister Mary Yvonne Jeann became the first Registered Inhalation Therapist and received registry number 1. The American Registry of Inhalation Therapists administered the first registry exams in Minneapolis, MN. both written and oral exams were required.

4. American Association for Respiratory Care. (n.d.). *About Us*. https://www.aarc.org/about-us/
5. Wisconsin Society for Respiratory Care. (n.d.). *About the WSRC*. https://www.wsrc.online/about-us
6. The National Board for Respiratory Care. (n.d). *About us.* https://www.nbrc.org/about/

Commission on Accreditation for Respiratory Care (CoARC)

The Commission on Accreditation for Respiratory Care (CoARC) accredits Entry into Professional Practice respiratory care programs at the associate, baccalaureate, and master's degree levels, as well as post-professional Degree Advancement respiratory care programs at the baccalaureate and master's degree levels and Advanced Practice respiratory care programs at the graduate level. The CoARC also accredits certificate programs that train sleep disorders specialists offered by any of its accredited respiratory care programs. CoARC accreditation is limited to programs physically located in the United States and its territories.[7]

American Thoracic Society (ATS)

The American Thoracic Society (ATS) significantly influences respiratory therapy by setting clinical practice guidelines, providing educational resources, advocating for policy changes, and promoting research. ATS guidelines help standardize care and improve patient outcomes in respiratory conditions. The organization also offers training opportunities and fosters continuous professional development for respiratory therapists. Additionally, the ATS advocates for the profession, highlighting the critical role of respiratory therapists in patient care. Through research and collaboration, the ATS ensures that respiratory therapists are equipped with the latest knowledge and tools to deliver high-quality care.[8]

Federal Organizations

The Joint Commission (TJC)

The Joint Commission (TJC) is a national organization that accredits and certifies over 20,000 health care organizations in the United States. The mission of TJC is to continuously improve health care for the public by inspiring health care organizations to excel in providing safe and effective care of the highest quality and value. TJC sets standards for providing safe, high-quality health care.[9]

Centers for Medicare & Medicaid Services (CMS)

The Centers for Medicare & Medicaid Services (CMS) is another federal agency that establishes regulations that affect nursing care. CMS is a part of the U.S. Department of Health and Human Services (HHS) that administers the Medicare program and works in partnership with state governments to administer Medicaid.

7. Commission on Accreditation for Respiratory Care. (n.d.). *Mission statement*. https://coarc.com/about/mission-and-vision-statements/
8. American Thoracic Society. (n.d.). *Overview*. https://site.thoracic.org/about-us/overview
9. The Joint Commission. (n.d.). *Who we are*. https://www.jointcommission.org/who-we-are/

The CMS establishes and enforces regulations to protect patient safety in hospitals that receive Medicare and Medicaid funding. For example, one CMS regulation states that a hospital's policies and procedures must require confirmation of specific information before medication is administered to patients. This CMS regulation is often referred to as "checking the rights of medication administration." CMS also enforces quality standards in health care organizations that receive Medicare and Medicaid funding. These organizations are reimbursed based on the quality of their patient outcomes. For example, organizations with high rates of healthcare-associated infections (HAI) receive less reimbursement for services they provide. As a result, many agencies have reexamined their policies, procedures, and protocols to promote optimal patient outcomes and maximum reimbursement.[10]

Exams/Credentialing and Licensure

Therapist Multiple-Choice/Clinical Simulation Examination (TMC/CSE) Credentialing Exams

The Therapist Multiple-Choice (TMC) Examination objectively measures essential knowledge, skills, and abilities required of respiratory therapists at entry into practice. Passing the TMC Examination and wearing the CRT badge of distinction signal to employers, colleagues, and patients that you are committed to excellence in respiratory care. Additionally, all 49 states that regulate the practice of respiratory care use the CRT or RRT credential as the basis for state licensure.

The TMC Examination also determines your eligibility for the Clinical Simulation Examination (CSE), which is required for the RRT credential.

The TMC Examination offers two cut scores that determine whether or not you will receive credentials as a CRT or as an RRT. If you achieve the low-cut score, you earn the CRT credential. If you achieve the high-cut score, you earn the CRT credential and become eligible for the Clinical Simulation Examination (CSE) (provided you are eligible to earn the RRT credential).

The TMC Examination consists of 160 multiple-choice questions (140 scored items and 20 pretest items). You will be given 3 hours to complete the TMC Examination.[11]

Once you are credentialed, you will need to maintain your credentials by participating in continuing education activities.

State Licensure

Once you have obtained your CRT or RRT credentials, you will have to apply for state licensure before you are able to practice. Most states require a CRT credential to obtain a license; however, there is a general movement toward the RRT credential. In 49 states, you will prepare an application and pay a fee to the licensure board for

10. Centers for Medicare & Medicaid Services. (n.d.). *About CMS*. https://www.cms.gov/about-cms

11. The National Board for Respiratory Care. (n.d.). *About us.* https://www.nbrc.org/about/

the state in which you live. Typically, professional licensure is required to be renewed, and continuing education needs to be completed to obtain licensure in certain states.

The requirements for state licensure as a respiratory therapist can vary depending on whether the individual holds a CRT or RRT credential.

Certified Respiratory Therapist (CRT): In many states, individuals who have passed the CRT examination (administered by the NBRC) are eligible to apply for state licensure. The CRT is typically the entry-level credential, and in some states, it may be sufficient to obtain a license to practice as a respiratory therapist.

Registered Respiratory Therapist (RRT): The RRT credential, which requires passing both the CRT and an advanced-level clinical examination, is often preferred by employers and may be required for certain positions or advanced responsibilities. Some states may require the RRT credential as part of their licensure process, especially for those practicing in more specialized or supervisory roles.

While state licensure requirements vary, the RRT credential is generally seen as a higher level of certification and can offer more career opportunities and job flexibility. Additionally, in states where both CRT and RRT credentials are accepted for licensure, employers may prefer candidates with the RRT due to its advanced scope of practice and recognition in the field.

Legal Considerations, Ethics, and Morality

Respiratory therapists must be aware of the legal implications associated with their practice. Since respiratory therapists are licensed in 49 states, they can be held legally liable for negligence, malpractice, or breaches of patient confidentiality. Such violations may result in legal action, financial penalties, or even licensure revocation.

Beyond legal considerations, respiratory therapists must also adhere to ethical and moral principles that guide patient care. Upholding professional integrity, maintaining patient dignity, and making evidence-based decisions are essential in ensuring safe and ethical practice. By understanding both the legal and ethical responsibilities of their role, respiratory therapists can provide high-quality, patient-centered care while protecting themselves and their profession.

Negligence and Malpractice

Negligence is a general term that denotes conduct lacking in due care, carelessness, and a deviation from the standard of care that a reasonable person would use in a particular set of circumstances. Malpractice is a more specific term that looks at a standard of care, as well as the professional status of the caregiver. (See Figure 2.) To prove negligence or malpractice, the following elements must be established in a court of law:

- Duty owed to the patient
- Breach of duty owed to the patient
- Foreseeability
- Causation
- Injury
- Damages

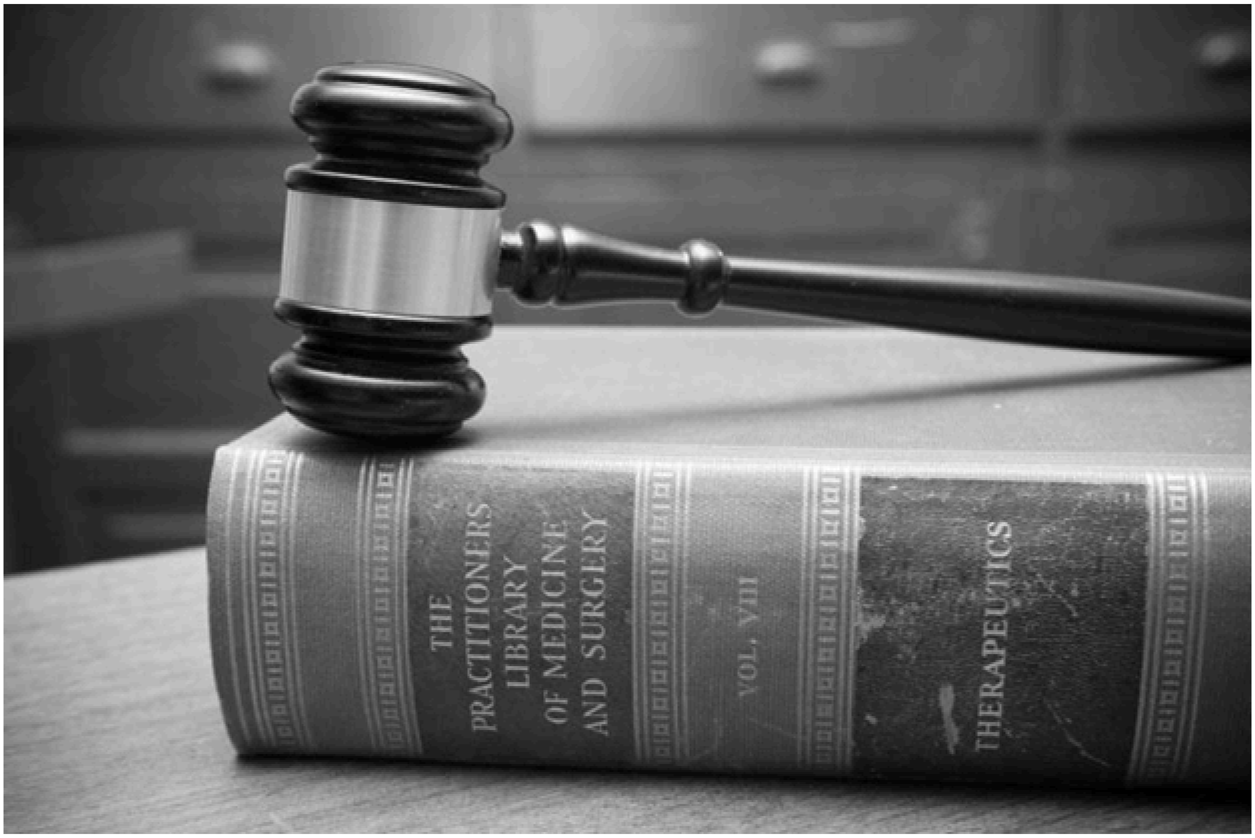

Figure 2. Medical book and courtroom gavel.

Patient Confidentiality

In addition to negligence and malpractice, patient confidentiality is a major legal consideration for healthcare providers. Patient confidentiality is the right of an individual to have personal, identifiable medical information, referred to as protected health information (PHI), kept private. This right is protected by federal regulations called the Health Insurance Portability and Accountability Act (HIPAA). HIPAA was enacted in 1996 and was prompted by the need to ensure privacy and protection of personal health records and data in an environment of electronic medical records and third-party insurance payers. There are two main sections of HIPAA law: the Privacy Rule and the Security Rule. The Privacy Rule addresses the use and disclosure of individuals' health information. The Security Rule sets national standards for protecting the confidentiality, integrity, and availability of electronically protected health information. HIPAA regulations extend beyond medical records and apply to patient information shared with others. Therefore, all types of patient information should only be shared with health care team members who are actively providing care to them.

You are required to adhere to HIPAA guidelines from the moment you begin to provide patient care. Respiratory students may be disciplined or expelled by their program for violating HIPAA. Respiratory therapists who violate HIPAA rules may be fired from their jobs or face lawsuits.[12]

12. Ernstmeyer, K., & Christman, E. (Eds.). (2024). *Nursing fundamentals 2E*. Open RN | WisTech Open. https://wtcs.pressbooks.pub/nursingfundamentals/

Morality and Ethics

In addition to legal considerations, there is a code of ethics that respiratory therapists should adhere to (see AARC Code of Ethics and Professional Conduct). There is a difference between morality, ethical principles, and a code of ethics. Morality refers to "personal values, character, or conduct of individuals within communities and societies." An ethical principle is a general guide, basic truth, or assumption that can be used with clinical judgment to determine a course of action. Some common ethical principles are beneficence (do good), nonmaleficence (do no harm), autonomy (control by the individual), veracity (be truthful), respondeat superior, and justice (fairness). A code of ethics is set for a profession and makes their primary obligations, values, and ideals explicit.[13]

> View this supplementary YouTube[14] video: How to be an Ethical Respiratory Therapist

13. Ernstmeyer, K., & Christman, E. (Eds.). (2024). *Nursing fundamentals 2E*. Open RN | WisTech Open. https://wtcs.pressbooks.pub/nursingfundamentals/

14. Respiratory Therapy Zone. (2022, June, 10). *How to be an ethical respiratory therapist* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=53fMtKurVe4&t=7s

1.2 Lab Activities

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=89#h5p-75

1.3 Critical Thinking Assessment

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https://wtcs.pressbooks.pub/respiratorysurvey/?p=174#h5p-42

2.1 Infection Control

Hand Hygiene and PPE

Respiratory therapists are on the front lines treating all types of respiratory diseases. It is important that they are knowledgeable in infection control and prevention of disease. As respiratory therapy students, you are responsible for learning about infection prevention and control practices, becoming competent in infection prevention and control skill techniques, and becoming knowledgeable in infection prevention and control guidelines according to your role. To gain competency in infection prevention and control skills, students need to continuously practice in the classroom and laboratory settings and then apply what they have learned throughout their health care placement with supervision and support from their clinical instructor or placement preceptor and faculty. As health care students, you must work in collaboration with other health care providers and students to create a safe environment.

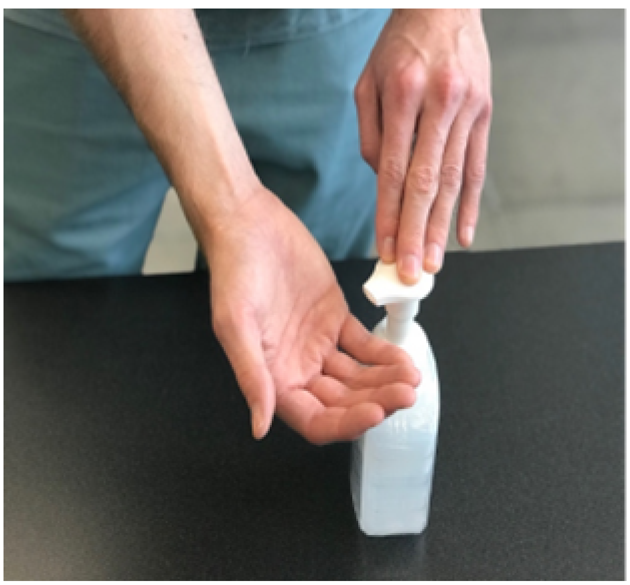
Health care providers' hands are the most common mode of transmission of microorganisms. As health care providers, your hands will touch various people and objects when providing care. As such, microorganisms can easily transfer from your hands to objects in the health care setting when proper hand hygiene practices are not followed. When you touch a client, their personal items, medical equipment, or the surrounding environment, you can indirectly transmit microorganisms to the client, another client, yourself, equipment, or transfer it to a new environment. Consistent and effective hand hygiene is required to break the chain of transmission.[1]

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=183#h5p-8

1. Hughes, M., Kenmir, A., St-Amant, O., Cosgrove, C., & Sharpe, G. (2021). *Introduction to infection prevention and control practices for the interprofessional learner*. OER Commons. https://ecampusontario.pressbooks.pub/introductiontoipcp/

Hand Hygiene[2]

There are two methods of hand hygiene commonly used in the health care setting: hand hygiene with an alcohol-based hand rub (see Figure 3[3]) and hand hygiene with soap and water (see Figure 4[4]).

Alcohol-Based Hand Rub (ABHR)	**Soap and Water**
Preferred method when hands are not visibly soiled (e.g., blood, body fluids, waste).	Preferred method when hands are visibly soiled to remove organic matter.
Takes less time.	Performed with suspected or confirmed diagnosis of C. difficile, norovirus, and *Bacillus anthraces*.
More effective.	Takes more time.
Less drying and irritating to hands.	Washing, rubbing, rinsing, and drying actions remove most transient bacteria.
Rubbing action until the ABHR is dry on hands, which should take approximately 20 seconds, is important to remove and kill transient bacteria.	Harsher on hands and increases risk of skin breakdown.
 *Figure 3. Health care provider performing alcohol-based hand rub.*	 *Figure 4. Health care provider washing hands with soap and water.*

2. Hughes, M., Kenmir, A., St-Amant, O., Cosgrove, C., & Sharpe, G. (2021). *Introduction to infection prevention and control practices for the interprofessional learner*. OER Commons. https://ecampusontario.pressbooks.pub/introductiontoipcp/

3. "Alcohol-based-Hand-Rub-.png" by unknown author are licensed under CC BY-NC 4.0. Access for free at https://ecampusontario.pressbooks.pub/introductiontoipcp/chapter/59/

4. "Soap-and-Water-350×341.png" by unknown author are licensed under CC BY-NC 4.0. Access for free at https://ecampusontario.pressbooks.pub/introductiontoipcp/chapter/59/

ABHR products, soap dispensers, and hand-washing sinks should be accessible at the point of care and placed in convenient locations for health care providers and visitors to use before and after client contact. The respiratory therapist should note that washing hands with soap and water is very effective at destroying germs because the lathering of hands with the soap molecules, and scrubbing creates friction that helps destroy some bacteria and viruses and lifts and washes away dirt, grease and other microbes under running water.[5]

View the following supplementary YouTube videos[6,7] to learn more about using the soap and water technique or the alcohol-based hand rub (ABHR) for proper hand hygiene for health care workers:

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://wtcs.pressbooks.pub/respiratorysurvey/?p=183#oembed-1

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://wtcs.pressbooks.pub/respiratorysurvey/?p=183#oembed-2

5. The Regents of the University of California. (2025). *Soap vs. hand sanitizer*. UCI Health. https://www.ucihealth.org/blog/2020/04/soap-vs-sanitizer

6. RegisteredNurseRN. (2018, December 1). *Hand hygiene for health workers | Hand washing soap and water technique nursing skill* [Video]. YouTube. Used with permission. All rights reserved. https://www.youtube.com/watch?v=G5-Rp-6FMCQ

7. World Health Organization. (2015, October 15). *WHO: How to handrub? With alcohol-based formulation* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=ZnSjFr6J9HI

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An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=183#h5p-10

Personal Protective Equipment (PPE)

As a respiratory therapy student, infection prevention and control techniques may not always seem intuitive. There are general rules and guidelines that can help you as you begin to practice safe care according to infection prevention and control guidelines. When using personal protective equipment (PPE), the first step is knowing the sequence to put on and remove PPE safely.

View the following supplementary YouTube video[8] to learn more about the proper way to don and doff PPE:

8. RegisteredNurseRN. (2020, May 29). *PPE Training Video: Donning and doffing PPE nursing skill* [Video]. YouTube. Used with permission. All rights reserved. https://www.youtube.com/watch?v=iwvnA_b9Q8Y

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://wtcs.pressbooks.pub/respiratorysurvey/?p=183#oembed-3

Gloves

- Gloves are critical for preventing the transmission of microorganisms, and it is important to wear them with all patient interactions, not just when you are handling bodily fluids. Ensure that gloves are removed and disposed of correctly.

Masks

- Medical masks protect the mucous membranes of the nose and mouth and should be worn during care, treatments, or procedures that may cause splashing or spraying of blood, body fluids, secretions, or excretions (i.e., intubation and extubation); when within 3 feet of a client who is coughing; or when required by routine practices or additional precautions (see Figure 5[9]).

9. "49721624231" by MC2 Sara Eshleman for U.S. Navy is licensed in the Public Domain

Figure 5. Health care worker donning a mask.

N95 Respirators

- Respirators protect the mucous membranes of the nose and mouth and have a high-filtration material that is more effective than medical masks in protecting the wearer from smaller airborne particles.
- Respirator masks are designed to fit snugly. Because faces vary in size and shape, respirators need to be specifically fitted. Every time a respirator is put on, a seal test must be done.
- Depending on the health care organization, a powered air purifying respirator (PAPR) may be used in place of a N95 mask to protect the health care worker (see Figure 6[10]).

10. "Portable_powered_HEPA_respirator" by Steven is licensed under CC BY 2.0

Figure 6. Health care worker wearing a powered air purifying respirator (PAPR).

Gowns

- Gowns protect from splashing or spraying of body fluids, as well as from the transmission of microorganisms.

- Gowns should have long sleeves with a snug fit at the wrist, cover both the front and the back of the body from the neck to the thighs, and overlap at the back.
- Ensure that the gown is worn correctly and that the ties on the gown are secure. Gowns need to be removed in a way that prevents contaminating clothes and skin.

Eye Protection

- Eye protection, including face shields, visors attached to masks, and goggles, are used to protect the eyes of health care providers when procedures or care activities are likely to cause splashing, spraying of body fluids, or when within 3 feet of a coughing client. When intubating, extubating, and suctioning with an exposed catheter, eye protection should be utilized by the therapist.

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An interactive H5P element has been excluded from this version of the text. You can view it online here:
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An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=183#h5p-13

Cleaning, Disinfection, and Sterilization

Health care settings have multiple people and pieces of equipment continuously coming in and out of the environment. Each of these individuals and items can potentially introduce new microorganisms into the environment. They may bring in infectious microorganisms, visit infectious clients, or touch contaminated surfaces. The continuous movement of people within the health care setting and their continuous interactions with the environment increase the risk of transmission of infectious agents.

One way to decrease the transmission of infectious agents is effective cleaning and disinfecting of the health care environments (e.g., table surfaces, clients' personal items, medical equipment; see Figure 7[11]). Routine cleaning and disinfecting practices can help to reduce the transmission of microorganisms and decrease the risk of health care-associated infections (HAIs). It is essential for health care providers to understand the various risks of transmission, the required cleaning, disinfection, or sterilization needed according to the setting and the cleaning products to use according to agency policies.

Figure 7. Health care worker using cleaning spray.

Before cleaning any surface, you need to determine what type of cleaning agent and disinfectant is compatible with the equipment. Familiarize yourself with your institutional policies and check manufacturer instructions (e.g., dilution rates, contact time, frequency, compatibility, safety considerations) if unsure. Identify and label

11. "pexels-matilda-wormwood-4099467" by Matlida Wormwood via Pexels.com is licensed under CC0

any damaged equipment, and report it to the proper department (e.g., environmental services manager, occupational health department). All equipment should come with the manufacturer's instructions for assembling/disassembling and cleaning (e.g., mechanical lifts, hospital beds, wheelchairs, ventilators). Cleaning agents and disinfectants required for medical equipment or surfaces should be readily available and approved for use at the health care setting according to the infection prevention and control guidelines.

Cleaning refers to the physical removal and reduction of foreign (e.g., dust, soil, grease, oils) and organic (e.g., blood, body secretion, microorganisms) materials from a surface through the use of mechanical action, water, and detergents. Cleaning is the first step in reprocessing, and if not performed correctly, all other steps are invalidated. Cleaning can be a one-step (e.g., soap and water) or two-step (e.g., bleach [sodium hypochlorite] and hydrogen peroxide cleaner disinfectant wipes) process depending on the surface, type of microorganism, and amount of contamination. The physical movement of friction is key when cleaning a surface area.

Disinfecting refers to the process of deactivating and killing most microorganisms (usually not effective against spores) through the use of disinfectants. High-level disinfection is used for semi-critical respiratory items. Examples include bronchoscopes, laryngoscope blades, temperature probes, and resuscitation bags. There is no one disinfectant solution that will work for every microorganism and in every setting. Examples of disinfectants include alcohol, hydrogen peroxide, bleach, iodophors, phenolics, and quaternary ammonium.

Sterilization refers to the process of killing all microorganisms through a physical (steam autoclave) or chemical (ethylene oxide) means. Medical devices contacting sterile body tissues or fluids are critical items and should be sterile before use.

Mode of Transmission

The mode of transmission is how the infectious agent travels and spreads from one person to another, either directly or indirectly.

These include:

- **Contact transmission** — Occurs directly by touching an infectious client with your hands, or indirectly by touching fomites, which are items or medical equipment that are contaminated with the infectious agent.
- **Droplet transmission** — Occurs through respiratory secretions from talking, sneezing, coughing, or laughing; droplets can travel up to 2 meters.
- **Airborne transmission** — Occurs through small nuclei traveling on air currents for long distances (over 2 meters).
- **Vehicle transmission** — Occurs through vehicles such as water, food, or air.
- **Vector transmission** — Occurs through living organisms that can transmit the infectious agent between humans biologically (e.g., mosquitoes) or mechanically from an animal to a human (e.g., fly or tick).[12]

12. Hughes, M., Kenmir, A., St-Amant, O., Cosgrove, C., & Sharpe, G. (2021). *Introduction to infection prevention and control practices for the interprofessional learner*. OER Commons. https://ecampusontario.pressbooks.pub/introductiontoipcp/

View the following supplementary YouTube video[13] that describes modes of disease transmission in more detail: [Modes of Transmission Explained | Lecurio Nursing Public Health](https://www.youtube.com/watch?v=QALD1Xexn8M&t=29s)

Chain of Transmission

An infectious agent is also known as a pathogen and causes the disease in the host. The reservoir can be a living organism or inanimate object where the infectious agent lives, survives, and has the ability to multiply and grow. The portal of exit is how the infectious agent leaves the reservoir or host. The mode of transmission is how the infectious agent travels and spreads from one person to another, either directly or indirectly. The portal of entry is how the infectious agent enters another person's body or new host. A susceptible host is anyone who is at risk of the infectious agent. However, some individuals are more susceptible than others.

In the activity below, drag the description over the correct term.

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Isolation Precautions

When a patient is suspected or confirmed to have an infectious pathogen, health care workers must implement additional precautions beyond routine practices to prevent the spread of infection. These precautions are determined by the mode of transmission, which can be categorized as **standard**, **contact**, **droplet**, or **airborne**.

13. Lecturio Nursing. (2023, January 14). *Modes of transmission explained | Lecurio Nursing Public Health* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=QALD1Xexn8M&t=29s

Standard Precautions

Standard precautions are a set of infection control practices used to prevent transmission of diseases that can be acquired by contact with blood, body fluids, non-intact skin (including rashes), and mucous membranes. These measures are to be used when providing care to all individuals, whether or not they appear infectious or symptomatic. These include hand hygiene, PPE, sharps and needlestick prevention, cleaning and disinfection, respiratory hygiene, and waste disposal.[14]

Types of Additional/Isolation Precautions

There are three categories of additional precautions: contact precautions, droplet precautions, and airborne precautions.

Contact precautions are the most common type of additional precautions. They are used in addition to routine practice for patients who are known or suspected to be infected with microorganisms that can be transferred by direct (touching) or indirect (shared equipment) contact. Types of organisms in this category are antibiotic-resistant organisms (AROs) such as *methicillin-resistant Staphylococcus aureus* (MRSA), *vancomycin-resistant Enterococci* (VRE), extended spectrum *beta-lactamase* (ESBL), *Clostridium difficile* (CDI), carbapenemase-producing organisms (CPO), diarrhea, and scabies. AROs are also known as multi-drug-resistant organisms (MDROs). If the patient is on contact precautions, you need to wear gloves and a gown if your skin or clothing will come into direct or indirect contact with the client or the contaminated environment.

Droplet precautions are used in addition to routine practices for patients who are known or suspected to be infected with microorganisms that are spread through the air by large droplets. Types of organisms and unconfirmed conditions in this category include mumps, influenza, vomiting of unknown cause, norovirus, and unconfirmed cough. If the patient is on droplet precautions, you need to wear a gown, gloves, mask and eye protection.

Airborne precautions are used in addition to routine practices for patients who are known to have or are suspected of having an illness that is transmitted by small droplet nuclei that may stay suspended in the air and be inhaled by others. These particles can remain infectious for a long period of time when spread through the air. Types of organisms in this category include tuberculosis (TB), measles, chicken pox (varicella), disseminated zoster, and severe acute respiratory syndrome (SARS). If the patient is on airborne precautions, the patient must be placed in a negative-pressure room, and you must wear a fit-tested N95 respirator mask, gown, gloves and eye protection.

The type of hand hygiene required depends on the diagnosis. For example, you can use an alcohol-based hand gel for clients diagnosed with influenza or MRSA. However, for clients diagnosed with C. difficile, you need to wash your hands with soap and water (see Figure 8[15]).[16]

14. Ernstmeyer, K., & Christman, E. (Eds.). (2024). *Nursing fundamentals 2E*. Open RN | WisTech Open. https://wtcs.pressbooks.pub/nursingfundamentals/

15. "Hand_Hygiene" by BruceBlaus is licensed under CC BY-SA 4.0

16. Wisconsin Department of Human Services. (n.d.). *Healthcare-associated infections: Precautions.* https://www.dhs.wisconsin.gov/hai/precautions.htm#:~:text=Standard%20precautions%20are%20a%20set,rashes)%2C%20and%20mucous%20membranes

Figure 8. Hand hygiene process with soap and water.

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An interactive H5P element has been excluded from this version of the text. You can view it online here:
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2.2 Lab Activities

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2.3 Critical Thinking Assessment

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3.1 Patient Safety and Communication

By focusing on key aspects of patient safety, such as emergency responses and evacuation, and understanding patient positioning and restraints, respiratory therapy students can develop a strong foundation for delivering safe and effective care to patients with respiratory conditions.

Patient Safety

Evacuation

In the event of a fire or other emergency situations, it is crucial to prioritize patient safety. You should always know the established safety plans for the health care facility and follow designated evacuation routes and assist patients as needed.

Both vertical and horizontal evacuations are essential components of an effective emergency evacuation plan, and the appropriate approach will depend on the specific circumstances and nature of the emergency. The goal is to ensure the safety and well-being of individuals by efficiently relocating them to a secure area or outside of the danger zone, minimizing the potential for harm during an emergency or disaster.

Vertical evacuation involves moving individuals from one level of a building or structure to another, typically in a vertical direction, such as going up or down stairs or using elevators. This approach is used when it's safer to move individuals within the building rather than directly outside. Vertical evacuation is often necessary in multistory health care facilities or structures with designated safe areas on different floors. Oftentimes a special chair or cot is used to move patients from one level to another (see Figure 9[1]).

1. "Evac_chair" by Daniel Morris is licensed under CC BY-SA 2.0

Figure 9. Vertical evacuation signage.

Example Scenarios

- Evacuating from lower to higher floors in a building to escape flooding or rising water levels.
- Moving to upper floors to avoid hazards such as fire or chemical leaks on lower levels.

Horizontal evacuation involves moving individuals horizontally or laterally, typically from one area of a building or facility to another on the same level or to an adjacent building. The purpose of horizontal evacuation is to move people away from an immediate threat while remaining on the same level. This approach is often used when it's unsafe to go up or down stairs or when exiting the building is not yet necessary.

Example Scenarios

- Moving from one wing of a building to another to escape a localized fire or hazardous materials leak.
- Relocating to a neighboring building or area to avoid a threat in the current facility, such as an explosive device or structural instability.

Fire Safety

The RACE protocol (see Figure 10[2]) serves as a guideline for responding to fires in health care facilities.

While the RACE acronym has a priority order, understand that these should ideally be done at the same time by multiple staff members. By taking a divide-and-conquer mentality, you will help ensure the safety of the staff and patients.

Rescue

The first step in the RACE protocol is to rescue individuals from immediate danger. If it is safe to do so, assist patients in evacuating the affected area. Remember to prioritize those who have difficulty moving or require additional assistance.

If you are evacuating residents from their rooms, make sure to tag the doors so the next person knows the room has been evacuated.

Alarm

Once individuals have been removed from the immediate danger zone, it is essential to activate the fire alarm system. Activate the nearest fire alarm pull station to alert other occupants and staff members about the fire. Promptly notifying everyone in the facility helps ensure a swift response and initiates the evacuation process.

You should follow the facility's processes for notifying emergency providers such as the fire department and emergency responders.

Contain

After sounding the alarm, take steps to confine the fire. Close any doors or windows in the area if it can be done safely and without risking personal harm. Confining the fire helps limit its spread and provides more time for evacuation and the arrival of emergency responders. However, only attempt this if you can do so without endangering yourself or others.

Extinguish or Evacuate

The last step in the RACE protocol depends on the severity of the fire and the resources available. If the fire is small and can be safely extinguished using a portable fire extinguisher, follow the appropriate protocols for its use. However, remember that personal safety should always take precedence over attempting to extinguish the fire.[3]

2. "R.A.C.E Acronym for How To Respond To A Fire First Response Safety Training.png" by Matt Esner is reused with permission. https://www.firstresponsecpr.com/blog/child-care-fire-evacuation/
3. Go, C. (2023). *Elder care facility fire safety tips, resources, & training*. First Response Safety Training. https://www.firstresponsecpr.com/blog/elder-care-fire-safety-tips/

Figure 10. RACE fire safety signage. Reused with permission.

Understanding the proper operation of fire extinguishers is crucial. (See Figure 11.[4]) The PASS acronym provides a helpful reminder of these steps to follow when using a fire extinguisher:

4. "FireExtinguisherABC" by Dante Alighieri is licensed under CC BY-NC-SA 2.0

Figure 11. Amerex brand fire extinguisher often found in health care facilities.

Pull the Pin

The first step of the PASS acronym is to pull the pin. This pin is usually located on the top of the fire extinguisher and is designed to prevent accidental discharge. By pulling the pin, you are preparing the extinguisher for immediate use, ensuring that it is ready to be deployed to suppress the fire.

Aim at the Base of the Fire

Once the pin is pulled, the next step is to aim at the base of the fire. The base of the fire is the area where the flames are originating. It is crucial to direct the extinguishing agent at the base because that's where the fuel source is located. By aiming at the base, you can effectively smother the fire and cut off its oxygen supply, aiding in its suppression.

Squeeze the Handle

After aiming at the base of the fire, firmly squeeze the handle of the fire extinguisher. Squeezing the handle activates the discharge mechanism, allowing the extinguishing agent to be expelled. It is essential to maintain a steady grip on the handle while squeezing it to control the flow of the extinguishing agent.

Sweep from Side to Side

While continuing to aim at the base of the fire, sweep the fire extinguisher from side to side. This sweeping motion ensures that the extinguishing agent covers the entire fire, effectively smothering it. By sweeping, you can prevent the fire from reigniting or spreading. It is important to cover the entire fire area with the extinguishing agent to ensure its complete suppression.[5]

View the following supplemental YouTube video[6] for a demonstration of the proper use of a fire extinguisher using the PASS method: [How to use a fire extinguisher using the PASS method](https://www.youtube.com/watch?v=PQV71INDaqY)

Restraints

Restraints are devices used in health care settings to prevent patients from causing harm to themselves or others when alternative interventions are not effective. Any restraint requires a valid provider order and time frame for use. A restraint is a device, method, or process that is used for the specific purpose of restricting a patient's freedom of movement without the permission of the person. These include mechanical devices such as a **tie wrist device**, **mitt type device**, **chemical restraints**, or **seclusion**.

The Joint Commission defines chemical restraint as a drug used to manage a patient's behavior, restrict the patient's freedom of movement, or impair the patient's ability to appropriately interact with their surroundings that is not standard treatment or dosage for the patient's condition. It is important to note that the definition states the medication "is not standard treatment or dosage for the patient's condition."

Seclusion is defined as the confinement of a patient in a locked room from which they cannot exit on their own. It is generally used as a method of discipline, convenience, or coercion. Seclusion limits freedom of movement because, although the patient is not mechanically restrained, they cannot leave the area.

Although restraints are used with the intention to keep a patient safe, they impact a patient's psychological safety and dignity and can cause additional safety issues and death. A restrained person has a natural tendency to struggle and try to remove the restraint and can fall or become fatally entangled in the restraint. Furthermore, immobility that results from the use of restraints can cause pressure injuries, contractures, and muscle loss. Restraints take a large emotional toll on the patient's self-esteem and may cause humiliation, fear, and anger. Respiratory therapy patients who are intubated for ventilation are typically restrained to prevent them from removing or dislodging their endotracheal tube.

Once restrained, the patient should be treated with humane care that preserves human dignity. In those instances where restraint, seclusion, or therapeutic holding is determined to be clinically appropriate and adequately justified, health care providers who possess the necessary knowledge and skills to effectively manage the situation must be actively involved in the assessment, implementation, and evaluation of the selected emergency measure, adhering to federal regulations and the standards of The Joint Commission regarding appropriate use of restraints and seclusion.

Side rails and enclosed beds may also be considered a restraint, depending on the purpose of the device. Recall the definition of a restraint as "a device, method, or process that is used for the specific purpose of

5. Go, C. (2023). *Elder care facility fire safety tips, resources, & training*. First Response Safety Training. https://www.firstresponsecpr.com/blog/elder-care-fire-safety-tips/

6. CQ Fire & Safety. (2020, September 22). *How to use a fire extinguisher using the PASS method* [Video]. YouTube. https://www.youtube.com/watch?v=PQV71INDaqY

restricting a patient's freedom of movement or access to movement without the permission of the person." If the purpose of raising the side rails is to prevent a patient from voluntarily getting out of bed or attempting to exit the bed, then use of the side rails would be considered a restraint. On the other hand, if the purpose of raising the side rails is to prevent the patient from inadvertently falling out of bed, then it is not considered a restraint. If a patient does not have the physical capacity to get out of bed, regardless of whether or not side rails are raised, then the use of side rails is not considered a restraint.

A hand mitt is a large, soft glove that covers a confused patient's hand to prevent them from inadvertently dislodging medical equipment (see Figure 12[7]). Hand mitts are considered a restraint by The Joint Commission if used under these circumstances:

- Are pinned or otherwise attached to the bed or bedding
- Are applied tightly so that the patient's hands or finger are immobilized
- Are bulky so that the patient's ability to use their hands is significantly reduced
- Cannot be easily removed intentionally by the patient in the same manner it was applied by staff, considering the patient's physical condition and ability to accomplish the objective[8]

Figure 12. Mitt type restraint.

7. "Hand Mitt" by Myra Reuter for [Chippewa Valley Technical College](#) is licensed under [CC BY 4.0](#)

8. Ernstmeyer, K., & Christman, E. (Eds.). (2024). *Nursing fundamentals 2E*. Open RN | WisTech Open. https://wtcs.pressbooks.pub/nursingfundamentals/

Patient Positioning

Proper patient positioning is crucial for ensuring both comfort and safety during medical procedures, treatments, or daily care. Careful consideration of the patient's condition, mobility, and specific requirements is essential to prevent discomfort, pressure injuries, and other potential risks, thus promoting a safe and conducive healing environment. Positioning a patient in bed is a common procedure in the hospital. There are various positions possible for patients in bed, which may be determined by their condition, preference, or treatment related to an illness.

Figure 13. Supine position.

The patient lying flat on their back is considered supine (see Figure 13[9]). Additional supportive devices may be added for comfort.

Figure 14. Prone position.

The patient lying on the stomach with their head turned to the side is considered prone (see Figure 14[10]). Patient can be placed in prone position to help with oxygenation.

9. "Supine_position.jpg" by Glynda Rees Doyle and Jodie Anita McCutcheon is licensed under CC BY 4.0
10. "Prone_position.jpg" by Glynda Rees Doyle and Jodie Anita McCutcheon is licensed under CC BY 4.0

Figure 15. Lateral position.

The patient lying on the side of their body with the top leg over the bottom leg is considered lateral (see Figure 15[11]). This position helps relieve pressure on the coccyx.

Figure 16. Fowler's position.

Fowler's position is when the patient's head of the bed is placed at a 45-degree angle (see Figure 16[12]). Their hips may or may not be flexed. This is a common position to provide patient comfort and care. Respiratory therapists utilize this position to help with common therapies such as hyperinflation and bronchial hygiene.

Figure 17. Semi-Fowler's position.

Semi-Fowler's position is when the patient's head of the bed is placed at a 30-degree angle (see Figure

11. "[Lateral_position.jpg]" by Glynda Rees Doyle and Jodie Anita McCutcheon is licensed under [CC BY 4.0]

12. "[Fowler%27s_Position.jpg]" by Glynda Rees Doyle and Jodie Anita McCutcheon is licensed under [CC BY 4.0]

17[13]). This position is used for patients who are on mechanical ventilation, or have cardiac or respiratory conditions.

Figure 18. Trendelenburg position.

Placing the head of the bed lower than the feet is considered the Trendelenburg position (see Figure 18[14]). This position is used in situations such as hypotension and medical emergencies. It helps promote venous return to major organs such as the head and heart. Respiratory therapists may use this position for postural drainage, percussion and vibration to promote secretion mobilization in certain lung segments.

Communication

Therapeutic communication is a type of professional communication used by health care providers with patients and defined as, "The purposeful, interpersonal information-transmitting process through words and behaviors based on both parties' knowledge, attitudes, and skills, which leads to patient understanding and participation."

When communicating with patients and family members, take note of your audience and adapt your message based on their characteristics such as age, developmental level, cognitive abilities, and any communication disorders. For patients with language differences, it is vital to provide trained medical interpreters when important information is communicated.

Adapting communication according to the patient's age and developmental level includes the following strategies:

- When communicating with children, speak calmly and gently. It is often helpful to demonstrate what will be done during a procedure on a doll or stuffed animal. To establish trust, try using play or drawing pictures.
- When communicating with adolescents, give freedom to make choices within established limits.
- When communicating with older adults, be aware of potential vision and hearing impairments that commonly occur and address these barriers accordingly. For example, if a patient has glasses and/or hearing aids, be sure these devices are in place before.

When communicating with any age, be an active listener. Active listening is a type of listening that shows you

13. "Semi-Fowler%27s_position.jpg" by Glynda Rees Doyle and Jodie Anita McCutcheon is licensed under CC BY 4.0

14. "Trendelenburg_position.jpg" by Glynda Rees Doyle and Jodie Anita McCutcheon is licensed under CC BY 4.0

are engaged in the conversation and that you hear and understand what the client is saying. Active listening is important to facilitate your understanding of, and the integration of, client's experiences, preferences, and health goals into their care. Being at eye level with a patient is beneficial in fostering effective communication and building rapport (see Figure 19[15]). This approach helps create a sense of connection, making the patient feel heard, respected, and valued. Maintaining eye contact at the same level can also reduce feelings of intimidation or anxiety, particularly in vulnerable situations. Additionally, it allows health care providers to better assess the patient's facial expressions, emotions, and overall comfort, leading to more patient-centered and compassionate care.

Figure 19. Health care worker interviewing patient.

Focused Health History

Taking a patient history is crucial in understanding the patient's medical background, current health status, lifestyle, and symptoms. This information helps health care professionals formulate an accurate diagnosis, develop appropriate treatment plans, and provide tailored care. Additionally, understanding a patient's medical history enables identification of potential risk factors, allergies, and contraindications for certain treatments,

15. "BP3I7661-2048×1365.jpg" by Nick Pearce is licensed under CC BY-NC-SA 4.0. Access for free at https://caul-cbua.pressbooks.pub/diversityexchange/

ensuring safe and effective health care delivery. It also establishes a foundation for building a trusted patient-provider relationship and promotes shared decision-making in the management of the patient's health.

The components of a focused health history include the following: demographic data, childhood diseases and development, hospitalizations, surgeries, injuries, accidents, and major illnesses. Additionally, questions should focus on allergies, medications, immunizations, general health, and previous sources of health care. Questions should also touch on family history; familial disease history; and social and environmental history, including alcohol, drug, smoking history, and satisfaction/stress with life situations that might affect health. A complete review of systems (ROS) should be conducted as well. The ROS provides subjective data or that which is evident only to the patient and cannot be perceived by an observer and can only be described by the patient.

The provider conducting the focused health history should use open-ended questions that encourage patients to describe events and symptoms, and they should use clarifying questions to get a complete patient description of their concerns. Interviews should be conducted with empathy, and a relaxed conversational style of speaking is helpful to mitigate patient anxiety.[16]

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https://wtcs.pressbooks.pub/respiratorysurvey/?p=189#h5p-119

16. Doyle, G. R. & McCutcheon, J. A. (2015). *Clinical procedures for safer patient care*. BCcampus. https://opentextbc.ca/clinicalskills/

3.2 Lab Activities

3.2a Positioning Activity

1. During the first half of your laboratory time, practice patient safety with transfers from a bed position to the standing position using a gait belt. Place your lab partners into the following positions: Fowlers, Semi-Fowlers, Trendelenburg, reverse Trendelenburg, lateral, prone, and supine. You will take a photo of each position and upload it to the LMS Assignment area.
2. During the second half of your laboratory time, start a list of questions on a separate piece of paper for your focused health history assignment for the "Interview Your Patient" lab activity that will be done the following week. See the "Interview Your Patient" lab activity for directions below. In addition, research one of the following diseases to prepare the "patient" answers to the focused health history. Diseases to choose from are asthma, COPD, bronchiectasis, pulmonary fibrosis, cystic fibrosis, and congestive heart failure. The "patient" answers should reflect likely responses to the chosen disease.

3.2b Interview Your Patient Activity

Ask your "patient" lab partner a series of questions to collect their complete focused health history.

You will need to create a set of questions on a separate piece of paper to "obtain a focused health history" during lab time. These questions should be VERY complete so the interview you perform takes at least 30-40 minutes. Remember, "Yes" or "No" questions are fine, but will need follow-up questions. You are designing your questions to get the information you need, and the more information you get, the better.

Example: Asking someone, "Do you smoke?" may not give you all the answers. If the patient answers "No," what will your follow-up questions be? How about, "Have you ever smoked?" "How old were you when you quit?" "How old were you when you started?" "What did you smoke?" or "How many packs a day did you average?"

We are focusing on the subjective portion of the SOAP note for this exercise. The SOAP note is how medical histories are written when documenting. **S** stands for "subjective data," **O** stands for "objective data," **A** stands for "assessment of data," and **P** stands for "plan of action for patient care."

Use this template to come up with questions to ask your "patient" during lab time:

3.2b Interview Your Patient

3.3 Critical Thinking Assessment

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4.1 Patient Assessment

Basic Vital Signs

You will learn about various vital signs, including temperature, pulse, respiration, blood pressure, oxygen saturation, and pain. Measurement of vital signs is a foundational psychomotor skill for health care providers and students in post-secondary health-related programs such as respiratory therapy. These measurements provide information about a person's overall state of health and, more specifically, about their cardiovascular and respiratory statuses. These measurements can also reveal changes in a patient's vital signs over time and changes in their overall state of health. Proficiency in vital sign measurement is essential to patient safety, care, and management. Measurements can influence clinical decision-making related to therapeutic interventions.

Determining the significance of vital sign measurements involves a process of diagnostic reasoning. The respiratory therapy student needs to know whether the patient's vital signs are normal or abnormal and whether the findings are significant to make appropriate treatment choices.

Additionally, the respiratory therapy student considers the patient's baseline vital signs to obtain a better sense of the patient's "normal" and to allow comparison (i.e., trends) over time. Typically, these trends can be assessed using a vital sign monitor (see Figure 20[1]).

Figure 20. Photo of a health care vital sign patient monitor.

1. "Unstable-VS-Monitor.png" by unknown author is reused under Fair Use. https://rebelem.com/topics-in-post-rosc-care/

Temperature

The human body's core temperature (internal body temperature) is measured in degrees Celsius (°C) or Fahrenheit (°F). In adults, the normal body temperature is 98.6°F or 37°C. It is slightly higher in children because of a higher metabolic rate. Important terms to know are hypothermia, which is low body temperature, and hyperthermia, which is a high body temperature. A person with a normal body temperature is afebrile, and a person with a fever or elevated body temperature is known as febrile. Temperature can be taken by several types of thermometers including tympanic or temporal (see Figures 21[2] and 22[3]).

Figure 21. Tympanic temperature probe.

2. "Tympanic-Thermometer-768×512" by unknown author is licensed under CC BY 4.0. Access for free at https://opentextbc.ca/vitalsignmeasurement/chapter/tympanic-temperature/

3. "Temporal Atery Thermometer" by Nic Ashman, WisTech Open is licensed under CC BY-NC 4.0

Figure 22. Temporal artery professional thermometer.

Pulse/Respiration

Pulse and respiration are discussed together because these vital signs are taken in succession.

Pulse

Pulse refers to a pressure wave that expands and recoils the artery when the heart contracts/beats. It is palpated at many points throughout the body. Pulse can be measured in many locations; the most common locations to accurately assess pulse as part of vital sign measurement include radial, brachial, and carotid. When determining the best location, health care providers consider the patient's age and health and illness state, as well as the reason for taking the pulse.

Pulse is measured in beats per minute, and the normal adult pulse rate (heart rate) at rest is 60–100 beats per minute. The pulse rhythm, rate, force, and equality are assessed when palpating pulses.

Use the pads of your first three fingers to gently palpate the radial pulse (see Figure 23[4]). The pads of the fingers are placed along the radius bone, which is on the lateral side of the wrist (the thumb side; the bone on the other side of the wrist is the ulnar bone). Place your fingers on the radius bone close to the flexor aspect of the wrist, where the wrist meets the hand and bends.

4. "radial-pulse" by unknown author is licensed under CC BY 4.0. Access for free at https://pressbooks.library.torontomu.ca/vitalsign/

Figure 23. Palpation of the radial pulse.

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Some terms that are helpful when assessing the pulse are **bradycardia**, a slow heart rate; **tachycardia**, a high heart rate; **pulsus paradoxus**, a pulse that becomes weaker on inspiration; and **pulsus alternans**, an alternating pattern of strong and weak pulses.

Respiration

Respiration refers to a person's breathing and the movement of air into and out of the lungs. The respiratory system provides oxygen to body tissues for cellular respiration, removes the waste product carbon dioxide, and helps maintain acid–base balance. A respiratory cycle (or one breath while you are measuring respiratory rate) is one sequence of inspiration and expiration. The normal adult respiratory rate is 12-20 breaths per minute.

The respiratory rate is counted after taking the pulse rate so that the patient is not aware that you are taking it. Once you have finished counting the pulse, leave your fingers in place and then begin assessing respiration. You should keep your fingers on the pulse while counting the respiratory rate to avoid alerting the patient, as they may unconsciously change their breathing pattern if they realize they are being observed. Observe the chest or abdomen rise and fall. One respiration includes a full respiratory cycle. Count for 30 seconds if the rhythm is regular or for a full minute if irregular. Respiration is assessed for quality, rhythm, and rate. Report the respiration as breaths per minute, as well as whether breathing is relaxed, silent, and has a regular rhythm. Report whether chest movement is symmetrical.

Measurement of pulse and respiration is important because these vital signs provide current data about the patient's health and illness state. Changes in pulse and respiration act as cues for health care providers' diagnostic reasoning and can be assessed for impending respiratory distress or respiratory failure (see Figure 24[5]).

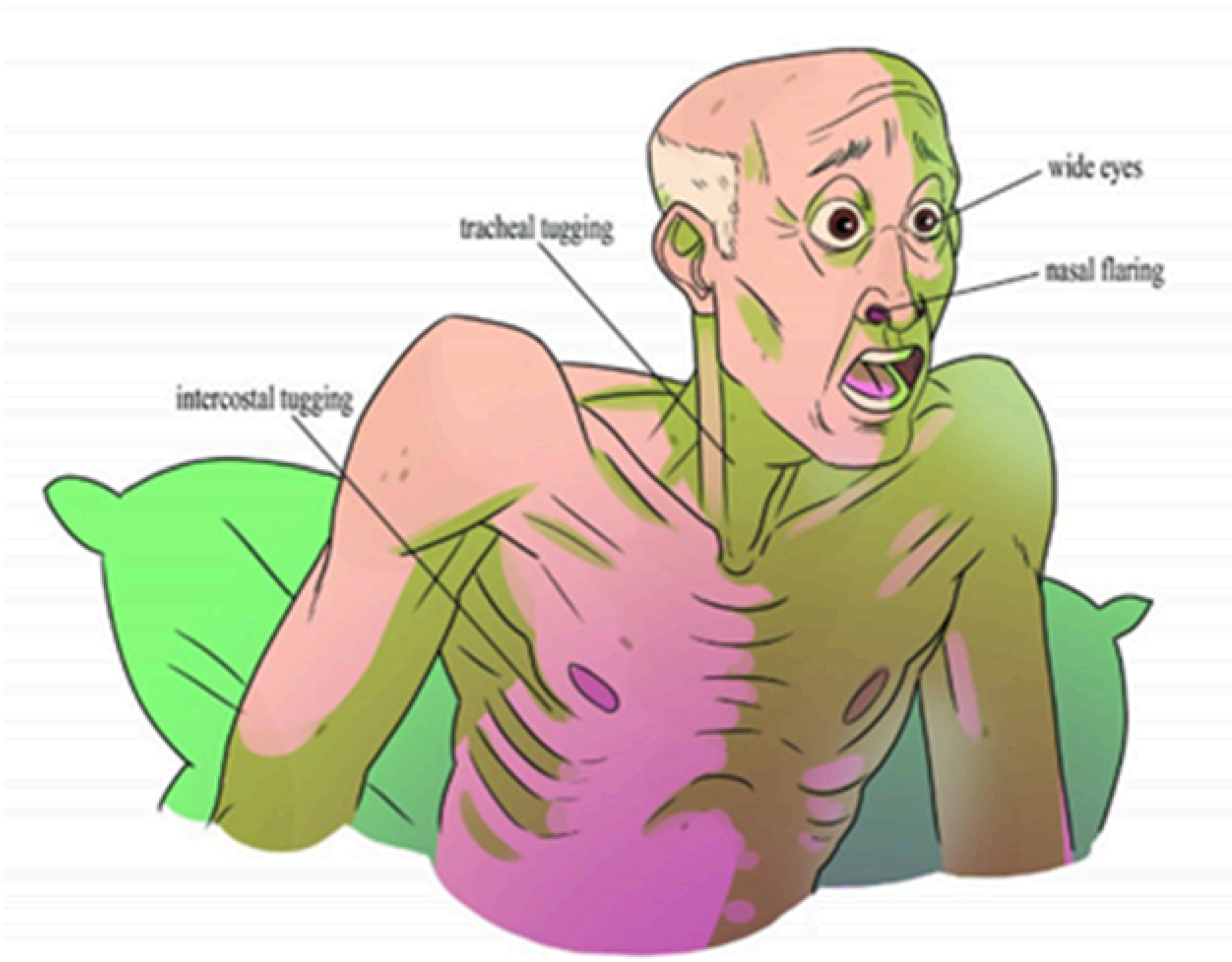

Figure 24. Signs of respiratory distress.

5. "Figure-3.6-Signs-of-respiratory-distress-final-1024×813.jpg" by Paige Jones is licensed under CC BY 4.0. Access for free at https://pressbooks.library.torontomu.ca/vitalsign/

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When determining the relevance of pulse and respiration data, health care providers consider the patient's baseline data and the situation. Diagnostic reasoning about pulse and respiration always considers additional information, including other vital sign measurements and subjective and objective patient data.

Blood Pressure

Manual blood pressure measurement is taken using a blood pressure cuff with a sphygmomanometer and a stethoscope. Blood pressure is reported in mm Hg, in which the systolic is the numerator and diastolic is the denominator. The normal average blood pressure for an adult is 120/80 mm Hg.

A health care provider uses a stethoscope and a blood pressure cuff with a sphygmomanometer to measure blood pressure manually (see Figure 25[6]). The stethoscope is used to listen to the blood pressure sounds, which are called Korotkoff sounds.

To measure a blood pressure, inflate the blood pressure cuff until the pulse is no longer felt, and then quickly continue to inflate 30 mm Hg more. Place the bell of the cleansed stethoscope over the brachial artery using a light touch with a complete seal. Open the valve slightly. Deflate the cuff slowly and evenly at about 2 mm Hg per second. Note the points at which you hear the first Korotkoff sound (systolic blood pressure) and the point in which the Korotkoff sounds go silent (diastolic blood pressure). Health care workers are sometimes trained in a two-step method for obtaining blood pressure. Either method is appropriate if done correctly.

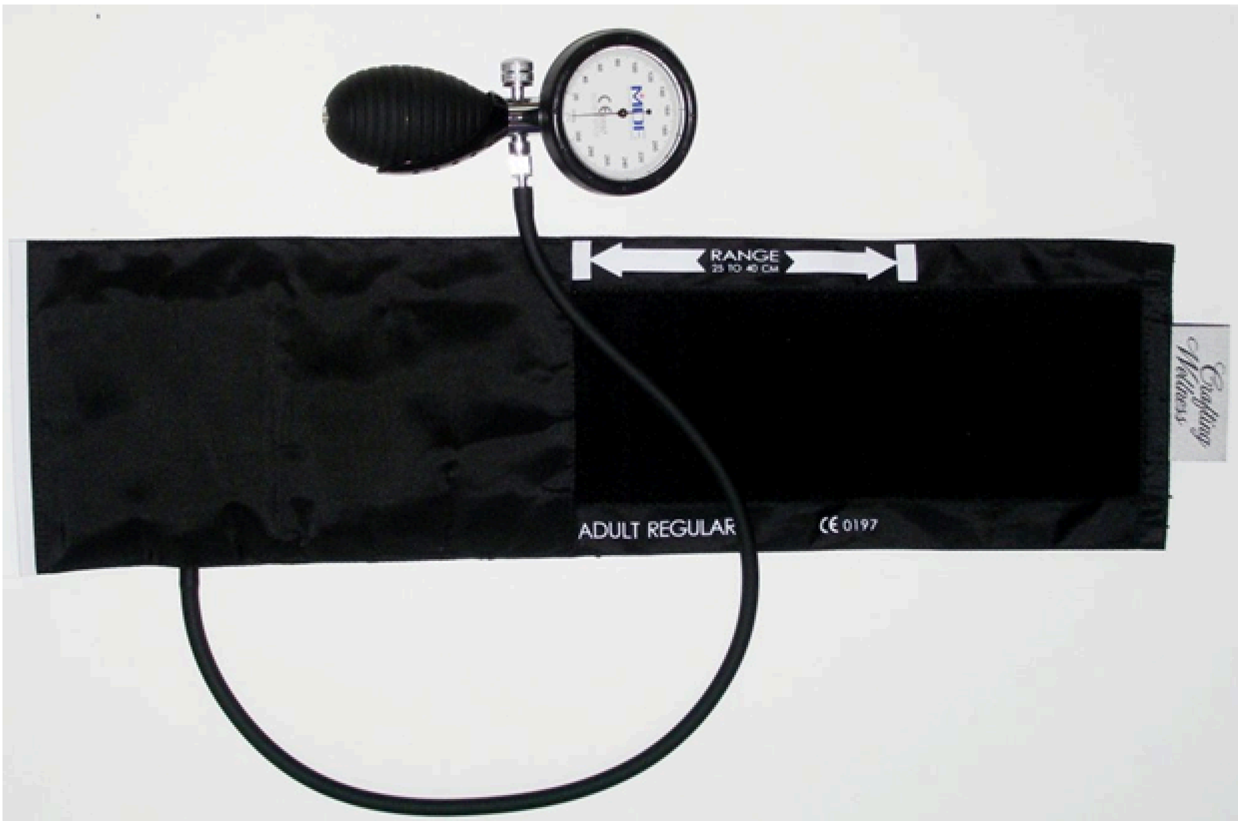

Figure 25. Manual blood pressure cuff.

Blood pressure measurement is important because it provides objective data about the patient's health and illness state. Changes in blood pressure act as a cue for health care providers' diagnostic reasoning. Blood pressure fluctuates with internal and external factors. Therefore, it is essential to take multiple measurements before making clinical decisions and to ensure the patient is in the proper body position, with their legs uncrossed and their arms relaxed.

6. "Sphygmomanometer&Cuff.JPG" by ML5 is in the Public Domain.

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Oxygen Saturation

Health care providers measure oxygen saturation because it provides information about a patient's state of health. The body's tissues and organs require oxygen for metabolism, and oxygen saturation can reveal whether there is sufficient oxygen in the blood or whether the patient is in a state called hypoxemia (insufficient oxygen in the blood).

Measuring oxygen saturation via pulse oximetry is a noninvasive way to quickly assess a patient's oxygen level and can influence clinical decisions about whether the patient is receiving sufficient oxygen and/or requires supplemental oxygen.

A pulse oximetry device includes a sensor that measures light absorption of hemoglobin and represents arterial SpO2. Oxyhemoglobin and deoxygenated hemoglobin absorb light differently. The sensor measures the relative amount of light absorbed by oxyhemoglobin and deoxygenated (reduced) hemoglobin and compares the amount of light emitted to light absorbed. This comparison is then converted to a ratio and is expressed as a percentage of SpO2. (See Figure 26[7]).

The normal oxygen saturation level for an adult is 95–100%. Older adults typically have lower oxygen saturation levels than younger adults. It is important to note that the oxygen saturation level varies considerably based on a person's state of health. Keep in mind that oxygen saturation readings can be overestimated or underestimated due to skin pigmentation. Therefore, it is important to consider this as just one part of trending a person's state of health. Thus, it is important to understand both baseline readings and underlying physiology associated with certain conditions to interpret oxygen saturation levels and changes in these levels. The term "SATS" is often used as a shorthand for oxygen saturation, but it should not be pronounced as "STATS."

7. "02-Sat-Apparatus-1-1024×682.jpg" by unknown author is licensed under CC BY 4.0. Access for free at https://pressbooks.library.torontomu.ca/vitalsign/

Figure 26. Portable pulse oximeter.

The sensor can be attached in many ways, including clipping and taping probes to the finger, toe, earlobe, and forehead. The type and location of the apparatus are selected based on the patient's age, the presence of vasoconstriction, the adequacy of peripheral perfusion, whether intermittent or continuous monitoring is required, and the patient's health and illness state.

When determining the relevance of the oxygen saturation reading, health care providers consider the patient's health and wellness state. Specifically, they consider other data related to oxygenation, including respiratory quality, rate, and rhythm; pulse; skin color and temperature; and the patient's subjective description of ease or difficulty breathing. Decreases in oxygen saturation readings are potentially life-threatening and require immediate intervention[8].

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8. Ernstmeyer, K., & Christman, E. (Eds.). (2023). *Nursing skills 2e*. Open RN. https://wtcs.pressbooks.pub/nursingskills/

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The Pulmonary Exam[9]

The pulmonary exam allows the respiratory therapist to gather valuable information for diagnosing respiratory conditions, developing treatment plans, and monitoring the patient's progress. Collaboration with other health care professionals is crucial for comprehensive patient care. The exam involves a series of evaluations to assess the patient's respiratory function and lung health. The assessment includes inspection, palpation, percussion, and auscultation.

Inspection

During the inspection, the respiratory therapist should pay attention to the pattern of breathing: thoracic breathing, thoracoabdominal breathing, costal markings, and use of accessory breathing muscles. The use of accessory breathing muscles (i.e., scalene muscles, sternocleidomastoid muscle, intercostal muscles) could point to excessive breathing effort caused by pathologies. The body habitus or visual appearance of the patient's body could provide information regarding chest compliance, especially in the case of severely obese patients where chest mobility and compliance are reduced due to added weight from excess tissue.

The position of the patient should also be noted. Patients with extreme pulmonary dysfunction will often sit upright, be in distress, and assume the tripod position (leaning forward, resting their hands on their knees). Additionally, the respiratory therapist should look for capillary refill of the nail beds and clubbing of the fingers, which indicate chronic hypoxemia, pedal edema, and fluid overload.

Pursed-lip breathing is a common technique observed in patients with chronic obstructive pulmonary disease (COPD), as it helps to improve air exchange and reduce breathlessness. During patient interviews, the inability to speak in full sentences or the onset of shortness of breath can indicate diminished pulmonary function or reduced respiratory reserve. These signs are clinically significant, as they may reflect advanced disease progression or compromised lung capacity.

Skeletal chest abnormalities should also be noted during the inspection. The most common chest

9. Ernstmeyer, K., & Christman, E. (Eds.). (2023). *Nursing skills 2e*. Open RN. https://wtcs.pressbooks.pub/nursingskills/

abnormality is pectus excavatum, where the sternum is depressed into the chest cavity (see Figure 27[10]). Pectus carinatum is the exact opposite of pectus excavatum. In pectus carinatum, the sternum is protruding from the chest wall (see Figure 28[11]).

Figure 27. Pectus excavatum.

Figure 28. Pectus carinatum.

Barrel chest could also be present, which consists of an increased anterior-posterior (AP) diameter of the chest wall and is a normal finding in children, but it is suggestive of hyperinflation with chronic obstructive pulmonary disease (COPD) in adults (see Figure 29[12]). Thoracic spine abnormalities such as kyphosis and scoliosis could also be noted during physical examination of the chest.

10. "Pectus1.jpg' by User:The Number C is licensed under CC BY-SA 3.0
11. "Ben_Fraser_pectus_carinatum.jpg" by Tolson411 is licensed under CC BY-SA 3.0
12. This image is derivative of "Βυτιοειδής_θώρακας_%28barrel_chest%29" by Open courses tei athinas and is licensed under CC BY-SA 3.0

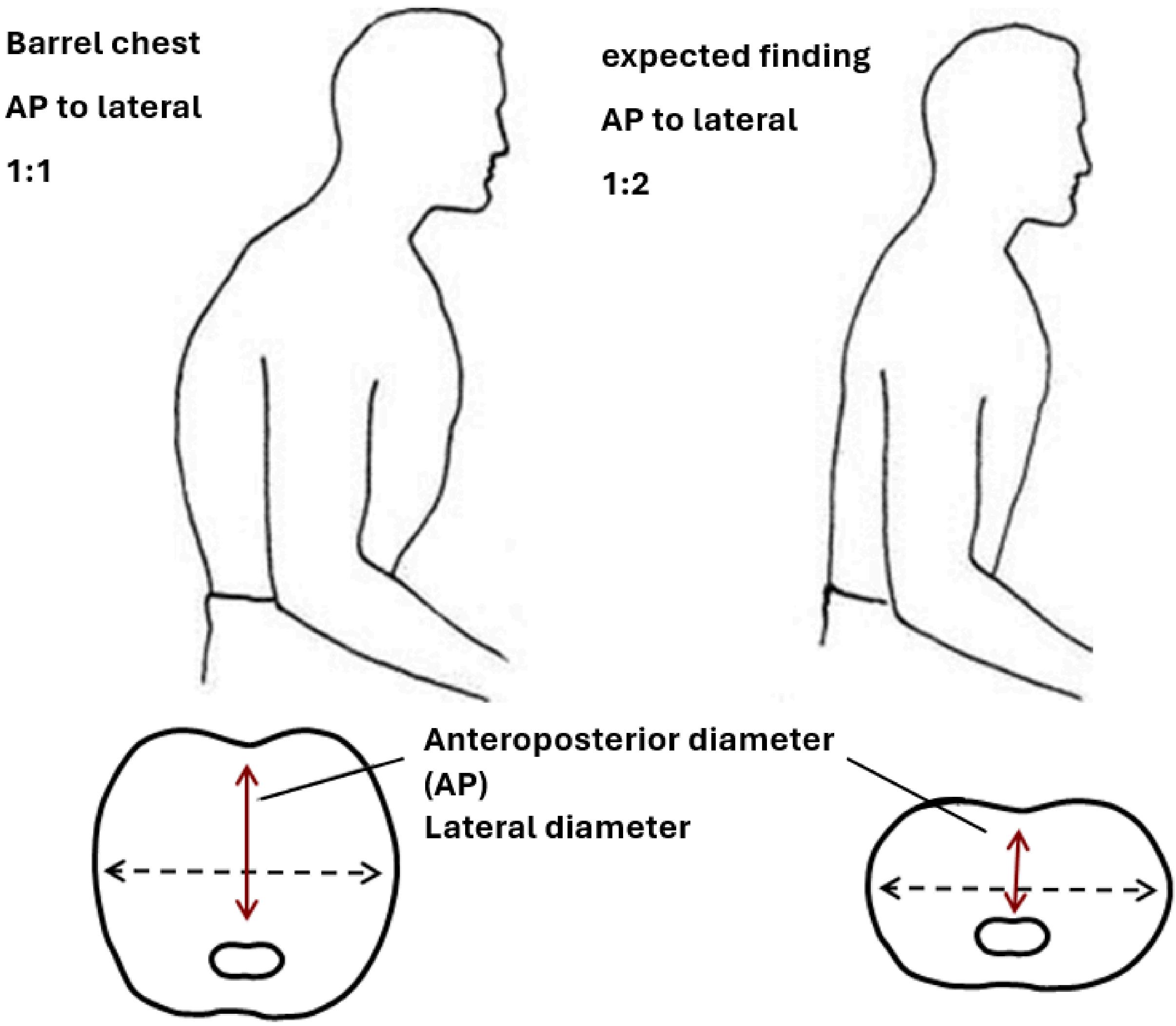

Figure 29. AP diameter ratio.

Digital clubbing is a physical deformity of the fingers and toes characterized by a widening and increased convexity of the nail bed. It develops due to chronic hypoxemia in certain chronic diseases such as bronchiectasis, cystic fibrosis, pulmonary fibrosis, and altered systemic circulation, leading to soft tissue and vascular changes in the fingertips (see Figure 30[13]). It is important for the respiratory therapist to inspect a patient's fingers for clubbing as it could indicate chronic respiratory conditions including, COPD, cystic fibrosis, or bronchiectasis.

13. "Clubbing_fingers_2" by Wesalius is licensed under CC BY-SA 4.0

Figure 30. Clubbed fingers.

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Palpation

Palpation of the chest may be performed to investigate for areas of abnormality related to injury or procedural complications. For example, if a patient has a chest tube or has recently had one removed, the nurse may palpate near the tube insertion site to assess for areas of air leak or crepitus. Crepitus feels like a popping or crackling sensation when the skin is palpated and is a sign of air trapped under the subcutaneous tissues. If palpating the chest, use light pressure with the fingertips to examine the anterior and posterior chest wall. Chest palpation may be performed to assess specifically for growths, masses, crepitus, pain, or tenderness.

Confirm symmetric chest expansion by placing your hands on the anterior or posterior chest at the same level, with thumbs over the sternum anteriorly or the spine posteriorly. As the patient inhales, your thumbs should move apart symmetrically. Unequal expansion can occur with pneumonia, thoracic trauma, such as fractured ribs, or pneumothorax.

> View this supplementary YouTube video[14] that demonstrates palpation of the chest:
>
> Palpitation of the thorax | Respiratory examination

Auscultation

Using the diaphragm of the stethoscope, listen to the movement of air through the airways during inspiration and expiration. Instruct the patient to take deep breaths through their mouth. Listen through the entire respiratory cycle because different sounds may be heard on inspiration and expiration. Allow the patient to rest between respiratory cycles, if needed, to avoid fatigue with deep breathing during auscultation. As you move across the different lung fields, the sounds produced by airflow vary depending on the area you are auscultating because the size of the airways change. You should move in a systematic manner from right to left on the front and back of the chest (see Figures 31[15] and 32[16]). Some health care textbooks may instruct you to begin auscultation at the lower lobes in order to catch certain sounds you may not have normally heard if you started in the upper lobes.

14. Clinical Examination Videos. (2018, August 15). *Palpitation of the thorax | Respiratory examination* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=MxBGzJsJKN8

15. "Anterior Respiratory Auscultation Pattern.png" by Meredith Pomietlo for Chippewa Valley Technical College is licensed under CC BY 4.0

16. "Posterior Respiratory Auscultation Pattern.png" by Meredith Pomietlo for Chippewa Valley Technical College is licensed under CC BY 4.0

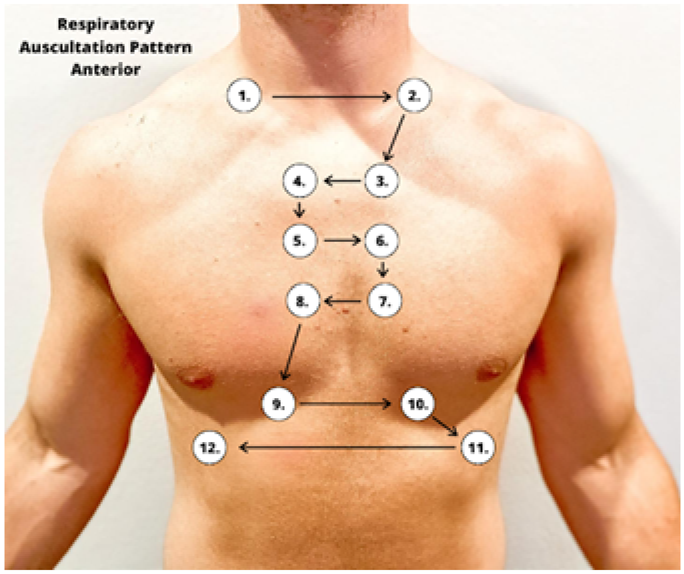

Figure 31. Auscultation pattern on front of the chest.

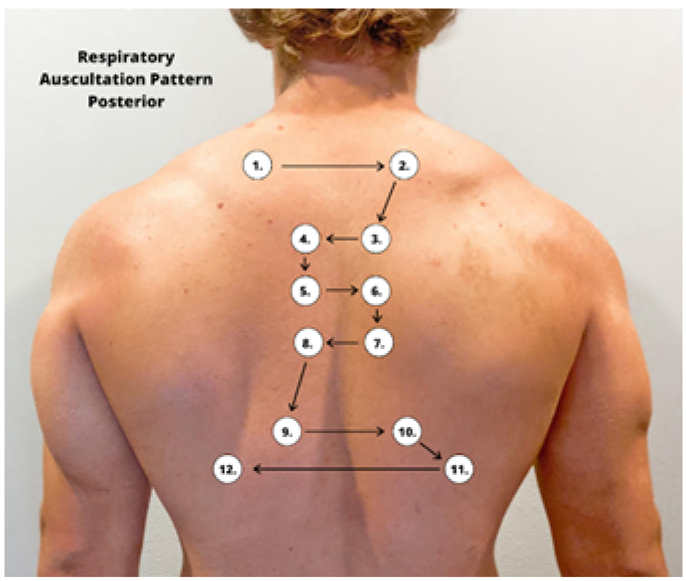

Figure 32. Auscultation pattern on back of the chest.

Correct placement of the stethoscope during auscultation of lung sounds is important to obtain a quality assessment. The stethoscope should not be placed over clothes or hair because these may create inaccurate sounds from friction. The best position to listen to lung sounds is with the patient sitting upright; however, if the patient is acutely ill or unable to sit upright, turn them side to side in a lying position. Avoid listening over bones, such as the scapulae or clavicles or over the female breasts, to ensure you are hearing adequate sound transmission. Listen to sounds from side to side rather than down one side and then down the other side. This side-to-side pattern allows you to compare sounds in symmetrical lung fields and allows for patient comfort throughout auscultation. Many patients may need a break from repetitive breathing, so the side-to-side pattern provides an opportunity for rest in between breaths.

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Special Auscultation Maneuvers

- **Whisper pectoriloquy** — Ask the patient to whisper a word such as "Ninety-nine" and listen with a stethoscope. Typically, words are heard faintly. In cases of consolidation, the whispered sounds will be heard clearly and distinctly.
- **Egophony** — Egophony is elicited by asking the patient to say "Ee," and it will sound like an "A." This may be suggestive of consolidation or pleural effusion.
- **Bronchophony** — Bronchophony is elicited by asking the patient to say "Ninety-nine" or "Ee" in a clear and loud voice. If the spoken phrase is clear, loud, and distinct, it may indicate increased lung density or consolidation, often seen in conditions like pneumonia or areas of lung collapse.

View the following YouTube video[17] for a demonstration of the pulmonary exam that can be performed by respiratory therapists:

17. RegisteredNurseRN. (2017, December 13). *Chest assessment nursing | Heart & lung assessment | Head-to-toe exam* [Video]. YouTube. Reused with permission. All rights reserved. https://www.youtube.com/watch?v=kv3B81mWc1E

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4.2 Lab Activities

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4.3 Critical Thinking Assessment

An interactive H5P element has been excluded from this version of the text. You can view it online here:
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5.1 SOAP Notes and Application

The **S**ubjective, **O**bjective, **A**ssessment, and **P**lan (SOAP) note is an acronym representing a widely used method of documentation for health care providers. The SOAP note is a way for health care workers to document in a structured and organized way.

The SOAP note helps guide health care workers to use their clinical reasoning to assess, diagnose, and treat a patient based on the information provided by them. SOAP notes are an essential piece of information about the health status of the patient, as well as a communication document among health professionals. The structure of documentation is a checklist that serves as a cognitive aid and a potential index to retrieve information for learning from the record.

SOAP Notes Structure

The four headings of a SOAP note are **S**ubjective, **O**bjective, **A**ssessment, and **P**lan. Each heading is described below.

Subjective

Subjective information is the first heading of the SOAP note. Documentation under this heading comes from the "subjective" experiences, personal views or feelings of a patient, or someone close to them. In the inpatient setting, interim information is included here. This information provides context for the Assessment and Plan.

Chief Complaint

The chief complaint (CC) or presenting problem is reported by the patient. This can be a symptom, condition, previous diagnosis, or another short statement that describes why the patient is presenting today. The CC is similar to the title of a paper, allowing the reader to get a sense of what the rest of the document will entail.

Examples

- Chest pain
- Decreased appetite
- Shortness of breath

However, a patient may have multiple CCs, and their first complaint may not be the most significant one. Thus, clinicians should encourage patients to state all their problems, while paying attention to detail to discover the most compelling problem. Identifying the main problem must occur to perform an effective and efficient diagnosis.

History of Present Illness (HPI)

The history of present illness (HPI) begins with a simple one-line opening statement, including the patient's age, sex. and reason for the visit.

Example

- This 47-year-old female is presenting with abdominal pain

This is the section where the patient can elaborate on their chief complaint. An acronym often used to organize the HPI is termed "OLDCARTS":

- **O**nset: When did the CC begin?
- **L**ocation: Where is the CC located?
- **D**uration: How long has the CC been occurring?
- **C**haracterization: How does the patient describe the CC?
- **A**lleviating and aggravating factors: What makes the CC better? Worse?
- **R**adiation: Does the CC move or stay in one location?
- **T**emporal factor: Is the CC worse (or better) at a certain time of the day?
- **S**everity: Using a scale of 1 to 10, with 1 being the least and 10 being the worst, how does the patient rate the CC?

It is important for clinicians to focus on the quality and clarity of their patient's notes rather than include excessive detail.

History

In this section, the clinician should ask the patient questions about their past medical/surgical and family/social history to help understand the patient's comorbidities.

- Medical history: Determine pertinent current or past medical conditions.
- Surgical history: Try to include the year of the surgery and surgeon if possible.
- Family history: Include pertinent family history. Avoid documenting the medical history of every person in the patient's family.
- Social history: Assess the client's social history. An acronym that may be used here is HEADSS, which stands for **H**ome and Environment; **E**ducation, Employment, Eating; **A**ctivities; **D**rugs; **S**exuality; and **S**uicide/Depression.

Current Medications/Allergies

Current medications and allergies may be listed under the Subjective or Objective sections. However, it is important that with any medication documented to include the medication name, dose, route, and how often.

Example

- Motrin 600 mg orally every 4-6 hours for 5 days

Objective

This section documents the objective data from the patient encounter, which includes the following:

- Vital signs
- Physical exam findings
- Laboratory data
- Imaging results
- Other diagnostic data
- Recognition and review of the documentation of other clinicians

A common mistake is distinguishing between symptoms and signs. Symptoms are the patient's subjective description and should be documented under the subjective heading, while a sign is an objective finding related to the associated symptom reported by the patient. An example of this is a patient stating he has "stomach pain," which is a symptom, documented under the subjective heading versus "abdominal tenderness to palpation," an objective sign documented under the objective heading.

Assessment

This section documents the synthesis of subjective and objective evidence to arrive at a diagnosis. This is the assessment of the patient's status through analysis of the problem, possible interaction of the problems, and changes in the status of the problems. Elements include the following:

Problem

List the problem list in order of importance. A problem is often known as a diagnosis.

Differential Diagnosis

This is a list of the different possible diagnoses, from most to least likely, and the thought process behind this list. This is where the decision-making process is explained in depth.

Plan

This section details the need for additional testing and consultation with other clinicians to address the patient's illnesses. It also addresses any additional steps being taken to treat the patient. This section helps future physicians understand what needs to be done next. For each problem, include the following:

- State which testing is needed and the rationale for choosing each test to resolve diagnostic ambiguities; ideally what the next step would be if positive or negative
- Therapy needed (medications)
- Specialist referral(s) or consult(s)
- Patient education and/or counseling

A comprehensive SOAP note has to take into account all subjective and objective information and accurately assess it to create the patient-specific assessment and plan.[1]

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An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=228#h5p-41

1. Podder, V., Lew, V., & Ghassemzadeh, S. (2023). SOAP notes. National Library of Medicine. https://www.ncbi.nlm.nih.gov/books/NBK482263/

5.2 Lab Activities

SOAP Notes

Objective: Collaborate with your lab partner to write a 500–800-word paragraph discussing the role of SOAP (Subjective, Objective, Assessment, Plan) notes in the clinical education of respiratory therapy students.

Instructions:

1. Review each component of SOAP notes and, using other sources, research how each part contributes to clinical practice, student learning, and patient care.

- Subjective: Patient's reported symptoms and concerns
- Objective: Observable, measurable data (e.g., vital signs, test results)
- Assessment: Analysis or diagnosis based on subjective and objective data
- Plan: Next steps for treatment or further assessment

2. Discuss the significance of SOAP notes and explain how the structured format of SOAP notes supports the following:

- How does this format help organize information and reinforce key concepts in respiratory therapy?
- How does SOAP documentation guide you in assessing, diagnosing, and planning patient care?
- In what ways does SOAP documentation improve communication, clarity, and consistency in care?

Use at least two credible sources that discuss the application and benefits of SOAP notes in clinical training. Cite in-text and include a reference list in APA format.

5.3 Critical Thinking Assessment

Printable Critical Thinking Assessment

Case Study

Mr. John Doe is a 5'7", 79-year-old man who came to the hospital because he had been "feeling sick with a bad cough" for the past five days. He had a bad cough that brought up yellowish mucus, along with a fever and shortness of breath. He felt more tired than usual, had no appetite, and was sweating a lot at night. His fever would rise to about 101°F, and he noticed it was harder to breathe when walking or climbing stairs. He didn't have any chest injuries or cough up blood, but he did have a dull pain in the right side of his chest that wouldn't go away. He does not complain of nausea or vomiting but states he has had diarrhea today.

Mr. Doe is a retired mechanic who worked in a factory for many years, often around dust and fumes. He also smoked a pack of cigarettes every day for 45 years but quit about 10 years ago. In addition to his smoking history, he has chronic breathing issues (COPD), high blood pressure, type 2 diabetes, and high cholesterol. His family history includes a father who passed away from lung disease at age 72 and a mother who died of cancer at 80. He has an older brother who is 82 and has heart disease and high blood pressure. Mr. Doe lives alone in a single-story house, and his two adult children live in other states. He takes lisinopril 10mg, atorvastatin 20mg, and aspirin 81mg at home. He is allergic to nuts and Sulfa.

Upon admission, Mr. Doe was found to be in mild respiratory distress, using accessory muscles to breathe. His vital signs included a temperature of 101.2°F, heart rate of 98 bpm, and respiratory rate of 22 breaths per minute. His oxygen saturation was 89% on room air, prompting the initiation of supplemental oxygen at 2L/min via nasal cannula. On physical examination, he appeared fatigued but alert, with decreased breath sounds and crackles noted over the right lower lung field. There was dullness to percussion and increased tactile fremitus in that area, suggesting consolidation or possible pleural effusion.

Lab results showed an elevated white blood cell count of 14,000/µL. His basic metabolic panel was largely unremarkable, except for a mildly elevated glucose of 130 mg/dL. Other lab results were as follows: Sodium 138 mmol/L, Potassium 4.0 mmol/L, Chloride 99 mmol/L, Bicarbonate 22 mmol/L, BUN 16 mg/dL, and Creatinine 1.0 mg/dL. The arterial blood gas on 2LNC was ph 7.45/PaCo2 36/PaO2 65/HCO3 23. A chest X-ray showed a right lower lobe infiltrate and revealed blunting of the right costophrenic angle. He was started on ceftriaxone 1g IV and azithromycin 500 mg IV in the ED. He was also given a Duoneb 2.5mg.

Using the case study above or one that your instructor provides to you, draft a complete SOAP note using the following template, save your SOAP note as a separate Word document, and upload to your designated LMS assignment.

SOAP Note

Name: Date: Gender: Age: Height: Weight:

SUBJECTIVE
CC:
HPI:
PMH:
FH:
SH:
OBJECTIVE
ALLERGIES:
HOME MEDICATIONS (list all home medications – in table format):

Drug	Dose	Route	Indication: Why is the patient taking this medication?

CURRENT MEDICATIONS (list all current medications – in table format):

Drug	Dose	Route	Indication: Why is the patient taking this medication?

PHYSICAL EXAM:

- General
- VS
- HEENT
- Chest
- CV
- Abdomen/GU
- Extremities
- Diet
- I/O status

X-RAY RESULTS:
LAB RESULTS:

Example			Normal	Reason Abnormal
WBC			3.5-10.5	
RBC			3.9-5.03	
HgB			12-15.5	

DIAGNOSTIC TEST RESULTS (list all other testing here):

ASSESSMENT
1.
2.

3.

PLAN

1.

2.

3.

Skills Assessments

Pulse Oximetry
Complete Pulmonary Exam

PART II

RESPIRATORY THERAPEUTICS I

Learning Objectives

- Explain the fundamental gas laws (Boyle's, Charles's, Gay-Lussac's, and Dalton's laws) and their relevance to respiratory therapy.
- Apply gas law principles to analyze clinical scenarios, such as oxygen delivery and lung mechanics.
- Calculate tank durations using medical gas cylinder tank factors.
- Demonstrate knowledge of medical gas cylinder safety, handling, and storage practices.
- Differentiate between high-flow, low-flow, and reservoir oxygen therapy devices and describe their clinical applications.
- Select appropriate oxygen therapy devices based on patient needs and clinical scenarios.
- Compare the function and use of small volume nebulizers, metered dose inhalers, and dry powder inhalers.
- Discuss the indications, advantages, and limitations of bland aerosol and humidification therapies.
- Describe the role of humidification in respiratory therapy and its effects on the respiratory tract.
- Accurately place electrodes for a 12-lead ECG and identify common abnormalities in readings.

1.1 Gas Laws

Key Gas Laws and Concepts for Respiratory Therapists

Understanding gas laws is essential for respiratory therapists, as these principles directly impact patient care. Respiratory therapists constantly work with gases, whether to deliver medications, drive respiratory equipment, or titrate gases to meet the physiological needs of the patient. Below is an overview of relevant gas laws, equations, and other key terms to support your practice.

Gas Laws and Equations

Boyle's Law

Boyle's law states, at constant temperature and mass, the volume of a gas varies inversely with pressure. In a given system, as the pressure goes up, the volume will go down. This is a concept that has application in the measurement of lung capacities and volumes in a body plethysmography box in a pulmonary function laboratory (see Figure 1[1]).

Figure 1. Body plethysmography box.

1. "Body_plethysmograph_box" by Stan3000 is licensed under CC BY-SA 3.0

Therefore, if we have a container at a known pressure and volume, then the pressure changes. Utilizing basic algebra you can solve for the unknown volume. The algebra formula is as follows:

$$V2 = \frac{P1V1}{P2}$$

Example

You are in a PFT laboratory with a patient. The initial pressure in the body plethysmography box is 1500 psi, and the volume is 420 mL. If the patient returns a several days later and the new pressure in the body plethysmography box is 1000 psi, solve for the new volume.

$$V2 = \frac{P1V1}{P2}$$

$$V2 = \frac{1500psi \times 420mL}{1000mL}$$

Charles' Law

Charles' law states, at constant pressure and mass, the volume of a gas varies directly with temperature. You should remember that Kelvin is the only linear temperature scale, and all temperatures must be converted to Kelvin.

$$V1T1 = V2T2$$

Utilizing basic algebra you can solve for the second volume. The algebra formula is as follows:

$$V2 = \frac{V1T1}{T2}$$

View the following supplementary YouTube video[2] that explains Charles' law in detail: [CHARLES' Law | Animation](https://www.youtube.com/watch?v=twCcSsHmMgI)

2. EarthPen. (2020, October 12). *CHARLES' law | animation* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=twCcSsHmMgI

Gay-Lussac's Law

Gay-Lussac's law states, at constant volume and mass, the pressure of a gas varies directly with temperature.

$$P1T1 = P2T2$$

Utilizing basic algebra you can solve for the second pressure (P2). The algebra formula is as follows:

$$P2 = \frac{P1T1}{T2}$$

View the following supplementary YouTube video[3] that explains Gay-Lussac's Law in detail: [Chemistry: Gay-Lussac's Law (Gas Laws) with 2 Example Problems](https://www.youtube.com/watch?v=0Oq7bCSDPxE)

Dalton's Law of Partial Pressures

The total pressure of a gas mixture is the sum of the partial pressures of each constituent gas. This gas law is important in several contexts in the clinical experience of the respiratory therapist. A patient who is placed in a hyperbaric chamber is breathing supra-atmospheric (in other words, giving higher than atmospheric pressure) pressurized O2 to enhance wound healing. In determining the oxygen content inside the lung structure of the alveolus, the different primary gas pressures are accounted for so when the math is complete, the respiratory therapist can accurately determine the PAO2 in the alveolar tissue of the lung.

- The partial pressure of each gas is what it would exert if alone.
- Each partial pressure is proportional to the percentage of the gas in the mixture.

Partial Pressure of a Gas

The partial pressure of a gas can be calculated using Dalton's law, which states the gas pressure in a system is the sum of the independent gasses ($P_N = P_{H2o} + P_{AO2} + P_{N2}$). In other words, the total is the sum of the parts.

3. Socratica. (2015, February 4). *Chemistry: Gay-Lussac's law (gas laws) with 2 example problems* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=0Oq7bCSDPxE

View the following supplementary YouTube video[4] that explains Dalton's Law in detail: [Breathing 5- Gas Laws](https://www.youtube.com/watch?v=q9eB-AYneA0)

Key Terms for Respiratory Therapy to Use With Gas Laws

- BTPS: Body temperature and pressure, saturated (conditions within the lungs)
- ATPS: Ambient temperature and pressure, saturated
- STPD: Standard temperature (0°C) and pressure (760 mm Hg), dry

Note: Water vapor exerts 47 mm Hg at 37°C. This is important for airway humidification to be considered at a later juncture.

Composition of Atmospheric Gases

It is important for respiratory therapists to know the primary gasses in Earth's atmosphere. These gasses include the following:

- Nitrogen (N2): 78.08%
- Oxygen (O2): 20.95%
- Argon (Ar): 0.93%
- Carbon Dioxide (CO2): 0.03%
- Trace elements: 0.01%

4. Wendy Riggs. (2015, March 17). *Breathing 5- gas laws* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=q9eB-AYneA0

Diffusion and Solubility Laws

Graham's Law

Graham's law states that the rate of diffusion of a gas into a liquid is inversely proportional to the square root of its density; denser gases diffuse more slowly. Conversely, a lighter gas, such as helium, will diffuse more quickly.

Henry's Law

Henry's law states that the amount of gas dissolving in a liquid at a given temperature is proportional to the partial pressure of that gas.

- Gases with higher partial pressures dissolve more readily in liquids.
- Although oxygen is less dense, carbon dioxide has a much higher solubility coefficient, resulting in CO_2 diffusing 19 times faster than O_2.
- Graham and Henry's law combine to demonstrate that there is 20 times more solubility of CO_2 compared to O_2 in the blood.

Fick's Law

In its simplest form, Fick's law identifies the diffusion across a permeable membrane. The thicker the membrane, the less diffusion occurs. Graham's law and Henry's law together form the basis for the coefficient for diffusion for the Fick equation.

Flow and Related Principles

Flow is the movement of a gas volume from one place to another over time and typically measured in liters per minute (L/min).

Flow can be increased by the following:

- Increasing the pressure gradient
- Increasing the size of the opening or reducing resistance or opposition to flow

Bernoulli Principle

The Bernoulli principle states that as the forward velocity of a gas increases, its lateral pressure decreases, with a corresponding increase in forward pressure. This is important because it explains the behavior of airflow through the airways such as the bronchi and the bronchioles. As air moves through the constricted parts of the respiratory system, like the bronchi and bronchioles, the velocity increases, causing a decrease in pressure[5].

Venturi Principle

The Venturi Principle suggests that by adding a gradually widening tube (funnel) after a jet orifice and keeping the angulation below 15°, lateral pressure can be restored to pre-jet levels (see Figure 2[6]).

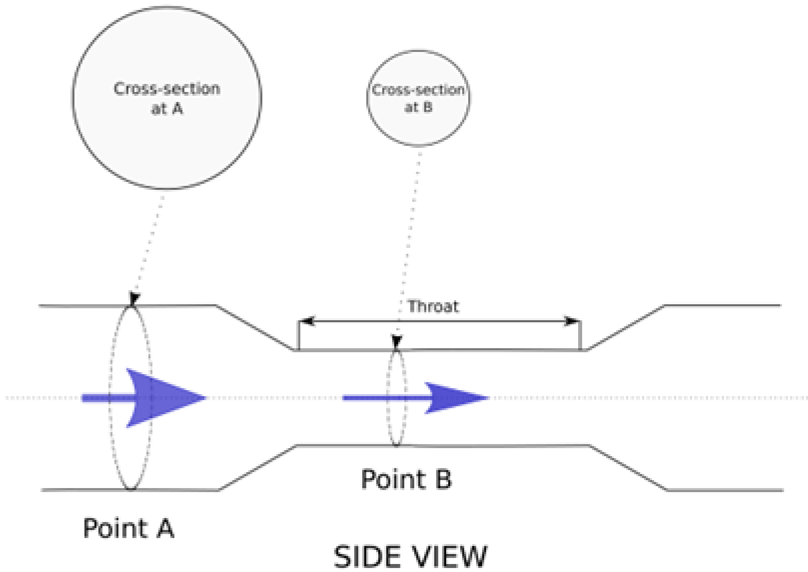


Figure 2. Visual of the lateral pressure drop going from A to B, demonstrating the Venturi Principle.

Effects of Resistance to Flow (i.e., "Back Pressure") and Obstruction

An obstruction downstream of an air entrainment device creates back pressure, which reduces entrainment of air and total flow given to the patient, and also increases oxygen concentration. A therapist will want to ensure that there is not a downstream obstruction as the device will not work properly and the patient could be harmed.

Entrainment System

The amount of entrainment (air intake) is influenced by the following:

5. Landry, J. (2024). *The 19+ laws of the lungs and respiratory system (2025)*. Respiratory Therapy Zone. https://www.respiratorytherapyzone.com/respiratory-system-laws/

6. "Venturi-nomaths" by unknown author is licensed under CC BY 3.0.

- Jet orifice size: Smaller orifices increase entrainment of air and total flow delivered to patient and reduces oxygen concentration.
- Entrainment port size: Larger ports increase entrainment of air and total flow delivered to patient and reduces oxygen concentration.

Poiseuille's Law

Poiseuille's law is critically important as it reflects the change in resistance in the lung in opposition to gas flow. This is true of the gas flow in the small airways of the lung, where the flow in the larger airways is a mixture of a linear flow and a turbulent flow, which is advantageous for the body to mobilize secretions.

The pressure needed to drive a gas (overcome airway resistance) increases if the following occurs:

- The length of the tube increases.
- The viscosity of the gas increases.
- The flow rate of the gas increases.
- The radius of the tube decreases.

View the following supplementary YouTube video[7] that explains Poiseuille's law in detail: Poiseuille's law

Reynold's Number and Turbulent Flow

The Reynolds number is the ratio of inertial forces to viscous forces within a fluid/gas that is subjected to relative internal movement due to different fluid/gas velocities. Gas flow is more likely to become turbulent when the following occur:

- Gas density is high.
- Flow rate is high.
- Tube diameter is large.
- Gas viscosity is low.

Turbulent flow typically begins when the Reynold's number exceeds 2,000.

7. Mechanisms and Logic in Human Physiology. (2022, September 7). *Poiseuille's law* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=r1_Uo9pGwy8

1.2 Lab Activities

Utilizing the equations from the workbook, the examples below, and other resources, you will complete the following questions on a separate sheet of paper and discuss the answers with your lab partner and then submit your responses to your laboratory instructor by the end of class.

Boyle's Law

An example of Boyle's law would be the act of breathing when the diaphragm drops, and the pressure drops in the thorax. There will be gas moving into the lungs.

1. The initial volume is 6,400 mL, and the initial pressure is 720 mm Hg. What is the new pressure if the volume changes to 4.75 L?

2. The first volume is 2.22 L, which exerts a pressure of 450 mm Hg. If the volume changes to 4.8 L, what is the new pressure exerted by the gas?

3. The initial volume of the gas is 1.85 L, and the initial pressure is 755 mm Hg. What is the new volume if the pressure changes to 740 mm Hg?

4. The first volume is 3.64 L, which exerts a pressure of 760 mm Hg. If the pressure changes to 725 mm Hg, what is the new volume of the gas?

Charles's Law

An example of Charles's law is when tire pressure in the summer increases due to the warmer weather, and in the winter the tire pressure decreases due to the colder weather.

1. The temperature of the gas is 36° C, with a gas volume of 5.12 L. What is the new volume if the temperature increases to 39° C?

2. The temperature of the gas is 41° C, with a gas volume of 4.66 L. What will be the new volume if the temperature decreases to 23° C?

3. The temperature of the gas is 37° C, with a gas volume of 2.98 L. What will be the new volume if the temperature decreased to 25° C?

Gay-Lussac's Law

An example of Gay-Lussac's law is an oxygen cylinder in the trunk of a car will have an increase in pressure when the temperature increases from 80° to 100° F.

1. The temperature of the gas is 22° C, and it exerts a gas pressure of 740 mm Hg. What is the new pressure if the temperature increases to 35° C?

2. The temperature of the gas is 21° C, and it exerts a gas pressure of 545 mm Hg. What is the new pressure if the temperature increases to 25° C?

3. The temperature of the gas is 25° C and exerts a gas pressure of 695 mm Hg. What is the new pressure if the temperature increases to 37° C?

Combined Gas Law

The combined gas law is really just a combination of all three gas laws affecting pressure, temperature, and volume.

1. The temperature of a gas is 25° C, with a gas volume of 5.25 L, which exerts a pressure of 740 mm Hg. What will the new pressure be if the temperature increases to 36° C, and the volume decreases to 4.7 L?

2. The temperature of a gas is 39° C, with a gas volume of 6.1 L, which exerts a pressure of 688 mm Hg. What will be the new volume if the temperature decreases to 29° C, and the pressure decreases to 515 mm Hg?

3. The temperature of a gas is 28° C, with a gas volume of 6.3 L, which exerts a pressure of 752 mm Hg. What will be the new temperature if the pressure decreases to 720 mm Hg, and the volume increases to 6.8 L?

Dalton's Law

An example of Dalton's law would be a high-altitude climber (e.g., Mount Everest) where the air is so thin, people must breathe pressurized O2, or they will not be able to remember the event due to the very low O2 concentrations at that height. Another example is a hyperbaric chamber where a patient will breathe 100% O2 at barometric pressure or when treating a patient with

carbon monoxide exposure after the CO is liberated from the hemoglobin with the O_2 at that higher pressure.

1. What is the total pressure of a gas mixture if the PO_2 = 90 mm Hg, PCO_2 = 40 mm Hg, PN_2 = 573 mm Hg, and PH_2O = 47 mm Hg?

2. The total pressure of a gas mixture is 847 mm Hg. If the PCO_2 = 47 mm Hg and the PH_2O = 47 mm Hg, what is the pressure of the remaining gases?

1.3 Critical Thinking Assessment

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=284#h5p-52

2.1 Medical Gas

Everything that a respiratory therapist does is in some way tied to the delivery or titration of medical gasses. The storage, transport, and delivery of gasses both in the hospital and in the homes of patients are essential to the field of respiratory therapy.

Oxygen therapy supports life and supports combustion; however, it is not flammable. While there are many benefits to inhaled oxygen, there are also hazards and side effects. Anyone involved in the administration of oxygen should be aware of potential hazards and side effects of this medication. Oxygen should be administered cautiously and according to the safety guidelines.

Oxygen Safety Guidelines

When helping patients with oxygen, you should follow these guidelines:

- Remind patients that oxygen is a medication and should not be adjusted without consultation with a physician or respiratory therapist.
- When using oxygen cylinders, store them upright, chained, or in appropriate holders so that they will not fall over (see Figure 3[1]).

1. “Oxygen Cylinder Holder” by Don Raymond, Chippewa Valley Technical College is licensed under CC BY-NC 4.0

Figure 3. Oxygen tank cylinder holder.

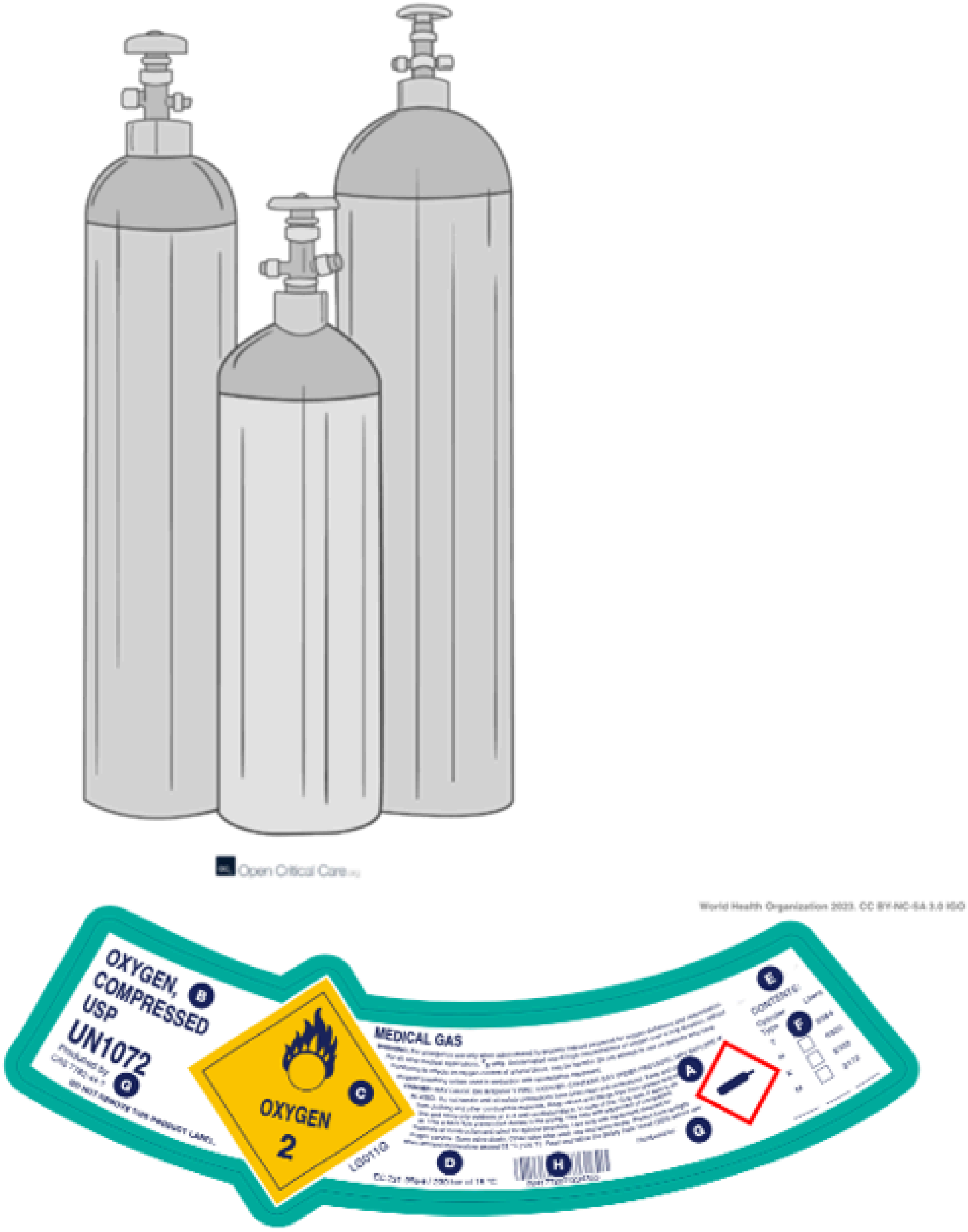
- Do not smoke around any oxygen delivery devices in the hospital or home environment because oxygen supports combustion.
- Keep oxygen delivery systems away from any heat source.
- Push oxygen tank cylinders instead of pulling them.
- Check for electrical hazards in the home or hospital prior to use. Determine that electrical equipment in the room or home is in safe working condition. A small electrical spark in the presence of oxygen will result in a serious fire. The use of a gas stove, kerosene space heater, or smoker is unsafe in the presence of oxygen. Avoid items that may create a spark (e.g., electrical razor, hair dryer, synthetic fabrics that cause static electricity, or mechanical toys) with nasal cannula in use.
- Check oxygen levels of portable tanks before transporting a patient to ensure that there is enough oxygen in the tank.
- Closely monitor high concentrations of oxygen therapy with formal assessment such as pulse oximetry and arterial blood gasses (ABGs).[2]

Oxygen Cylinder Facts

- **O2 Concentration:** Varies depending on the type and the quality of the source (e.g., 99.9% if filled from liquid oxygen [LOX]; 94% if filled from low-quality source).
- **Distribution:** Can be placed at the bedside (secured) or connected to a manifold pipeline distribution system.
- **Capacity:** Wide range of sizes, ranging from 100-10,000L (gaseous) capacity (see Figure 4[3]).
- **Costs:** Moderate cost (e.g., $60-$250) for the "E" cylinder but also requires regulator, flowmeter, and delivery; ongoing costs can be high, including cylinder deposit or leasing fee, refill costs, and transport costs.
- **Labels:** All cylinders come with a standard oxygen label, which includes items such as manufacturer, size, weight, filling pressure, etc. (see Figure 4).
- **Advantages:** Portable, common, can be used at facilities without O2 piping systems, do not require power, easy to use.
- **Disadvantages:** Large cylinders are heavy, require special facilities to refill (often not available at hospitals), have exhaustible supply, are easy to place in areas that cylinders are not intended to be stored, can be a safety hazard if not properly secured and maintained.

2. Doyle, G. R., & McCutcheon, J. A. (2015). *Clinical procedures for safer patient care*. BCcampus. https://opentextbc.ca/clinicalskills/

3. "Oxygen Cylinders" and "Cylinder Labeling" by Open Critical Care are licensed under CC BY-NC-SA 4.0



No.	Description
A	Hazards and precautions notice
B	Name of the product
C	Hazard diamond
D	Filling pressure
E	Gross weight
F	Cylinder size
G	Manufacturer brand name and contact
H	Serial number

Figure 4. Image of different sized oxygen cylinders and a standard oxygen cylinder label.

View the following supplementary YouTube video[4] shows how a cylinder of compressed medical gas can be dangerous if not handled properly: MythBusters Air Cylinder Rocket

Valves, Regulators, and Accessories

Cylinders require several accessories for safe use in clinical settings. Each cylinder has a valve that must be opened with a specialized key, hand wheel, or toggle. For valves that require a key, it is recommended to secure these to the cylinders.

For more information on cylinder regulators and valves, check out the article on oxygen connector types.

Once oxygen leaves the cylinder valve at high pressure, it must be lowered to a pressure safe for administration to a patient or an oxygen delivery device. Regulators are specialized devices used for the purpose of lowering pressure to a level where a device can be used to further control flow to the patient (see Figure 5[5]).

Important Note: It is unsafe to connect a patient directly to an oxygen cylinder without a pressure regulator.

4. FPC CAP. (2013, April 11). *MythBusters air cylinder rocket* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=C4kb-8CjVYg

5. "Oxygen cylinder regulator" by Open Critical Care is licensed under CC BY-NC-SA 4.0

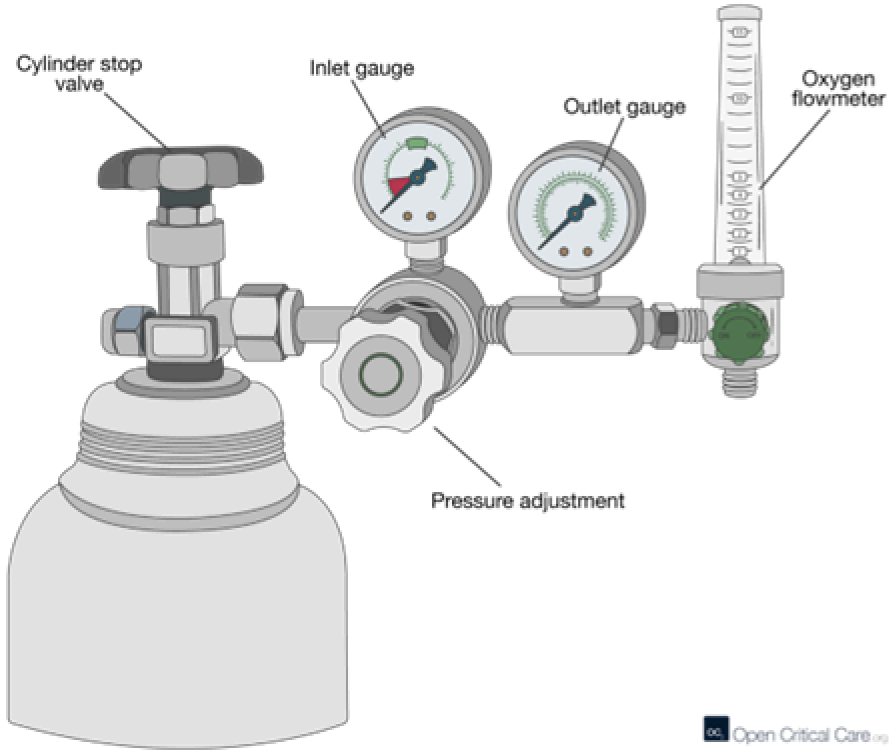


Figure 5. Oxygen tank with pressure regulator.

Types of Regulators

- **Bourdon Gauge** – Fixed orifice, integrated pressure reducing valve, accepts variable inlet pressure, used only with cylinders, unaffected by gravity, not back pressure compensated, with increased flow the indicated flow reading becomes inaccurate [6].

View the following supplementary YouTube video[7] explaining more about a Bourdon guage: [Bourdon Gauge (Medical definition) | Quick Explainer Video](https://www.youtube.com/watch?v=MIDKp-d9zu8)

- **Preset Regulator** – A medical device that's attached to an oxygen tank and has a preset pressure. It's

6. Lipnick, M., Vanderburg, S., Sendagire, C., & Neighbour, R. (2023). *Overview of oxygen connector types*. Open Critical Care. https://opencriticalcare.org/encyclopedia/overview-of-oxygen-connector-types/

7. Respiratory Therapy Zone. (2021, June 15). *Bourdon gauge (Medical definition) | Quick explainer video* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=MIDKp-d9zu8

designed to control the delivery of oxygen for use with portable oxygen tanks (see Figure 6[8]).

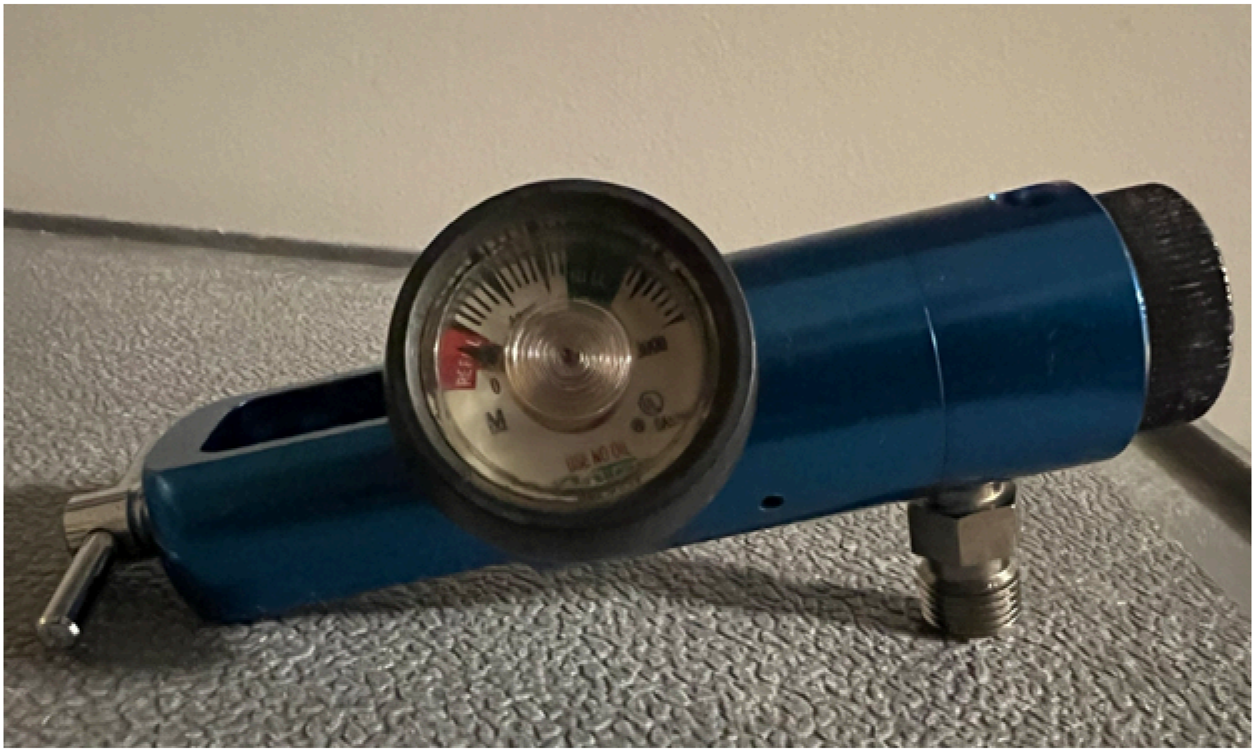


Figure 6. Preset regulator.

View the following supplementary YouTube video[9] on how to place a preset regulator on an oxygen tank: [Regulator on an E-cylinder](https://www.youtube.com/watch?v=4QLmMyuVqKc)

Cylinder Tank Factors and Calculations

The most common cylinders used in hospital facilities are E cylinders and H cylinders. Respiratory therapists should be familiar with how to calculate how long an oxygen tank will last for patient safety. The E tank factor is 0.28 L/psig, and the H tank factor is 3.14L/psig. This tank factor ("L/psig") converts tank pressures to liters of gas. To calculate how long a cylinder's contents will last, you should use the following equation:

8. "Preset Regulator" by Don Raymond, Chippewa Valley Technical College is licensed under CC BY-NC 4.0

9. Respiratory Therapy Educational Resources. (2017, October 3). *Regulator on an E-cylinder* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=4QLmMyuVqKc

Minutes remaining in cylinder = Cylinder pressure x Cylinder tank factor / flow rate L/min

For more information on how to calculate cylinder duration, you can visit the [Oxygen Calculator](#).

Example

A respiratory therapist has an E oxygen cylinder with 1500 psi remaining and patient who is on 2L of flow. The cylinder will last for 210 minutes or 3.5 hours.

1500psi x 0.28L/psi/2L = 210 mins

Pressurized Hospital Gas

In a hospital, oxygen and medical air are constantly being utilized by the respiratory therapist. The Thorpe tube is used to deliver gas, which is stored in the O2 piping in copper tubing from a liquid gas system or a compressed medical gas source. The flowmeter is placed into the wall in several ways using a form of a "Quick Connect" system (see Figures 7[10] and 8[11]).

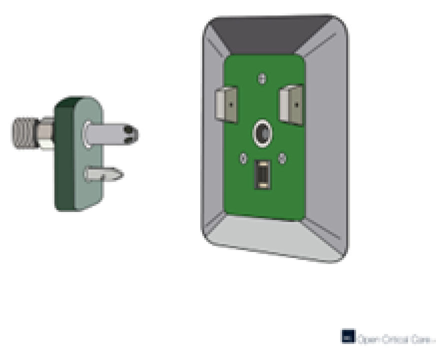


Figure 7. Chemtron Quick Connect.

10. "hemetron-NCG-Rectangle-Locking-Pin-vp3p31-768×593" by Open Critical Care is licensed under CC BY-NC-SA 4.0

11. "Ohmeda-quick-connect-oxygen-connector-zbjq22-768×593" by Open Critical Care is licensed under CC BY-NC-SA 4.0

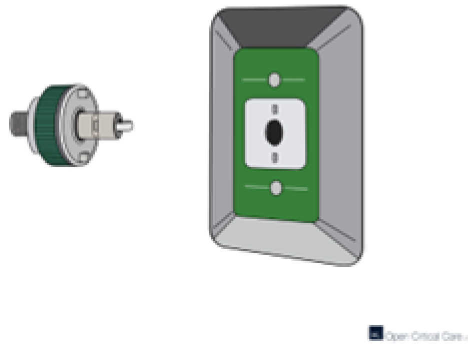


Figure 8. Ohio Quick Connect.

The wall system in a hospital delivers pressurized oxygen at 50 psi. A standard adult flow meter has a flow range of 0–15 liters per minute (L/min), but when fully open (also called "flush"), the flow can exceed 40 L/min.

Thorpe Tubes

Thorpe tube flowmeters are commonly used because they are easy to operate and provide accurate flow measurements when pressure compensated. They display and measure flow accurately, even if there is back pressure in the system (such as from a kinked or blocked delivery device). (See Figure 9.[12])

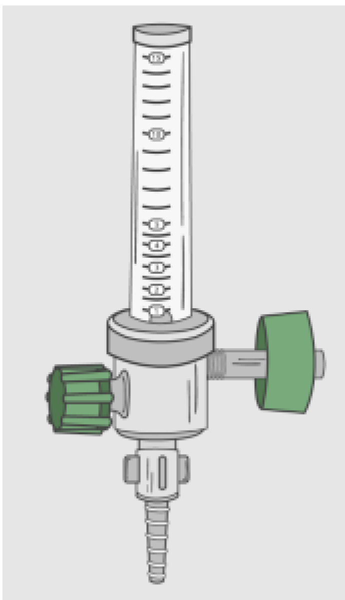


Figure 9. Thorpe tube flowmeter.

12. "Oxygen-flowmeter-15-Side-set-to-5 LPM-ave qa8" by Open Critical Care is licensed under CC BY-NC-SA 4.0

Limitations of Thorpe Tubes

- They are fragile and can break easily.
- They must be used in an upright position, as gravity affects their accuracy.
- If they are not pressure-compensated, they may display inaccurate flow when back pressure is present.

View the following supplementary YouTube video[13] explaining more about the Thorpe tube flowmeter: Thorpe Tube (Medical Definition) | Quick Explainer Video

How to Test the Thorpe Tube Flowmeter

1. Connect your oxygen adapter (see Figure 10[14]) to the flowmeter and insert the flowmeter to the oxygen quick-connect.
2. Attach a non-rebreather mask with oxygen tubing to the flowmeter.
3. Set the flowmeter to the flush (fully open) setting. Assess the ball jumping in the flowmeter.
4. Observe any changes to the reservoir bag on the oxygen mask, and note any sounds produced.
5. If the Thorpe tube is working correctly, the reservoir bag should inflate.

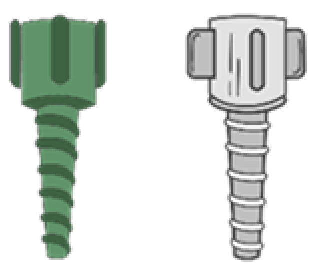


Figure 10. Nipple nut oxygen adapters.

13. Respiratory Therapy Zone. (2021, July 31). *Thorpe tube (Medical definition) | Quick explainer video* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=DFuoqhz8X8M

14. "barbed-christmas-tree-oxygen-adapter-wzzz3q.png" by Open Critical Care is licensed under CC BY-NC-SA 4.0

Liquid Oxygen

Most of the oxygen in a hospital is delivered to patients by tubing in the walls that come from a liquid oxygen tank system. This is from a process known as fractional distillation. (See Figures 11[15] and 12.[16])

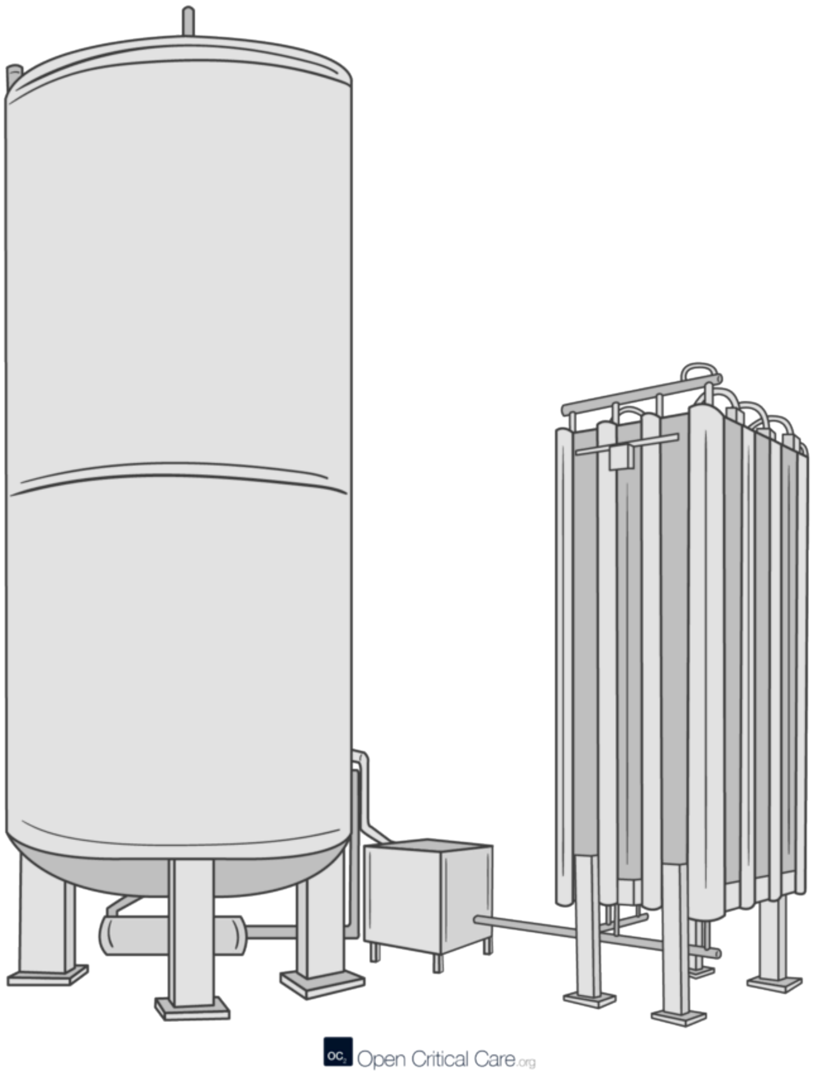


Figure 11. Liquid oxygen plant.

15. "Liquid_Oxygen.png" by Open Critical Care is licensed under CC BY-NC-SA 4.0

16. "Oxygen Tanks_Outside" by Don Raymond, Chippewa Valley Technical College is licensed under CC BY-NC 4.0

Figure 12. Liquid oxygen tanks outside of a hospital.

Liquid Oxygen Portable Shoulder Pack

Home-care patients may use a small, portable liquid oxygen pack, which requires special handling (see Figures 13[17] and 14[18]). Because liquid oxygen will gradually evaporate from the portable unit, always keep it in an upright position. If the unit is accidentally tipped over, you may notice hissing sounds and see oxygen vapor escaping. In this case, immediately place the unit upright and allow it to settle. Always store the pack in a well-ventilated area. Oxygen flow is typically measured in liters per minute (L/min), and the duration of a portable oxygen tank depends on the continuous flow rate.

To calculate how long the oxygen in a liquid container will last, first weigh the container. One liter of liquid oxygen weights 2.5 lbs. Multiply the weight by 344 to find the number of liters available. Then, divide this value

17. "Portable Liquid Oxygen Tank" by Don Raymond, Chippewa Valley Technical College is licensed under CC BY-NC 4.0

18. "Top View_Portable Oxygen Tank" by Don Raymond, Chippewa Valley Technical College is licensed under CC BY-NC 4.0

by the patient's required liter flow. This final figure will provide the estimated time remaining for the oxygen system[19].

Example

A liquid oxygen tank contains 3 lbs of liquid oxygen. The patient is receiving oxygen at 4L/min via a nasal cannula. How long with the liquid oxygen last?

3 lbs x 344 = 1032 L/min available

1032L/4 = 258 mins remaining or 4.3 hours

Figure 13. Portable liquid oxygen tank.

19. Vanderburg, S., Lipnick, M., Neighbour, R., & Sendagire, C. (2024). *Overview of oxygen sources*. Open Critical Care. https://opencriticalcare.org/encyclopedia/overview-of-oxygen-sources/

Figure 14. Top view of portable liquid oxygen tank.

2.2 Lab Activities

2.2a Cylinder Diagramming

1. In the laboratory, you will obtain an oxygen tank if available. Then on a separate piece of paper, beginning with an E cylinder in a secure cart, you will "draw" the cylinder and label the following markings:

A. Manufacturer's mark
B. Serial number of the cylinder
C. Original hydrostatic testing date
D. DOT specifications mark
E. Retest dates
F. Service pressure of the cylinder
G. Ownership mark
H. Inspector's mark
I. Elastic expansion (if present)
J. Type of gas
K. All warnings concerning use
L. Statement of purity
M. Manufacturer

Record as many as you can find.

2. Draw and label the following on a separate piece of paper. Show this labeled drawing to your instructor.

A. Diagram and label a PISS connector valve, both external and in cutaway form
B. Gas inlet
C. Gas outlet
D. Derive which controls gas flow from the cylinder
E. Pressure relief device
F. Gas channel
G. PISS connector(s)

3. Draw a cylinder label with the following on a separate piece of paper. Show this drawing to your instructor.

A. Type of gas
B. All warnings concerning use
C. Statement of purity
D. Manufacturer

2.2b Regulator Placement

If you have a new cylinder, you will need to remove the plastic cover over the O2 outlet. After doing so, you will "crack" the tank, which means you will quickly open and close the valve with the tank key to expel a small amount of gas and remove any dirt or debris from the outlet.

Then, turn the regulator screw out adequately to place it on the cylinder, aligning the PISS safety system pins.

Tighten the screw and then using the “tank key,” open the tank. If your alignment is correct, you can then see the pressure on the regulator dial. If you hear a leak, reseat the regulator and try again.

2.2c Flowmeters

Obtain a Thorpe tube flowmeter with an appropriate nipple nut oxygen adapter. Insert the flowmeter in the quick connect system. What is the name of the quick connect you are using?

Connect an oxygen tubing to the flowmeter. Set the flow to 10 L/min.

2.3 Critical Thinking Assessment

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=306#h5p-53

3.1 Medical Gas Therapy/Devices

Oxygen Masks and Devices Categories

The delivery of gasses, including oxygen, is a fundamental part of the life and work of the respiratory therapist. There are several types of oxygen masks and device categories. **Low flow** devices do not meet the patient's inspiratory flow needs. The patient supplements the oxygen flow by inhaling room air in addition to the delivered oxygen when using a low-flow O2 device. **High flow** devices meet or exceed the patient's inspiratory demands and deliver precise oxygen percentages. **Reservoir** devices deliver a higher concentration of oxygen during the inspiratory phase of the patient's breath.

NASAL CANNULA (Low Flow)

A nasal cannula is the simplest oxygenation device and consists of oxygen tubing connected to two short prongs that are inserted into the patient's nares (see Figure 15[1]). The tubing is connected to the flow meter of the oxygen supply source. To prevent drying out the patient's mucus membranes, bubble humidification may be added for hospitalized patients receiving oxygen flow rates greater than 4 L/min or for those receiving oxygen therapy for longer periods of time.[2]

Nasal cannulas are the most common type of oxygen equipment. They are used for short- and long-term therapy (i.e., COPD patients) and are best used with stable patients who require low amounts of oxygen. Nasal cannulas should be positioned with the prongs facing downward, following the natural shape of the nares, and the thinner tubing should be secured behind the patient's ears.

Flow Rate: Nasal cannulas can have a flow rate ranging from 1 to 6 liters per minute (L/min), with a 4% increase from 20 in FiO2 for every liter of oxygen, resulting in a range of fraction of inspired oxygen (FiO2) levels of 24–44%.

Advantages: Nasal cannulas are easy to use, inexpensive, and disposable. They are convenient because the patient can talk and eat while receiving oxygen.

Limitations: The nasal prongs of nasal cannula are easily dislodged, especially when the patient is sleeping. The tubing placed on the face can cause skin breakdown in the nose and above the ears, so the respiratory therapist and other health care providers must vigilantly monitor these areas. Based on policy, the respiratory therapist and other health care providers should add padding to the oxygen tubing as needed to avoid skin breakdown and may apply a water-based lubricant to prevent drying. However, petroleum-based lubricant

1. "Image00011.jpg" by British Columbia Institute of Technology is licensed under CC BY 4.0. Access for free at https://opentextbc.ca/clinicalskills/chapter/5-5-oxygen-therapy-systems/

2. Ernstmeyer, K., & Christman, E. (Eds.). (2023). *Nursing skills 2e*. Open RN. https://wtcs.pressbooks.pub/nursingskills/

should not be used due to the risk of flammability and the risk of a lipoid pneumonia. Nasal cannulas are not as effective if the patient is a mouth-breather or has blocked nostrils, a deviated septum, or nasal polyps.[3]

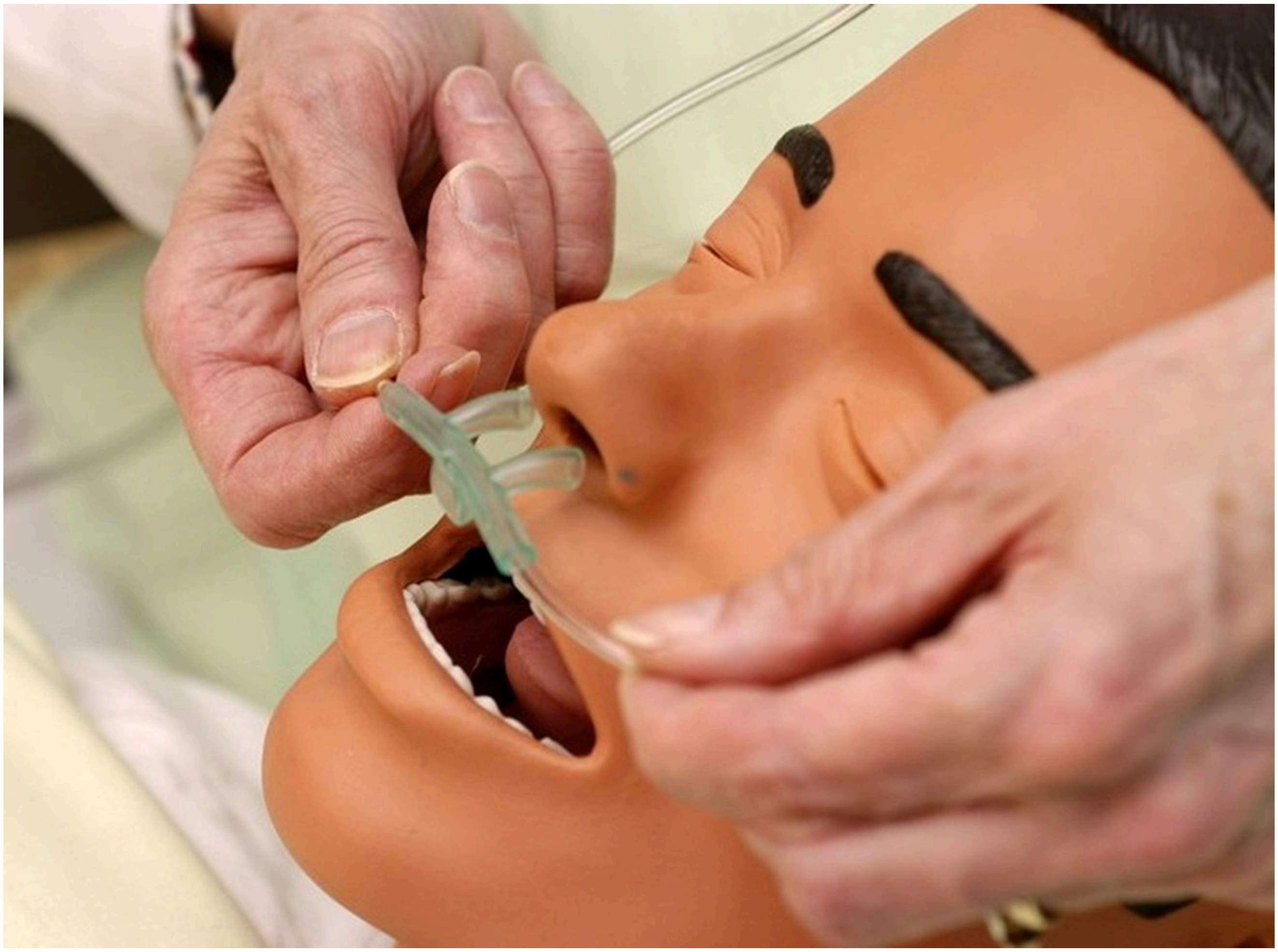


Figure 15. Nasal cannula.

SIMPLE MASK (Low Flow)

A simple mask fits over the mouth and nose of the patient and contains exhalation ports (i.e., holes on the side of the mask) through which the patient exhales carbon dioxide. These holes should always remain open. The mask is held in place by an elastic band placed around the back of the head. It also has a metal piece near

3. Ernstmeyer, K., & Christman, E. (Eds.). (2023). *Nursing skills 2e*. Open RN. https://wtcs.pressbooks.pub/nursingskills/

the top that can be pinched and shaped over the patient's nose to create a better fit. Humidified air may be attached if the oxygen concentrations are drying for the patient. (See Figure 16.[4])

Flow Rate: Simple masks should be set to a flow rate of 6–10 L/min, resulting in oxygen concentration (FiO2) levels of 35–50%. The flow rate should never be set below 6 L/min because this can result in the patient rebreathing their exhaled carbon dioxide, which could lead to patient impairment or injury.

Advantages: Simple face masks are used to provide moderate oxygen concentrations. Their efficiency in oxygen delivery depends on how well the mask fits and the patient's respiratory demands.

Disadvantages: Simple face masks must be removed when eating, and they may feel confining for some patients who feel claustrophobic while wearing the mask.

Figure 16. Simple mask.

NON-REBREATHER MASK (Reservoir)

A non-rebreather mask consists of a mask attached to a reservoir bag that is attached with tubing to a flow

4. "DSC_2086.jpg" by British Columbia Institute of Technology is licensed under CC BY 4.0. Access for free at https://opentextbc.ca/clinicalskills/chapter/5-5-oxygen-therapy-systems/

meter (see Figure 17[5]). It has a series of one-way valves between the mask and the bag and also on the side of the mask that cover the exhalation ports, ensuring a high concentration of oxygen. The reservoir bag should remain 1/3 inflated during inhalation; if the bag deflates, there is a problem and immediate intervention is required. The one-way valves function so that on inspiration, the patient only breathes in from the reservoir bag; on exhalation, carbon dioxide is directed out through the exhalation ports. Non-rebreather masks are used for patients who can breathe on their own but require higher concentrations of oxygen to maintain satisfactory blood oxygenation levels. The non-rebreather is a high-flow mask system because it meets all the inspiratory needs of the patient. A nasal cannula, on the other hand, is a low-flow device because it does not meet all the inspiratory needs of the patient.

Flow Rate: The flow rate for a non-rebreather mask should be set to deliver a minimum of 10–15 L/min. The bag must not deflate during the patient's inspiration. If it does, the flow should be adjusted to a higher flow. The flow can be adjusted higher than 15 L/min, and the standard outlet can reach 40 L/min. The reservoir bag should be inflated prior to placing the mask on the patient. With a good fit, the non-rebreather mask can deliver between 60% and 80% FiO2.

Advantages: Non-rebreather masks deliver high levels of oxygen noninvasively to patients who can otherwise breathe unassisted.

Disadvantages: Due to the one-way valves in non-rebreather masks, there is a high risk of suffocation if the gas flow is interrupted. The mask requires a tight seal and may feel hot and confining to the patient. It will interfere with talking, and the patient cannot eat while wearing the mask.

5. "DSC_2083.jpg" by British Columbia Institute of Technology is licensed under CC BY 4.0. Access for free at https://opentextbc.ca/clinicalskills/chapter/5-5-oxygen-therapy-systems/

Figure 17. Non-rebreather mask.

PARTIAL REBREATHER MASK (Reservoir)

The partial rebreather mask looks very similar to the non-rebreather mask. The difference between the masks is a partial rebreather mask contains one-way valves on each side of the mask, so the patient's exhaled air does not mix with their inhaled air. A partial rebreather mask requires 10–15 L/min of oxygen but only delivers 35–50% FiO2.

VENTURI MASK (High Flow)

Venturi masks are indicated for patients who require a specific amount of supplemental oxygen to avoid complications, such as those with COPD. Different types of adapters are attached to a face mask that set the flow rate to achieve a specific FiO2, ranging from 24% to 60% (see Figure 18[6]). Venturi adapters are typically set up by a respiratory therapist as there are different oxygen concentration adaptors available (see Figure 19[7]).

A respiratory therapist should know the air/oxygen ratios when utilizing a Venturi mask or system.

O2 Percentage	Air/O2 Ratio	**The oxygen percentage can be calculated by using the following formula:** $\frac{100-x}{x-21} = \frac{Parts of Air Entrainment}{1 part of O2}$ Example for 40% FiO2 the Air/O2 ratio can be calculated: 100-40/40-21 = 60/20 = 3/1 or 3:1
60%	1:1	
50%	1.7:1	
40%	3:1	
35%	5:1	
24%	25:1	

Flow Rate: The flow rate depends on the adapter and does not correspond to the flow meter. Consult with a respiratory therapist before changing the flow rate.

Advantages: A precise amount of FiO2 is delivered to patients whose breathing status may be affected by high levels of oxygen. The benefit of using this device is that it is able to obtain an accurate FiO2.

6. "Air-entrainment-delivery-device-mask-fn4yot.png" by Open Critical Care is licensed under CC BY-NC-SA 4.0

7. "Entrainment ports" by Don Raymond, Chippewa Valley Technical College is licensed under CC BY-NC 4.0

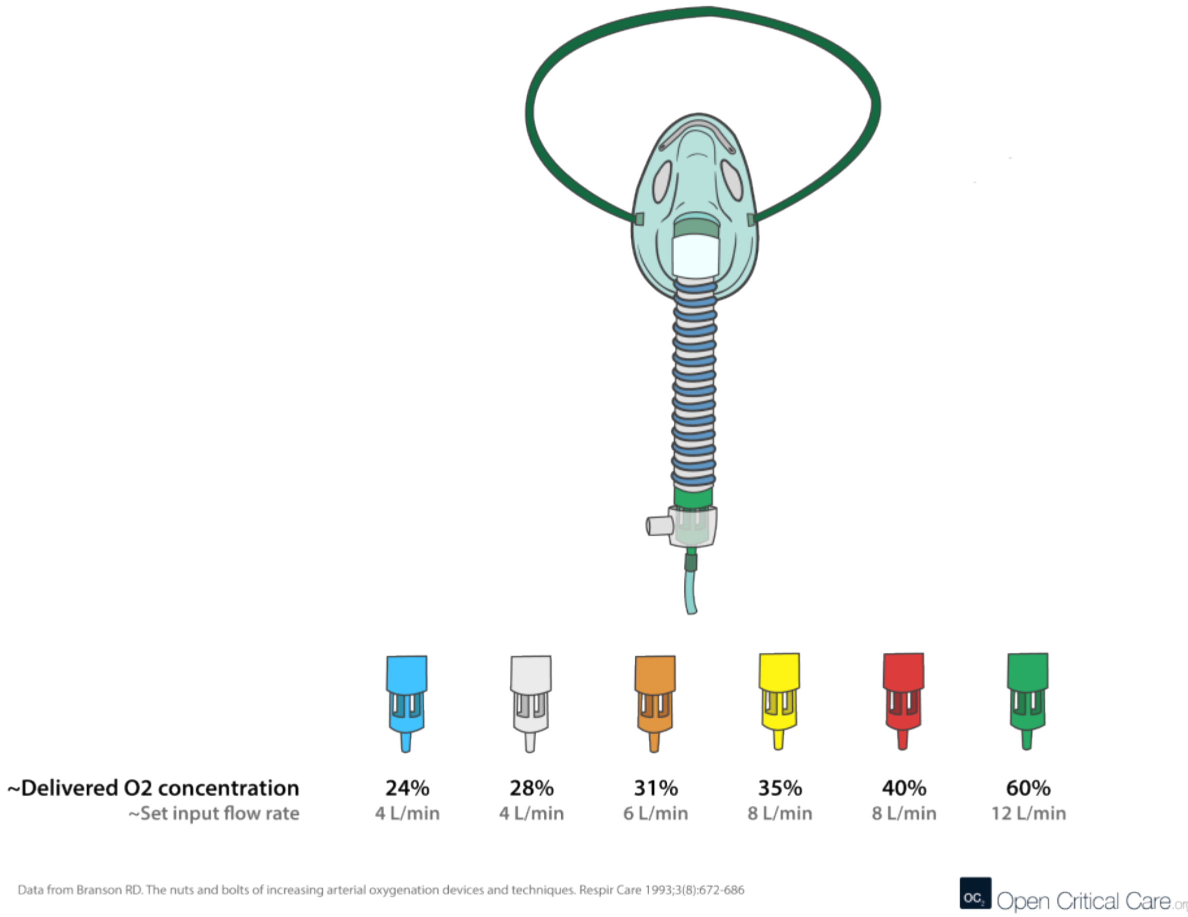


Figure 18. Venturi mask with various oxygen concentration ports.

Figure 19. Different sized entrainment ports of Venturi mask.

OXYMASK (Low Flow)

An OxyMask™ (see Figure 20[8]) is an oxygen delivery device that has an open design that eliminates the need for valves and reservoirs. O2 flow is directed towards the nose and mouth. Large openings in the mask allow CO2 to escape, decrease claustrophobia, increase the ability to communicate, and allow for delivery of fluids and medications without removing the mask.

Flow Rate: An OxyMask™ can deliver 24–90% oxygen concentration on 1–15 L/min oxygen, which increases flexibility and safety of the product.

Advantages: The OxyMask™ increases flexibility and safety due to variable oxygen flow rates. It also can decrease claustrophobia and increase the ability to communicate without removing the mask. Another advantage is the ability to perform oral suctioning with a Yankauer suctioning tip through the mask openings.

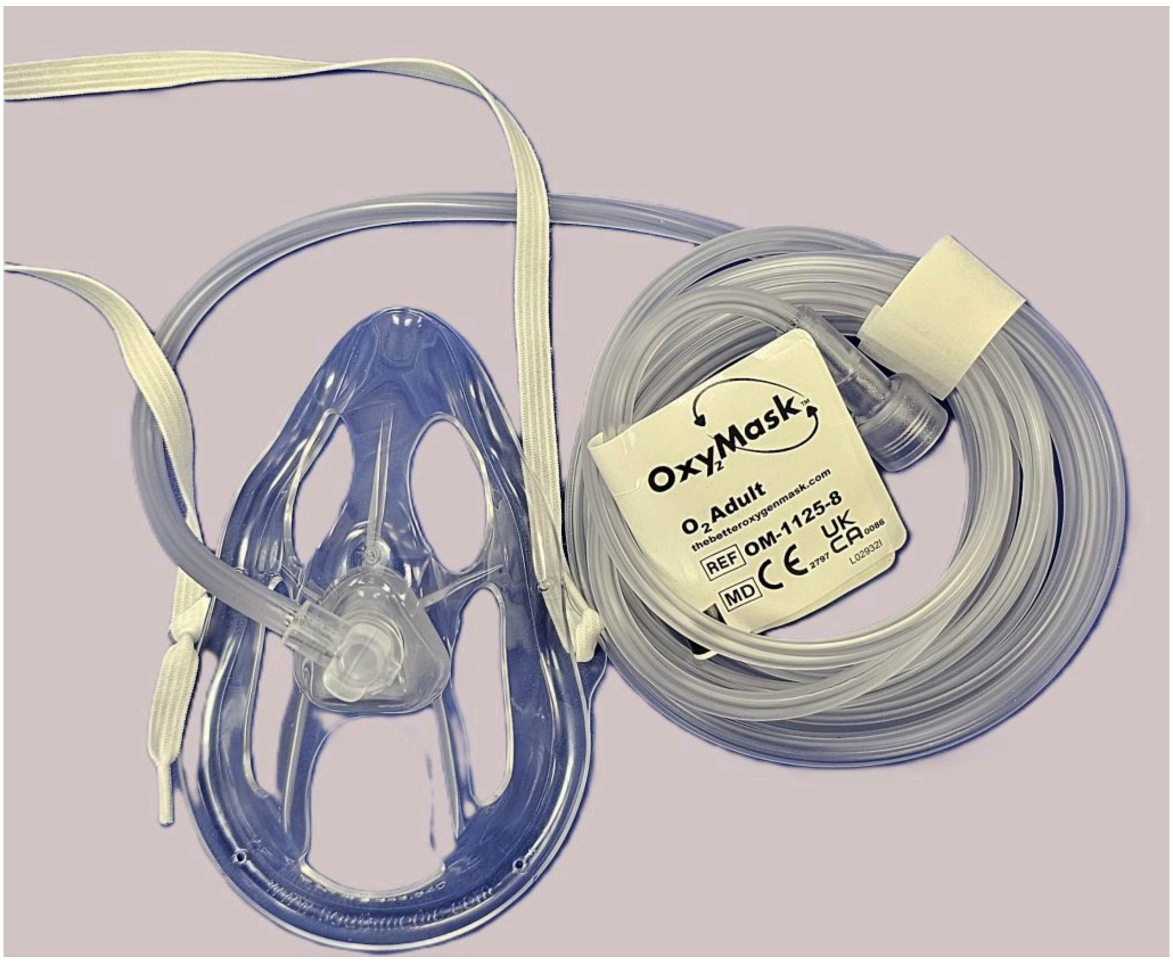


Figure 20. OxyMask™.

8. "oxymask" by Kirsten Holbrook, Chippewa Valley Technical College is licensed under CC BY-NC 4.0

OXYMIZER (Reservoir)

An oxymizer (see Figure 21[9]) is a special nasal cannula that provides a larger luminal diameter in combination with an oxygen reservoir. The oxymizer is designed as either a mustache or pendant style. Some patients don't like the weight of the device, which is greater due to the oxygen reservoir and tubing size.

Flow Rate: The flow rate is 1/4 to 1/2 of the set flow rate. The oxymizer can deliver up to 15 L/min.

Advantages: The oxymizer is able to help maintain adequate O2 saturations in hypoxic patients with a lower flow rate, resulting in reduced O2 costs, longer portable O2 sources, and decreased nasal irritation and dryness.

9. "oxymizer" by Kirsten Holbrook, Chippewa Valley Technical College is licensed under CC BY-NC 4.0

Figure 21. Oxymizer.

HEATED HIGH-FLOW NASAL CANNULA (High Flow)

High-flow nasal cannula (HFNC) therapy is an oxygen supply system capable of delivering up to 100% humidified and heated oxygen at a flow rate of up to 60 L/min (see Figure 22[10]). All settings are controlled independently, allowing for greater confidence in the delivery of supplemental oxygen, as well as better outcomes when used. In addition to greater control over the delivery of FiO2, there are several benefits to using a high-flow nasal cannula.

Flow Rate: The flow rate is up to 60–75 L/min depending on the device. The HFNC can deliver up to 95–100% FiO2 depending on the device.

Advantages: Many high-flow nasal cannula systems are designed with inline warming and humidification systems that provide appropriately humidified and body temperature air that is non-irritating to the mucosa, increasing patient comfort (31–37° C). Increased comfort leads to improved compliance and, therefore, better outcomes of therapy. Additionally, it can provide a small amount of "PEEP" by applying a splinting force to keep alveolar airways from collapsing under increased surface tensile stresses during exhalation. It is important to note that the patient needs to keep their mouth closed in order for this to be physiologically beneficial.

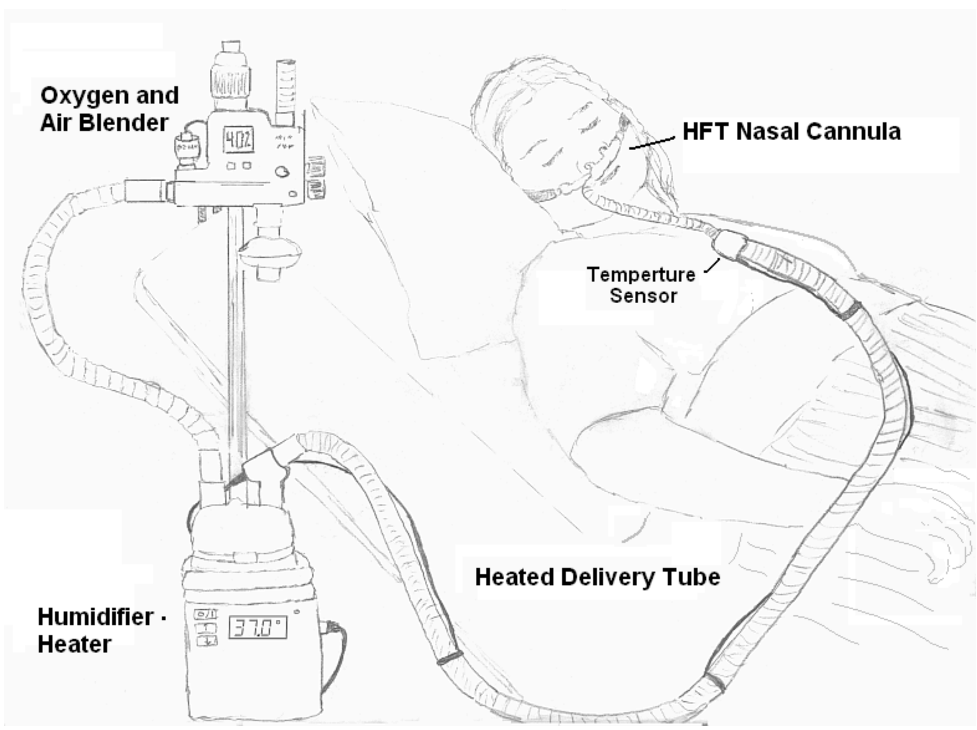


Figure 22. Heated high-flow nasal cannula.

10. "HFT diagram.png" by Strangecow is in the Public Domain.

Humidity Concepts

An essential part of care of patients with bypassed airways due to artificial airway (i.e, endotracheal tubes, tracheostomies) is humidification. It is important to have an appreciation of the anatomical structures of the upper airway, and that understanding is essential to the application of humidification systems to our patients. Humidification can be heated or cooled.

There are several key concepts that a respiratory therapy student should understand regarding humidity.

Relative Humidity – The ratio of the moisture a gas is actually holding to what it can hold when saturated at a given temperature. This is represented by the following formula: absolute humidity (content) / moisture capacity (according to charts) x 100. This value is expressed as a percentage.

Absolute Humidity – The actual amount of moisture contained in a gas (i.e., content).

Body Humidity – The relative humidity of a gas at body temperature (37° C). This is represented by the following formula: absolute humidity (content) / moisture capacity at body temperature x 100. This value is expressed as a percentage.

Body Humidity Deficit – The difference between the capacity and the content of the gas being delivered to the patient.

Temperature (°Celcius)	Vapor Pressure (mmHg)	Water Vapor Content (mg/L)
20	17.50	17.30
21	18.62	18.35
22	19.80	19.42
23	21.10	20.58
24	22.40	21.78
25	23.80	23.04
26	25.20	24.36
27	26.70	25.75
28	28.30	27.22
29	30.00	28.75

30	31.80	30.35
31	33.70	32.01
32	35.70	33.76
33	37.70	35.61
34	39.30	37.57
35	42.20	39.60
Figures calculated using the Clausius-Clapeyron equation.[11]		

11. Chung, P. & Censullo, A. (2025). *Clausius-Clapeyron equation*. Chemistry LibreTexts. https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Physical_Properties_of_Matter/States_of_Matter/Phase_Transitions/Clausius-Clapeyron_Equation

3.2 Lab Activities

3.2a Nasal Cannula

Instructions for Using a Nasal Cannula in Oxygen Therapy

View the following supplementary YouTube video[1] and then perform each of the numbered items following the video.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://wtcs.pressbooks.pub/respiratorysurvey/?p=318#oembed-1

1. Connect the nasal cannula to an oxygen flowmeter and place it in your nose and set the flow rate to 1 liter, then 3 liters, and then 6 liters per minute (L/min).
2. Observe the prong positioning and note any differences in your comfort at various flow rates.
3. Use a humidifier (bubbler) when administering oxygen at flow rates greater than 4 L/min to maintain moisture and comfort for the patient.
4. Apply the nasal cannula properly:
    - Position the prongs to face downward into the nostrils.
    - Secure the tubing behind the ears and under the chin, allowing for easy removal.
    - Ensure the fit minimizes the risk of strangulation or discomfort.
5. Understand normal flow rates: The standard flow range for a nasal cannula is 0–6 L/min. To estimate the approximate FiO2, multiply the flow rate by 4% per L/min. For example, an oxygen flow rate of 3 L/min will deliver an approximate FiO2 of 30–33%.
6. Consider patient-specific factors. Keep in mind that the actual delivered FiO2 can vary based on the patient's depth of respiration and breathing pattern.
7. Once you have completed the nasal cannula activity, take the nasal cannula quiz.

1. Donald Raymond. (2023, May 30). *Nasal canula* [Video]. YouTube. https://www.youtube.com/watch?v=z5HzR3fgvsU

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=318#h5p-95

3.2b Simple Mask

Instructions for Using a Simple Mask in Oxygen Therapy

View the following supplementary YouTube video[2] then perform each of the numbered items following the video.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://wtcs.pressbooks.pub/respiratorysurvey/?p=318#oembed-2

1. Connect the simple mask to an oxygen flowmeter and place the mask on your face and set the flow rate to 5 liters, then 8 liters, and then 10 liters.
2. When using a simple mask, it is important to ensure adequate oxygen flow. Apply the mask to the patient in a way that creates a secure seal without causing discomfort. The normal flow rate for a simple mask is 6–10 L/min, and the anticipated FiO2 (fraction of inspired oxygen) range is typically 35–50%. Ensuring the correct flow rate and mask fit helps maintain patient safety and optimal oxygen delivery.

2. Donald Raymond. (2023, May 30). *Simple mask* [Video]. YouTube. https://www.youtube.com/watch?v=z5HzR3fgvsU

3.2c Non-Rebreather

Instructions for Using a Non-Rebreather in Oxygen Therapy

View the supplementary YouTube video[3] and then perform each of the numbered items following the video: [Oxygen Therapy: How to Apply a Non-Rebreathe Mask]

1. Connect the non-rebreather mask to an oxygen flowmeter. Set the flow rate between 10 and 15 liters, ensuring that the reservoir bag inflates. Then, place the mask on your face.
2. To determine if the device is set accurately, observe the patient breathing at the prescribed flow rate and ensure that the reservoir bag deflates during inspiration. The FiO2 typically ranges between 60–80%, though some sources may extend this range to 70–90%.
3. A non-rebreathing mask provides the highest FiO2 available without the use of a mechanical device. This mask features two one-way valves: one on the reservoir bag and another on the side of the mask. These valves help ensure the highest possible FiO2 by allowing oxygen to flow in while preventing room air from diluting it and stopping exhaled air from reentering the bag.

3.2d Venturi Mask

Instructions for Using a Venturi Mask in Oxygen Therapy

View the supplementary YouTube video[4] and then perform each of the numbered items following the video: [Oxygen Therapy: How to set up a Patient on Venturi Oxygen Delivery Device]

1. Connect the Venturi port to the aerosol mask and set the port to 50%. Set the flow rate that aligns with 50% and then place the mask on your face. You will need to use the manufacturer's flow range to

3. Harrogate and District NHS Foundation Trust. (2023, January 24). *Oxygen therapy: How to apply a non-rebreathe mask* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=qB3udpXVVY4

4. Harrogate and District NHS Foundation Trust. (2023, January 24). *Oxygen therapy: How to set up a patient on Venturi oxygen delivery device* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=TnPYN6deVsg

determine the appropriate flow for the device.
2. Determine the total flow for the device based on the flow from the flowmeter and the FiO2 utilizing the air/O2 entrainment ratio.
3. The Venturi mask is different from the other oxygen masks. It is a high-flow oxygen mask that utilizes the Venturi principle. The FiO2 ranges from 24–50%. The mask features an adjustable setting to control the amount of air entrained, while other designs use variable-sized Venturi adapters for this purpose.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=318#h5p-96

3.2e Humidity and Heated High Flow

Utilizing the humidity definitions for Absolute Humidity, Relative Humidity, Body Humidity and Humidity deficit stated below; the Water Vapor Pressure and Content table in the previous section; and the corresponding equations, you should answer the following questions:

Absolute Humidity (AH) – The actual amount of moisture "or content" contained in a gas.

AH = RH x Capacity

Relative Humidity (RH) – The ratio of the moisture a gas is actually holding to what it can hold when saturated at a given temperature. This is represented by the formula: absolute humidity (content) / moisture capacity (according to charts) x 100. This value is expressed as a percentage.

RH = AH/Capacity x 100

Body Humidity (BH) – The relative humidity of a gas at body temperature (37° C). This is represented by the formula: absolute humidity (content) / moisture capacity at body temperature x 100. This value is expressed as a percentage.

BH = AH/44mg/L x 100

Humidity Deficit (HD) – The actual amount of moisture deficit between the inspired air and the needs of the body. This is represented by the formula: capacity at body temperature – absolute humidity = humidity deficit.

HD = 44mg/L – AH

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=318#h5p-97

3.3 Critical Thinking Assessment

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=323#h5p-54

4.1 MDI/DPI and SVN

The lungs have a large surface area with an increased amount of blood flow, so medications are easily absorbed. Medications inhaled from the mouth into the lungs can be administered using a metered-dose inhaler (MDI), a dry powder inhaler (DPI), or a small-volume nebulizer (SVN).

Metered-Dose Inhaler (MDI)

A metered-dose inhaler (MDI) provides a mist of medication that is inhaled through the mouth into the lungs (see Figure 23[1]). However, during inhalation from an MDI, small medication particles can get trapped on the tongue or aerosolize into the air and not make it into the lungs, so a spacer is optimally used for full absorption of medication.

Figure 23. Metered-dose inhaler.

Dry Powder Inhaler (DPI)

A dry powder inhaler (DPI) is medication provided in a powder form that is inhaled from the mouth into the

1. RESIZED+SERIALIZED+1202-1.jpg" courtesy of the U.S.National Library of Medicine is in the Public Domain.

lungs using a quick breath to activate the medication and move it into the lungs from the inhaler (see Figures 24[2] and 25[3]).

Figure 24. Advair dry powder inhaler.

Figure 25. Breo Ellipta dry powder inhaler.

Small-Volume Nebulizer (SVN)

Since the development of the field of respiratory therapy, the small-volume nebulizer (SVN) has been the

2. "advair-diskus-spl-graphic-16.jpg" courtesy of the U.S.National Library of Medicine in the Public Domain.

3. "breo-ellipta-for-article_765295.jpg" courtesy of EMPR.com. This image is included on the basis of Fair Use.

primary way that medications are delivered to a patient's lungs. The SVN requires a pneumatic gas source that runs 6–8 L/min. Some SVNs are breath-actuated and have a more complex design. There are simpler versions, referred to as high-humidity nebulizers (HHN), which run continuously and have a lower percentage of the medication that deposits into the lung compared to the breath actuated systems. There are also vibrating mesh nebulizers that do not add additional inspiratory flow to the patient and studies have shown greater medication deposition when using these types of nebulizers.

Hand-held, small-volume nebulizers provide a fine mist using oxygen or compressed air to transport the liquid medication (see Figure 26[4]) from the nebulizer cup into the mouth and into the lungs as the patient breathes normally.[5]

Figure 26. Nebulized liquid medications.

MDI/DPI and nebulized medications are delivered to the lungs by inhalation. Respiratory therapists are the primary health care providers responsible for delivery of inhaled medication. Deposition of the medication is determined by a number of factors such as the type of device used, the patient, the drug delivered, and the patient's disease state. One of the major factors affecting the deposition of inhaled aerosolized medications in the lungs is particle size.

4. "Ipratropium_Bromide_(1).JPG" by Intropin is licensed under CC BY-SA 3.0

5. Ernstmeyer, K., & Christman, E. (Eds.). (2023). *Nursing skills 2e*. Open RN. https://wtcs.pressbooks.pub/nursingskills/

View the following supplementary YouTube video[6] that explains particle deposition in detail: Particle Deposition in Respiratory Tract

Medication Administration

Before administering an inhaler, the respiratory therapist should perform hand hygiene and check medication rights as with all medication. If the patient is self-administering the medication, advise them to wash their hands. The patient's respiratory system should be assessed and documented before and after the administration of inhaled medications, including assessment of respiratory rate, pulse oximetry, heart rate, and lung sounds.

When administering an MDI, the respiratory therapist should shake the inhaler and add a spacer or a valved holding chamber onto the mouthpiece. The use of spacers with MDIs is considered best practice because they help ensure the medication is inhaled rather than inadvertently placed in the mouth. They also reduce waste by ensuring the patient receives the full amount of medication. The patient should be instructed to exhale while placing the spacer's mouthpiece into their mouth. The inhaler is depressed to move the aerosolized medication into the spacer, and the patient should breathe in normally through the spacer to receive the medication. If a spacer is not available, the patient should exhale and hold the inhaler mouthpiece about 1–2 inches away from their mouth to help ensure the medication is inhaled via the larynx and not sprayed onto the posterior pharynx. As the inhaler is depressed, the patient should inhale the medication deeply through their mouth and into their lungs. The patient should be advised to hold their breath for 5–10 seconds after inhaling the medication and then exhale through pursed lips. The patient should wait for 1–5 minutes between each puff of medication. When administering inhaled corticosteroids via MDI, the patient should rinse their mouth with water afterwards to prevent fungal infection.[7]

When using a DPI, the respiratory therapist should load the medication into the devices as required and then activate the inhaler per the manufacturer's guidelines. The patient should be instructed to hold the device level once the dose has been loaded and activated. Then, the patient should exhale and then place their lips around the mouthpiece and inhale strongly and deeply. After they have inhaled, they should hold their breath for 10 seconds or as long as comfortable and then exhale through pursed lips. The patient should wait 1–5 minutes between puffs of medication. If the DPI contains a corticosteroid medication, the patient should gargle and rinse with tap water to decrease the risk of developing a fungal infection.

When using an SVN, the respiratory therapist pours the liquid medication (using sterile technique – without touching the inside of the cup) into the medication cup of the nebulizer. When possible, the patient should be sitting or positioned in high-Fowler's position to enhance deep breaths and absorption of medication. The bottom end of the tubing is attached to the oxygen flowmeter, and the flow rate should be set between 6 to

6. METPHAST. (2018, November 19). *Particle deposition in respiratory tract* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=6ih3F1S9MZw

7. Ernstmeyer, K., & Christman, E. (Eds.). (2023). *Nursing skills 2e*. Open RN. https://wtcs.pressbooks.pub/nursingskills/

10 L/min, based on the manufacturer's recommendations. The top end of the tubing is connected to either a nebulizer mask or mouthpiece. The patient should be instructed to inhale slowly through the device into their mouth and hold each breath for a slight pause before exhaling. (See Figure 27.[8]) Remain with the patient during the nebulizer treatment, which usually takes about 8–10 minutes. After treatment, the patient should be encouraged to cough and perform oral care. The patient's respiratory system should be reevaluated after the administration of inhaled medications to document therapeutic effects, as well as to monitor for adverse effects.[9]

Figure 27. Administration of nebulized medication via aerosol mask.

8. "Administering_inhaled_medication.jpg" by British Columbia Institute of Technology (BCIT) is licensed under CC BY 4.0

9. Ernstmeyer, K., & Christman, E. (Eds.). (2023). *Nursing skills 2e*. Open RN. https://wtcs.pressbooks.pub/nursingskills/

4.2 Lab Activities

4.2a Small-Volume Nebulizer (SVN)

1. In the laboratory classroom, you and a partner should locate the small-volume nebulizer (SVN acorn type; see Figure 28[1]) and, if available, the breath-actuated nebulizer (BAN type; see Figure 29[2]). Explain their operations, and label and identify the parts and draw them on a separate piece of paper. Show this drawing and your explanation to your lab instructor.

Figure 28. SVN (acorn type).

1. "Acorn type" by Don Raymond, Chippewa Valley Technical College is licensed under CC BY-NC 4.0
2. "BAN" by Don Raymond, Chippewa Valley Technical College is licensed under CC BY-NC 4.0

Figure 29. SVN (breath-actuated nebulizer type).

2. With your partner, practice setting up the SVN and, if available, the BAN. Use a viral filter for the mouthpiece and normal saline bullets as the placebo medication. Answer the following questions on a separate piece of paper. Show your answers to your lab instructor.

   a. At what level should the flowmeter be set?
   b. How does the nebulizer sound when it is running?
   c. When do you know the medication is gone?
   d. What happens to the delivery of the medication if the device is not positioned properly?

4.2b Metered-Dose Inhaler (MDI)

1. In the laboratory classroom, you and a partner should locate a metered-dose inhaler (MDI; see Figure 30[3]). Explain its operation and label and identify the parts and draw it on a separate piece of paper. Show this drawing and your explanation to your lab instructor.

3. "MDI" by Don Raymond, Chippewa Valley Technical College is licensed under [CC BY-NC 4.0]

Figure 30. Metered-dose inhaler (MDI).

2. With your partner, practice instructing a patient on how to use an MDI and spacer. Answer the following questions on a separate piece of paper. Show your answers to your lab instructor.

a. Why should a spacer be used with an MDI?

b. How long should a patient hold their breath for optimal deposition?

c. Why is it important to instruct a patient to wait between puffs?

4.2c Dry Powder Inhaler (DPI)

1. In the laboratory classroom, you and a partner should locate a dry powder inhaler (DPI; see Figure 31[4]). Explain its operation and label and identify the parts and draw it on a separate piece of paper. Show your drawing and explanation to your lab instructor.

4. "Dry Powder Inhaler" by Don Raymond, Chippewa Valley Technical College is licensed under [CC BY-NC 4.0](https://creativecommons.org/licenses/by-nc/4.0/)

Figure 31. Ellipta Dry Powder Inhaler (DPI).

2. With your partner, practice instructing a patient on how to use a DPI. Answer the following questions on a separate piece of paper. Show your answers to your lab instructor.

  a. How much flow does a patient need to generate to get the proper deposition from the DPI?
  b. Why is it important for the patient to rinse out their mouth after administration of a corticosteroid?
  c. True or false – DPIs do not need to have hand-breathing coordination to be actuated.
  d. What is your solution if the patient cannot inhale the DPI?

4.3 Critical Thinking Assessment

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=336#h5p-55

5.1 Electrocardiogram (EKG or ECG)

Respiratory therapists need to understand electrocardiograms (EKG or ECG) because they often care for patients with cardiopulmonary conditions where the heart and lungs are interconnected, meaning that changes in cardiac function can directly impact respiratory status and vice versa. Therefore, being able to interpret an ECG allows them to monitor a patient's heart rhythm, identify potential cardiac complications, and make informed treatment decisions, especially in critical care situations where rapid intervention may be necessary.

An ECG is a noninvasive test that measures the electrical activity of your heart. An ECG records the electrical signals that travel through your heart each time it beats. The recording looks like wavy lines on a graph that a health care provider can interpret to identify abnormal heart activity. An ECG can show how fast your heart is beating, if your rhythm is regular or irregular, and the strength and timing of electrical signals in each part of your heart.

First, we will learn to measure time on graph paper. This is helpful when you need to know how long it takes for a particular wave to occur. A "small box" denoted by the thinner lines represents 0.04 seconds of time. The "big box" is denoted by the bold lines and is composed of five small boxes and represents 0.2 seconds of time. (See Figure 32.[1])

In this example, we will measure the wave complex drawn on the graph. We will start at the beginning of the complex (where it deviates upward from the baseline in this example) and end at the end of the complex (where it returns to the baseline). It is acceptable to estimate to the nearest small box because ECG wave forms rarely line up exactly on the graph lines. This example below measures the complex at approximately three small boxes wide. Each small box represents 0.04 seconds, so we know this wave on the ECG graph took place in 0.12 seconds (see Figure 32).

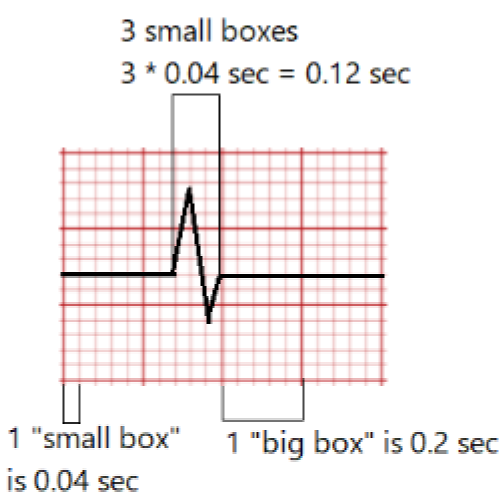


Figure 32. ECG graph paper.

1. "3 small boxes" by Nurses International Team is licensed under CC BY 4.0. Access for free at https://projects.nursesinternational.org/resources/ekg-guide

It is a good idea to get comfortable with measuring waves in this manner and calculating the time per wave, as it will help your ECG interpretation greatly. ECGs measure electrical activity in the heart. They do not measure actual movement, only the electrical impulses that cause muscle contractions. In a normal heart, the electrical impulse starts in the SA node and then travels from there through the atria to the AV node. The electrical impulse is held there briefly and then is allowed to continue on through the bundle of His to the Purkinje fibers into the ventricles.

View the following supplementary YouTube video[2] which demonstrates ECG interpretation for the beginner: [12 Lead ECG (Electrocardiogram) for beginners🔥🤯]

ECG Waveform

The heart's electrical activity, visible on an ECG, includes several key components that reflect its rhythm and function (see Figure 33[3]). The P wave marks the electrical flow from the SA node through the atria to the AV node, causing the atria to contract. Following this, the PR segment represents a pause as the AV node temporarily holds the impulse, allowing the ventricles to fill. The PR interval, from the start of the P wave to the beginning of the Q wave, typically ranges from 0.12 to 0.2 seconds. The QRS complex shows the rapid conduction from the AV node through the bundle of His and Purkinje fibers, leading to ventricular contraction. After this, the T wave reflects ventricular repolarization. The QT interval, from the start of the Q wave to the end of the T wave, should be approximately 0.45 seconds, though it varies with heart rate. Finally, the ST segment represents the period from the end of the S wave to the beginning of the T wave, marking the transition to ventricular repolarization. Each component provides valuable insights into the heart's function and rhythm.

E C G waveform

Figure 33. ECG waveform.

2. The Learn Medicine Show. (2023, April 2). *12 Lead ECG (Electrocardiogram) for beginners🔥🤯*[Video]. Youtube. All rights reserved. https://www.youtube.com/watch?v=oLlx3Dj4AbE

3. "P wave" by unknown author, MDPI is licensed under CC BY 4.0. Access for free at https://www.mdpi.com/2073-431X/10/6/82

View the following supplementary YouTube video[4] that will help you understand cardiac conduction and the ECG waveform: [Cardiac Conduction System and Understanding ECG, Animation](https://www.youtube.com/watch?v=RYZ4daFwMa8&t=2s)

Systematic Interpretation of ECG and Cardiac Rhythms

Respiratory therapists play a critical role in managing patients with cardiopulmonary disorders, often working in high-acuity settings where rapid assessment and intervention can be lifesaving. A systematic approach to interpreting ECGs and cardiac rhythms is essential for respiratory therapists to recognize early signs of cardiac dysfunction, guide appropriate interventions, and collaborate effectively with the health care team. Given the close relationship between the respiratory and cardiovascular systems, understanding ECG patterns can help respiratory therapists differentiate between primary cardiac events and respiratory-induced changes, ensuring timely and appropriate patient management. By adopting a structured method of ECG interpretation, respiratory therapists can enhance their clinical decision-making, improve patient outcomes, and elevate their role as integral members of the critical care team.

1. **Measuring the Rate.** Most ECG machines will automatically provide a rate, provided they are setup correctly. ECG machines usually measure the QRS complex rate as the overall rate. However, the easiest alternative way to measure rate is to count the number of QRS complexes in a 6-second strip and then multiply that count by 10. A normal heart rate is 60–100 bpm.
2. **Finding the P Wave.** Is there a P wave for every QRS complex? Is there a QRS complex for every P wave? The ratio of P waves to QRS complexes should be 1:1 in a normal rhythm (discussed in more detail in the next segment). Noting a P to QRS ratio that is different from a 1:1 ratio will help you discern certain rhythms.
3. **Is the Rhythm Regular or Irregular?** You should analyze the ECG or 6-second strip and ask yourself, do the P waves come at consistent intervals? Do the QRS complexes come at consistent intervals? "March out" means they all occur at consistent, regular intervals. It is most accurate to use a pair of calipers to measure this, but you can often see clearly when it does not march out in regular intervals, as with the irregular QRS complexes on Figure 34.[5]

4. Alila Medical Media. (2014, April 29). *Cardiac conduction system and understanding ECG, animation* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=RYZ4daFwMa8&t=2s

5. "Irregular QRS Complexes" by Nurses International Team is licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/). Access for free at https://projects.nursesinternational.org/resources/ekg-guide

Figure 34. Irregular 6-second rhythm strip.

4. **Is the PR Interval Prolonged?** A normal PR interval measures 0.12–0.20 seconds. This is the time it takes for the impulse to travel from the SA node through the AV node.
5. **Is the QRS Complex Wide or Narrow?** A normal QRS complex is 0.12 seconds or less, which is referred to as a narrow complex. Three of the small ECG boxes are equal to 0.12 seconds (see Figure 35[6]). A wide QRS complex is considered anything above 0.12 seconds. You may see certain rhythms referred to as “wide complex” or “narrow complex”; these terms refer to the width of the QRS complex and will help you distinguish certain rhythms. We will discuss what these types of QRS complexes mean with regards to physiology in another segment.
6. **Are There T Waves?** A normal T wave should point in the same direction as the QRS complexes.

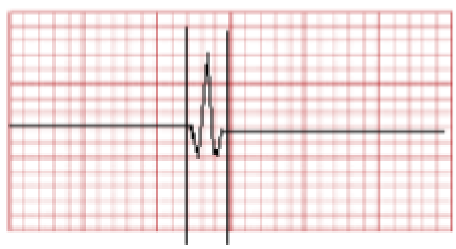


Figure 35. Narrow QRS complex.

Now it is time to put all the above information about the rhythm strip together. It is often helpful to have a diagram you use to measure and interpret each piece of the ECG to help you get into the habit of thinking about the parts.

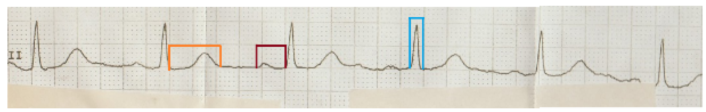
In the example below (see Figure 36[7]), note the following:

- The rate is measured at 60, as there are six QRS complexes in this 6-second strip.

6. “Normal QRS Complex” by Nurses International Team is licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/). Access for free at https://projects.nursesinternational.org/resources/ekg-guide

7. “Example EKG Tracing” and “Putting it all Together” by Nurses International Team are licensed under CC BY 4.0. Access for free at https://projects.nursesinternational.org/resources/ekg-guide

- The rhythm is regular because the QRS complexes occur at regular intervals.
- The P waves are upright and occur at the same interval every time (red box).
- The PR interval, QRS complex, and ST segments are 0.24 seconds, 0.12 seconds, and 0.44 seconds in duration (blue box).
- The T waves are upright (orange box).



Rate	60
Rhythm	Regular
P waves	Upright, regular
PR interval	0.24 sec
QRS complex	0.12 sec
ST segment	0.44 sec
T waves	Upright

Figure 36. Systematic ECG diagram.

This would be interpreted as a normal sinus cardiac rhythm.

Practice the systematic interpretation of ECG strips using this [Rhythm Game](#).

12-Lead ECG Placement

Respiratory therapists are often the clinicians who perform the task of 12-lead ECGs on patients; therefore, it is important to make sure leads are placed correctly for a 12-lead. (See Figure 37.[8]) V1 is the only lead that is located to the right of the sternum. V1 and V2 are placed at the fourth intercostal space to the right and left of the sternum, respectively. It is recommended to physically palpate the first four intercostal spaces when you place leads V1 and V2; the location is anatomically lower on the chest wall than it appears at a glance.

V3 and V4 are placed next, both in the fourth intercostal space. V4 should be placed in the fourth intercostal space directly below the nipple. This is also about the midclavicular line. V3 is placed in the fourth intercostal space directly but laterally placed halfway between V2 and V4.

V5 and V6 are placed in the fifth intercostal space. V6 is placed horizontally along the midaxillary line in the fifth intercostal space. V5 is placed in the fifth intercostal space, halfway between V4 and V6.

8. “12 Lead Electrode Placement” by Nurses International Team is licensed under CC BY 4.0. Access for free at https://projects.nursesinternational.org/resources/ekg-guide

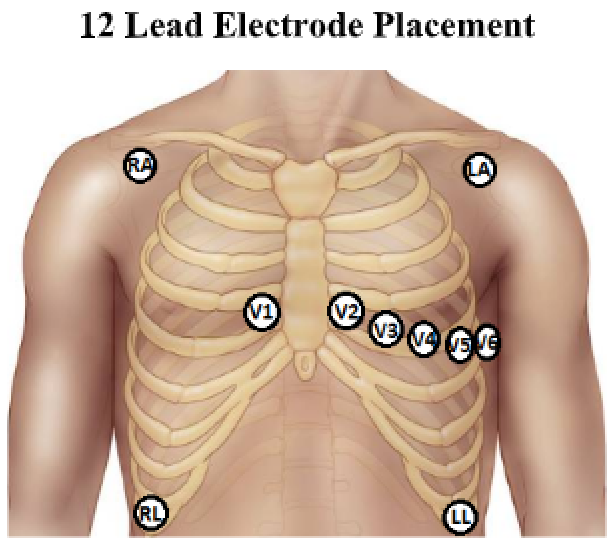


Figure 37. 12-lead ECG electrode placement.

5.2 Lab Activities

ECG

1. In the lab today you will be practicing the ECG Competency.
2. Using the systematic approach to ECG interpretation as discussed in the previous section (under the heading "Systematic Interpretation of ECG and Cardiac Rhythms"), answer the following:
    1. What is the rate?
    2. Is the rhythm regular?
    3. Are there P waves?
    4. Determine the duration of the PR interval.
    5. Is the QRS wide or narrow?
    6. Name of the rhythm.

Rhythm 1

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=348#h5p-98

Rhythm 2

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=348#h5p-99

Rhythm 3

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Rhythm 4

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Rhythm 5

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https://wtcs.pressbooks.pub/respiratorysurvey/?p=348#h5p-102

Rhythm 6

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https://wtcs.pressbooks.pub/respiratorysurvey/?p=348#h5p-103

5.3 Critical Thinking Assessment

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=350#h5p-56

Skills Assessments

Oxygen Cylinder
- Administering Oxygen Therapy
- Bland Aerosol Cool or Heated Via Mask
- Heated High-Flow Nasal Cannula
- Small-Volume Nebulizer
- MDI_DPI

PART III

RESPIRATORY THERAPEUTICS 2

Learning Objectives

- Explain the purpose and principles of hyperinflation therapy devices (e.g., incentive spirometer, PAP devices, and IPPB).
- Demonstrate proper use of hyperinflation devices to prevent or treat atelectasis.
- Identify and describe bronchial hygiene techniques and various handheld devices.
- Identify and describe postural drainage, percussion, and vibration, and the various patient placement positions for proper airway clearance.
- Teach effective coughing techniques to enhance secretion clearance.
- Perform arterial punctures safely and accurately, including Allen's test to assess collateral circulation.
- Describe the goals and components of pulmonary rehabilitation programs.
- Discuss the role of respiratory therapists in home care and other alternative settings.
- Describe the purpose and benefits of therapist-driven protocols in clinical practice.
- Explain the importance of evidence-based medicine in respiratory therapy.

1.1 Hyperinflation

Treating and preventing atelectasis is a foundational skill for respiratory therapists to understand and master. Atelectasis is a partial or complete collapse of alveoli that can lead to a patient's pulmonary status being compromised and can cause hypoxemia, tachycardia, desaturation, and may lead to respiratory distress or failure. Hyperinflation therapy, sometimes referred to as lung expansion therapy, is a common treatment for patients with respiratory compromise that involves inflating the lungs with a greater than normal volume of air to inflate collapsed alveoli. Hyperinflation therapy should be implemented early for bedridden or postoperative patients to prevent or correct atelectasis. Patients who are at the greatest risk for postoperative atelectasis are patients who have had thoracic and upper abdominal surgeries or procedures and those with a history of mucus producing diseases. There are several devices that respiratory therapists can use to improve a patient's pulmonary status. These hyperinflation devices can include incentive spirometry, Ezpap™/Versapap™, or intermittent positive pressure breathing (IPPB).

An important calculation that is necessary when performing hyperinflation is a patient's ideal body weight (IBW). One way to calculate this is to utilize the formulas below:

Female: 105 + 5 (height in inches – 60)

Males: 106 + 6 (height in inches – 60)

Change the units from pounds to kilograms by dividing your answer by 2.2.

Example

To figure out the IBW of a 5'7" female, calculate and perform the order of algebraic operations: 105 + 5 (67 – 60) = 140

Divide that number by 2.2 = 63.63kg. IBW is always measured in kilograms.

Incentive Spirometry

An incentive spirometer is a medical device commonly prescribed after surgery to expand the lungs to keep alveoli open, reduce the buildup of fluid in the lungs, and prevent pneumonia. See Figure 1[1] for an image of a patient using an incentive spirometer. While sitting upright, if possible, the patient should exhale normally, place the mouthpiece in their mouth, and create a tight seal with their lips around it. They should breathe in slowly and as deeply as possible through the tubing with the goal of raising the piston to their prescribed level. The resistance indicator on the right side should be monitored to ensure they are not breathing in too quickly. The patient should attempt to hold their breath for as long as possible (at least 5 seconds) and then exhale and rest for a few seconds. Sustained maximal inhalation (SMI) should be achieved. Then, the patient should perform

1. "Incentive Spirometer.png" by BruceBlaus is licensed under CC BY-SA 4.0

a breath hold at the point of SMI. Coughing is expected due to alveoli stretching to open more fully. Encourage the patient to expel any mucus produced and not swallow it. This technique should be repeated by the patient ten times every hour while awake.[2] The benefit of this therapy is dependent on the patient's full effort.

Figure 1. Using an incentive spirometer.

View the following supplementary YouTube video[3] demonstrating proper use of an incentive spirometer: How to Use an Incentive Spirometer – Nemours KidsHealth

PAP Therapy

PAP therapy includes several different devices. The Ezpap (see Figure 2[4]) and Versapap (see Figure 3[5]) are devices that are handheld and amplify an input flow of either air or oxygen approximately four times (Coanda

2. Ernstmeyer, K., & Christman, E. (Eds.). (2024). *Nursing fundamentals 2E*. Open RN | WisTech Open. https://wtcs.pressbooks.pub/nursingfundamentals/

3. Nemours. (2018, January 16). *How to Use an Incentive Spirometer – Nemours KidsHealth* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=Rmxfznw8Grk

4. "23-0747.jpeg" by unknown author is used on the basis of Fair Use.

5. "VersaPAP®-Device-3.jpg" by unknown author is used on the basis of Fair Use.

effect), which allows positive pressure to be maintained throughout the patient's breathing cycle. When ensuring an effective treatment, the respiratory therapist should make sure that there are no leaks coming from the patient. The patient should be appropriately coached and told to breathe through the mouthpiece with a tight seal. If the patient cannot keep a tight seal, the use of an Ambu mask is best to avoid leaks. Otherwise, a nose clip is suggested for patients who utilize the mouthpiece. This augmentation provides a larger flow and volume with less effort than an unsupported inspiration, and positive expiratory pressure (PEP) is provided on expiration. The prolonged exaltation time during this therapy enhances the effectiveness. Studies have shown that it is easier to tolerate than intermittent positive pressure breathing (IPPB) and has greater effect in reversing atelectasis than incentive spirometry. Thus, it can be used within physiotherapy to increase lung volume, clear secretions, and improve gaseous exchange.[6] When performing PAP therapy, we are looking for a therapeutic result of 10–20 cmH20 for exhalation and 2–5 cmH20 for inhalation. It should be noted that certain nebulizer devices can work in conjunction with these devices for a combined treatment.

Figure 2. Ezpap device.

6. Elliott, S. (2011). A study to investigate the clinical use and outcomes of EZPAP positive pressure device. *Thorax*, 66(A96). https://thorax.bmj.com/content/66/Suppl_4/A96.1

Figure 3. Versapap device.

View the following supplementary YouTube video[7] demonstrating how to set up an Ezpap device: EZPAP

Intermittent Positive Pressure Breathing (IPPB)

Intermittent positive pressure breathing (IPPB) is a technique used to provide short-term or intermittent mechanical ventilation via mouthpiece or mask for the purpose of augmenting lung expansion. IPPB is usually not a therapy of choice in treating lung collapse, as there are other techniques that are less expensive and easier to administer; however, it can be effective when a patient needs a more aggressive lung expansion therapy and when PAP therapy is not effective. It is usually used when other therapies have failed, or a patient is not cooperating.[8]

The clinician asks the patient to breathe in on the IPPB circuit, and the machine gives some positive pressure support, followed by airway pressure returning to atmospheric pressure with passive expiration. The Bird Mark 7 IPPB machine (see Figure 4[9]) is a pressure-cycled device convenient to use for providing IPPB as an adjunct to hyperinflation therapy in the spontaneously breathing patient. The respiratory therapist can the set flow to

7. WorkWeb. (2020, January 28). *EXPAP* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=X5taRLl8zTg

8. Physiopedia. (2022). *Intermittent positive pressure breathing*. https://www.physio-pedia.com/Intermittent_positive_pressure_breathing

9. "Bird_Mark_8_Medical_respirator1.JPG" by Stefan Bellini is licensed under CC0

help reach targeted pressures to help ensure a longer inspiratory time, which aids in lung expansion. IPPB may be applied to intubated and nonintubated patients.

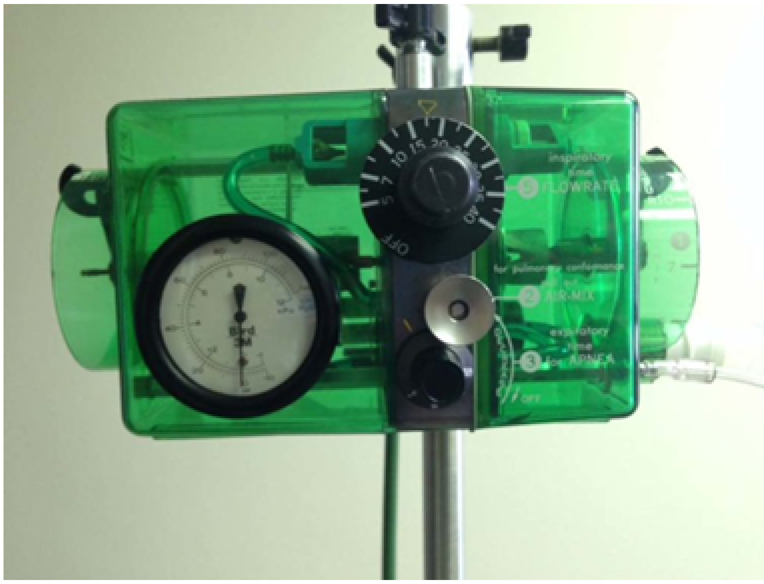

Figure 4. Bird Mark IPPB machine.

1.2 Lab Activities

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=363#h5p-57

1.3 Critical Thinking Assessment

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=367#h5p-58

2.1 Bronchial Hygiene

Bronchial hygiene, sometimes called airway clearance therapy (ACT) or pulmonary toilet, is a critical component of respiratory care aimed at maintaining a patent airway and ensuring effective ventilation and oxygenation. It involves a variety of techniques and interventions designed to remove mucus or secretions from the respiratory tract. Proper airway clearance is essential for patient care and plays a significant role in recovery from acute illnesses, particularly those affecting the respiratory system.

There are several techniques that a respiratory therapist can choose to use when treating patients with excess mucus or secretions.

Chest Physiotherapy (CPT): This involves postural drainage, manual percussion, and vibration of the chest to loosen secretions, making them easier to expectorate. This is also sometimes referred to as postural drainage percussion vibration (PDPV).

Positive Expiratory Pressure (PEP) Therapy: PEP uses devices that create resistance during exhalation, helping to keep the airways open and mobilize secretions.

High-Frequency Chest Wall Oscillation (HFCWO): High-frequency chest wall oscillation uses a mechanical vest that vibrates at high frequencies to help loosen and mobilize mucus.

Breathing and Cough Techniques: This involves coaching a patient to purposefully cough to aid in effective removal of secretions. These techniques include the huff cough or forced expiratory technique (FET), autogenic drainage, and quad cough.

Mechanical Insufflation Exsufflation (MIE) Therapy: This device delivers positive pressures of 30 to 50 cmH_2O over a 1–3 second period and then the airway pressure is suddenly reversed to a negative pressure of -30 to -50 cmH_2O. This helps patients with neuromuscular diseases generate expiratory flow rates to mobilize secretions.

Intrapulmonary Percussive Ventilation (IPV): This involves a series of small tidal volumes delivered at high-frequency pressurized bursts of gas cycles. The pulses of gas flow help break up secretions for mobilization.

Continuous Positive Expiratory Pressure/High-Frequency Oscillation (CPEP/CHFO): These devices involve two modes that provide hyperinflation for 2.5 minutes and continuous pulses of positive pressure for 2.5 minutes. These are repeated for a 10-minute therapy cycle.

Chest Physiotherapy[1]

This technique involves postural drainage, along with percussion and vibration, to facilitate secretion clearance.

Postural drainage involves positioning a person with the assistance of gravity to aid the normal airway clearance mechanism. Postural drainage positioning varies based on specific segments of the lungs with a large amount of secretions. Postural drainage is the drainage of secretions, by the effect of gravity, from one or more lung segments to the central airways (where they can be removed by a cough or mechanical aspiration). Each position consists of placing the target lung segment(s) superior to the carina. Positions should generally be held for 3–15 minutes. Standard positions are modified as the patient's condition and tolerance warrant. Before determining the postural drainage position, it is very important to auscultate the lungs and identify the lung segments where added sound is heard.

1. Physiopedia. (2023). *Respiratory physiotherapy*. https://www.physio-pedia.com/index.php?title=Respiratory_Physiotherapy&oldid=334898

View the following supplementary YouTube video[2] demonstrating the postural drainage positions and CPT: Postural Drainage Positions and Chest Physiotherapy (CPT)

Percussion is also referred to as cupping. The purpose of percussion is to intermittently apply kinetic energy to the chest wall and lungs. This is accomplished by rhythmically striking the thorax with a cupped hand or mechanical device directly over the lung segment(s) being drained.

Vibration involves the application of a fine tremorous action (manually performed by pressing in the direction that the ribs and soft tissue of the chest move during expiration) over the draining area. In this technique, a rapid vibratory impulse is transmitted through the chest wall from the flattened hands of the therapist by isometric alternate contraction of the forearm flexor and extensor muscles to loosen and dislodge the airway secretions.

View the following supplementary YouTube video[3] where percussion and vibration is demonstrated: Chest Physical Therapy (CPT) | Medical Definition (Explainer Video)

Vibratory Positive Expiratory Pressure[4]

Vibratory positive expiratory pressure (PEP) – sometimes called oscillatory PEP (OPEP) therapy – uses handheld devices such as flutter valves, Acapella (see Figure 5[5]), or Aerobika devices for patients who need assistance in clearing mucus from their airways. These devices require a prescription and are used in collaboration with a respiratory therapist or advanced health care provider. To use vibratory PEP therapy, the patient should sit up, take a deep breath, and blow into the device. A flutter valve within the device creates vibrations that help break up the mucus so the patient can cough and spit it out. Additionally, a small amount of positive end-expiratory pressure (PEEP) is created in the airways that helps to keep them open so that more air can be exhaled.

2. NURSES- NOOK & CORNER. (2020, July 12). *Postural Drainage Positions and Chest Physiotherapy (CPT)* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=Rx2ADUgH_iw

3. Respiratory Therapy Zone. (2021, December 14). *Chest physical therapy (CPT) | medical definition (explainer video)* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=kg4wITMke08&t=75s

4. O'Hara-Leslie, E. K., Wade, A. C., & McLain, K. B. (2016). *Foundations for assisting in home care*. Open SUNY Textbooks. https://milnepublishing.geneseo.edu/home-health-aide/

5. "Flutter Valve Breathing Device 3I3A0982.jpg" by Deanna Hoyord, Chippewa Valley Technical College is licensed under CC BY 4.0

Figure 5. Acapella.

View the following supplementary YouTube video[6] where the proper use of the Aerobika is demonstrated: [How to Use the Aerobika* Oscillating Positive Expiratory Pressure Therapy System](https://www.youtube.com/watch?v=iy2oYadhF9Q)

High-Frequency Chest Wall Oscillation

High-frequency chest wall oscillation (HFCWO) is an airway clearance technique in which external chest wall oscillations are applied to the chest using an inflatable vest that wraps around the chest. These machines produce vibrations at variable frequencies and intensities, helping to loosen and thin mucus and separate it from airway walls.

HFCWO involves an inflatable jacket that is attached to a pulse generator by hoses that mechanically enable

6. Trudell Medical International. (2013, June 13). *How to Use the Aerobika* Oscillating Positive Expiratory Pressure Therapy System* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=iy2oYadhF9Q

the equipment to perform at variable frequencies (5–25 Hz). The generator sends air through the hose, which causes the vest to inflate and deflate rapidly. The vibrations not only separate mucus from the airway walls but also help move it up into the large airways. Typically, it is paused during the 20- to 30-minute HFCWO treatment every 5 minutes to cough out loosened mucus that has moved into the large airways.

View the following supplementary YouTube video[7] where a "vest" treatment is being performed: [Giving a vest therapy treatment](http://www.youtube.com/embed/mKiix67dd90)

Coughing Techniques and Deep Breathing

Active cycle of breathing technique is a technique performed by the patient and can be used to mobilize and clear excess pulmonary secretions and to generally improve lung function. It has a series of three main phases: breathing control, thoracic expansion, and forced expiratory technique (see Figure 6[8]).

Autogenic drainage is a diaphragmatic breathing pattern used by patients with respiratory illnesses (e.g., cystic fibrosis, bronchiectasis) to clear the lungs of mucus and other secretions. Various techniques are used, all of which combine positive reinforcement of deep breathing and voluntary cough suppression for as long as possible before evacuating the airways of mucus.

7. Pediatric Home Service. (2018, November 30). *Giving a vest therapy treatment* [Video]. YouTube. All rights reserved. www.youtube.com/embed/mKiix67dd90

8. "Active Cycle of Breathing" by Kirsten Holbrook, Chippewa Valley Technical College is licensed under CC BY-NC 4.0

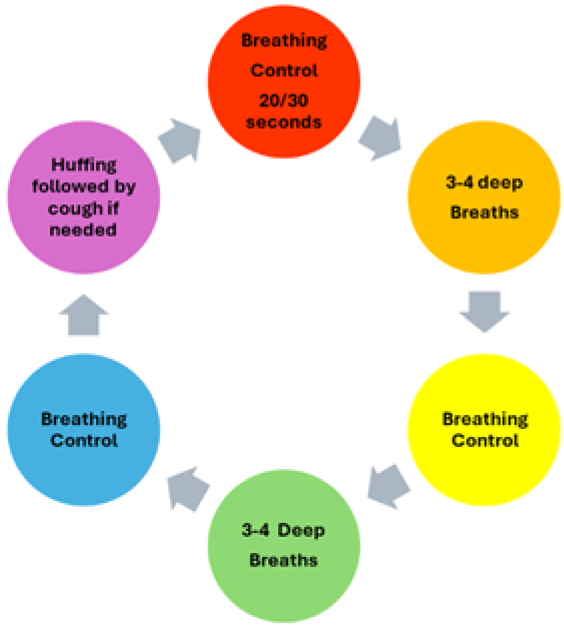

Figure 6. Active breathing cycle.

Coughing and deep breathing is a breathing technique similar to incentive spirometry but no device is required. The patient is encouraged to take deep, slow breaths and then exhale slowly. After each set of breaths, the patient should cough and attempt to expectorate secretions. This technique is repeated ten times every hour. Similar to an incentive spirometer, the purpose of coughing and deep breathing is to keep the airways open and clear of mucus to prevent atelectasis and pneumonia.[9]

The huff cough technique is helpful to teach patients who have difficulty coughing and expectorating mucus. Teach the patient to inhale with a medium-sized breath and then make a sound like "Ha" to push the air out quickly with the mouth slightly open. Huff cough is also called the forced expiratory technique (FET) and is best used to promote distal airways to remain open or prevent air trapping in obstructive diseases.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=370#h5p-104

9. Ernstmeyer, K., & Christman, E. (Eds.). (2024). *Nursing fundamentals 2E*. Open RN | WisTech Open. https://wtcs.pressbooks.pub/nursingfundamentals/

2.2 Lab Activities

2.2 Lab Activity

In the laboratory classroom, you and a partner will place each other in the postural drainage positions as illustrated in Figure 7[1] below and will practice manual percussion and vibration.

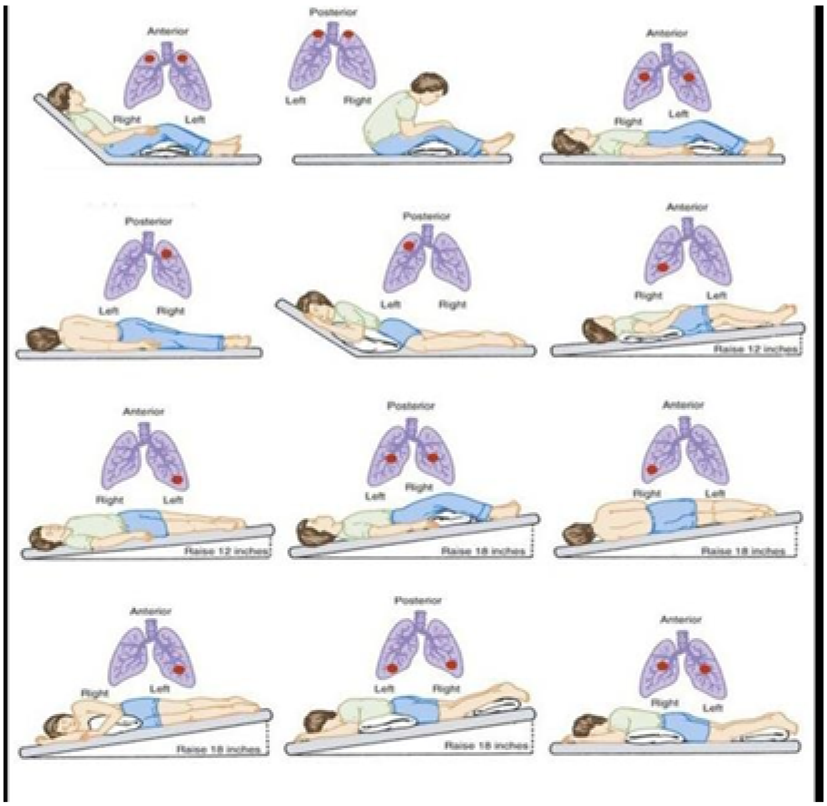

Figure 7. Positions for chest physiotherapy.

1. On a separate piece of paper, list the indications and contraindications for chest physiotherapy (CPT).

2. With your laboratory partner, obtain the positive expiratory pressure (PEP) devices, practice and explain the operation of the devices used in your lab.

3. On a separate piece of paper, list the indications and contraindications for PEP.

4. With your laboratory partner, obtain the high-frequency chest wall oscillation (HFCWO) device and practice

1. "Postural Drainage Positions" is used on the basis of Fair Use. Access for free at https://www.researchgate.net/figure/Postural-Drainage-Positions_fig1_348620409

and explain the operation of the device. Place the device on each other and manipulate the hertz and pressure by pressing the up and down button located on the front of the device.

5. List the indications and contraindications for HFCWO on a separate piece of paper.

6. Teach your laboratory partner how to huff cough.

7. View the following supplementary YouTube videos[2,3] on active cycle of breathing and autogenic drainage:

Active cycle of breathing technique (ACBT)

Autogenic drainage

2. NHS University Hospitals Plymouth Physiotherapy. (2015, May 12). *Active cycle of breathing technique (ACBT)* [Video]. YouTube. https://www.youtube.com/watch?v=XvorhwGZGm8&t=26s

3. NHS University Hospitals Plymouth Physiotherapy. (2015, May 12). *Autogenic drainage* [Video]. YouTube. https://www.youtube.com/watch?v=_n0nuy8VWmI

2.3 Critical Thinking Assessment

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=376#h5p-59

3.1 Arterial Puncture

Respiratory therapists routinely use the information from an arterial blood gas to make decisions regarding patient care and mechanical ventilation changes. A respiratory therapist should also be able to safely perform an arterial puncture. Several different arteries can be used for blood collection. These include radial, brachial, femoral, and dorsalis pedis. The first choice is the radial artery, which is located on the thumb side of the wrist. Because of its small size, use of this artery requires extensive skill in arterial blood sampling. Alternative sites for access are the brachial or femoral arteries, but these have the following disadvantages:

- They may be harder to locate because they are less superficial than the radial artery.
- They have poor collateral circulation.
- They are surrounded by structures that could be damaged by faulty technique.
- They may require longer periods of post sampling pressure/occlusion for the site to clot, especially in the presence of blood thinners.

Prior to performing a radial puncture, a modified Allen test should be performed. The modified Allen test is used to measure arterial competency and should be performed before taking an arterial sample. This ensures that there is adequate collateral circulation through the ulnar artery in the event that the radial artery is damaged during the blood draw.[1]

View the following supplementary video[2] showing how to perform a modified Allen's test: Modified Allen's Test | UKMLA | CPSA | PLAB2

1. Instruct the patient to clench their fist; if the patient is unable to do this, close the person's hand tightly.
2. Using your fingers, apply occlusive pressure to both the ulnar and radial arteries to obstruct blood flow to the hand.
3. While applying occlusive pressure to both arteries, have the patient relax their hand and check whether the palm and fingers have blanched. If this is not the case, you have not completely occluded the arteries with your fingers.
4. Release the occlusive pressure on the ulnar artery only to determine whether the modified Allen test is positive or negative.

1. U.S. National Library of Medicine. (2010). *Modified allen test*. WHO Guidelines on Drawing Blood: Best Practices in Phlebotomy. https://www.ncbi.nlm.nih.gov/books/NBK138652/

2. Geeky Medics. (2017, May 13). *Modified Allen's Test | UKMLA | CPSA | PLAB2* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=wXH6YbDAwbI

- **Positive Modified Allen Test** – If the hand flushes within 5–15 seconds, it indicates that the ulnar artery has good blood flow; this normal flushing of the hand is considered to be a positive test.
- **Negative Modified Allen Test** – If the hand does not flush within 5–15 seconds, it indicates that ulnar circulation is inadequate or nonexistent; in this situation, the radial artery supplying arterial blood to that hand should not be punctured.

Once the Allen test is determined to be positive, then it is safe to perform the arterial blood puncture and retrieve a sample. An arterial blood sample is collected from an artery primarily to determine arterial blood gasses. The sample can be obtained either through a catheter placed in an artery or by using a needle and syringe to puncture an artery. These syringes are pre-heparinized and handled to minimize air exposure that will alter the blood gas values.

Complications Related to Arterial Blood Sampling

There are several potential complications related to arterial blood sampling. The items below list some of the complications related to the procedure and how they can be prevented:

- Arteriospasm or involuntary contraction of the artery may be prevented simply by helping the patient relax; this can be achieved, for example, by explaining the procedure and positioning the person comfortably.
- Hematoma or excessive bleeding can be prevented by inserting the needle without puncturing the far side of the vessel and by applying pressure immediately after blood is drawn. Due to the higher pressure present in arteries, pressure should be applied for a longer time than when sampling from a vein and should be supervised more closely to check for cessation of bleeding. Ensure that you always check the chart to see if the patient is on blood thinners.
- Nerve damage can be prevented by choosing an appropriate sampling site and avoiding redirection of the needle.
- Fainting or a vasovagal response can be prevented by ensuring that the patient is supine (lying down on their back) with their feet elevated before beginning the blood draw. Patients requiring arterial blood sampling are usually inpatients or in the emergency ward, so they will generally already be lying in a hospital bed. Children may feel a loss of control and fight more if placed in a supine position; in such cases, it may be preferable to have the child sitting on a parent's lap, so that the parent can gently restrain the child.
- Other problems can include a drop in blood pressure, complaints of feeling faint, or sweating or pallor that may precede a loss of consciousness.

Sampling Errors

Inappropriate collection and handling of arterial blood specimens can produce incorrect results. Reasons for an inaccurate blood result are as follows:

- Presence of air in the sample
- Collection of venous blood rather than arterial blood
- An improper quantity of heparin in the syringe or improper mixing after blood is drawn
- A delay in specimen transportation

> View the following supplementary video[3] demonstrating how to perform an arterial blood gas puncture: Basic Clinical Skills: Arterial Blood Gas

3. Medical Education Leeds. (2020, June 14). *Basic Clinical Skills: Arterial Blood Gas* [Video]. YouTube. https://www.youtube.com/watch?v=8AznWNiETgM

3.2 Lab Activities

3.2 Lab – Arterial Puncture

For this lab activity, you will need to gather the supplies below and either obtain an arterial arm manikin or a navel orange to simulate the skin.

Figure 7. Arterial arm.

- Pre-heparinized syringe
- Needles (choose a size that is appropriate for the site)
- A safety syringe with a needle cover that allows the syringe to be capped before transport, without manually recapping (this is best practice for radial blood sampling)
- A gauze and bandage to cover the puncture site after collection
- A container with crushed ice for transportation of the sample to the laboratory (if the analysis is not done at the point of care)
- Where applicable, local anesthetic and an additional single-use sterile syringe and needle

On your arterial arm manikin or navel orange, practice the arterial puncture using the steps below[1]:

1. Approach the patient, introduce yourself, and ask the patient to state their full name and date of birth.
2. Place the patient on their back, lying flat. Ask for assistance if the patient's position needs to be altered to make them more comfortable. If the patient is clenching their fist, holding their breath, or crying, this can change breathing and thus alter the test result.
3. Perform hand hygiene and put on gloves. Locate the radial artery by performing an Allen test for collateral circulation. If the initial test fails, repeat the test on the other hand. Make sure when assessing a patient's limbs that you look for any identifier that would exclude that limb. These could include restricted extremities due to dialysis fistulas, history of mastectomy, etc. Most facilities will place a "restricted extremity" wrist band on the limb that should not be used for blood draws. Once a site is identified, note anatomic landmarks to be able to find the site again.

1. U.S. National Library of Medicine. (2010). *Arterial blood sampling*. WHO Guidelines on Drawing Blood: Best Practices in Phlebotomy. https://www.ncbi.nlm.nih.gov/books/NBK138661/

4. Clear off a bedside work area and prepare the supplies. Use proper personal protective equipment, if exposure to blood is anticipated.
5. Disinfect the sampling site on the patient with 70% alcohol and allow it to dry.
6. If the needle and syringe are not preassembled, assemble the needle and heparinized syringe and pull the syringe plunger to the required fill level recommended by the local laboratory.
7. Holding the syringe and needle like a dart, use the index finger to locate the pulse again. Inform the patient that the skin is about to be pierced and then insert the needle at a 45-degree angle, approximately 1 cm distal to (i.e., away from) the index finger to avoid contaminating the area where the needle enters the skin.
8. Advance the needle into the radial artery until a blood flashback appears and then allow the syringe to fill to the appropriate level. DO NOT pull back the syringe plunger.
9. Withdraw the needle and syringe; place a clean, dry piece of gauze or cotton wool over the site and have the patient or an assistant apply firm pressure for sufficient time to stop the bleeding. Check whether bleeding has stopped after 2–3 minutes. Five minutes or more may be needed for patients who have high blood pressure, a bleeding disorder, or taking anticoagulants.
10. Activate the mechanisms of a safety needle to cover the needle before placing it in the ice cup. Expel any air bubbles, cap the syringe, and roll the specimen between the hands to gently mix it. Capping the syringe is done to prevent contact between the arterial blood sample and the air and to prevent leaking during transport to the laboratory.
11. Label the sample syringe with your initials, date/time, and FiO_2 or O_2 liter flow.
12. Dispose appropriately of all used materials and personal protective equipment.
13. Remove gloves and wash the hands thoroughly with soap and water and then dry the hands using single-use towels; an alternative to soap and water is to use an alcohol-rub solution.
14. Check the patient site for bleeding (if necessary, apply additional pressure) and thank the patient.
15. Transport the sample immediately to the laboratory or place the sample on ice if it cannot be tested within 30 minutes and ensure to follow laboratory handling procedures.

3.3 Critical Thinking Assessment

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=382#h5p-60

4.1 Pulmonary Rehabilitation

In your career as a respiratory therapist, it is very likely that one day you will encounter someone who tells you they are "short of breath." This very ambiguous statement will set off alarm bells in your head as your mind races to find the appropriate follow-up questions. Is it difficult to inhale? To exhale? Is the force of inhalation or exhalation compromised? Given the long list of things that can cause shortness of breath, you may decide to test this patient's lung function to rule out some common pulmonary disorders and move forward with treatment.[1]

Once a patient's lung function has been evaluated and depending on the results, you may want to suggest the patient enroll in a pulmonary rehabilitation program so they can optimize their remaining lung function. The American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR) is a multidisciplinary professional association of health professionals who serve in the field of cardiac and pulmonary rehabilitation. Members include cardiovascular and pulmonary physicians, nurses, exercise physiologists, physical therapists, behavioral scientists, respiratory therapists, dieticians, and nutritionists.[2] This is the same organization that sets and accredits pulmonary rehabilitation programs and sets guidelines for programs to follow.

What is pulmonary rehabilitation exactly? According to the American Heart Association, pulmonary rehabilitation is a program of education and exercise to increase awareness about a patient's lungs and disease. Patients will learn to achieve exercise with less shortness of breath. The classes are offered in a group setting so patients get the chance to meet others with similar conditions, which provides an opportunity to give and receive peer support. The skills and knowledge learned in the program will help patients feel better and manage their chronic lung diseases. Patients become stronger by increasing their level of fitness. Exercising their lungs and muscles helps patients be more active so they can do the things they enjoy with their loved ones. In addition, pulmonary rehabilitation may even decrease the need for hospital visits.[3]

> To learn more about pulmonary rehabilitation and how you can develop a plan for your patients, visit the Patient Resources section of the AACVPR website.

1. Jenks, A. (2022). *Lab Techniques in Exercise Physiology*. British Columbia/Yukon Pressbooks. https://pressbooks.bccampus.ca/capalan/chapter/respiratory-techniques/
2. American Association of Cardiovascular and Pulmonary Rehabilitation. (n.d.). *About*. https://www.aacvpr.org/About
3. American Lung Association. (n.d.). *The basics of pulmonary rehabilitation*. https://www.lung.org/lung-health-diseases/lung-procedures-and-tests/pulmonary-rehab

5.1 Respiratory Care in Alternative Settings

Home care or home health care is supportive care that is provided in the home. Home care allows a person to remain in the comfort of their home while they are receiving services to recover from illness, injury, or disability. Home care services are also provided for people who have chronic conditions such as ventilator-dependent individuals, oxygen-dependent individuals, and individuals with chronic obstructive pulmonary disease (COPD). Home care may also be provided for patients who are on hospice. Hospice home care is for patients who have been diagnosed with a terminal illness (an illness that cannot be cured) and who have a prognosis of 6 months or less. Hospice home care allows people with a terminal illness to remain in the comfort of their homes, surrounded by familiar people and things.

People who receive home care have a variety of needs depending on their physical condition and specific disease or injury. Patients may need assistance with ventilator/noninvasive ventilation equipment or oxygen equipment.

Home health care may be provided by licensed medical personnel such as physicians, registered nurses (RNs), licensed practical nurses (LPNs), physical therapists (PTs), occupational therapists (OTs), speech language pathologists (SLPs), registered dieticians (RDs), social workers (MSWs), respiratory therapists (RTs), wound care specialists, and unlicensed but certified workers such as home health aides, nursing assistants, and personal care aides. Unlicensed personnel such as home health aides and personal care aides are vital members of the home health care team. Every member of the home health care team has a role to play. When all members work together, they can achieve the goal of caring for the patient.[1]

> View the following supplementary YouTube video[2] showing a day in the life of a home care respiratory therapist: BJC Home Care Services: Respiratory Therapist

Respiratory therapists who work in the home care setting should be aware of hazards in the home and adapt a care plan to assist patients in maintaining safety, especially when using oxygen. The following are guidelines for patients who use oxygen in their home:

1. Never smoke while using oxygen and warn visitors not to smoke near you when you are using oxygen.
2. “No smoking” signs should be posted in your home or on exterior doors to alert visitors that oxygen is being used and/or stored in the home.
3. Stay at least 5 feet away from open flames, including lighted cigarettes, gas stoves, candles, lighted open fireplaces, or other heat sources.

1. O’Hara-Leslie, E. K., Wade, A. C., & McLain, K. B. (2016). *Foundations for assisting in home care*. Open SUNY Textbooks. https://milnepublishing.geneseo.edu/home-health-aide/

2. BJC HealthCare. (2014, June 10). *BJC home care services: respiratory therapist* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=Hkpih004Vbw

4. Do not use any flammable products like grease, oils, aerosol sprays, or any petroleum-based lubricants or personal hygiene products while using your oxygen.
5. Store your oxygen system in a clean, secure area away from flammable items. Oxygen cylinders should be secured to prevent accidental falling.
6. Have a fire extinguisher close by. You may wish to notify your fire department that you have oxygen in your home.
7. When using an oxygen concentrator: Avoid using an extension cord. Store the oxygen concentrator in an area that will allow proper air circulation and prevent overheating (not a closet). Store an oxygen concentrator 12-18 inches from any drapes or walls.[3]

3. MedPro Respiratory Care. (n.d.). *Home oxygen safety*. https://www.medprorespiratory.com/home-oxygen-therapy/home-oxygen-safety/

6.1 Respiratory Therapist-Driven Protocols

Most health care facilities and hospitals utilize respiratory therapist-driven protocols. The American Association for Respiratory Care (AARC) defines respiratory care protocols as initiation or modification of a patient care plan following a predetermined structured set of physician orders, instructions, or interventions in which the therapist is allowed to initiate, discontinue, refine, transition, or restart therapy as the patient's medical condition dictates.[1]

Protocols that allow respiratory therapists to practice to the full extent of their competencies, knowledge, and skills result in elimination of waste in both resources and wages, a reduction in health service utilization and length of stay, and ventilator days. The benefits are even more enhanced when costly interventions with a high volume of patients or protocols are targeted to enable respiratory therapists to practice at the top of their scope of practice.[2]

By using therapist-driven protocols, studies have shown that respiratory care protocol use is associated with benefits regarding respiratory therapist turnover and job satisfaction. In addition to their positive effect on allocation of respiratory care treatments, improved outcomes, and reduced costs, use of respiratory care protocols can also be used to increase respiratory therapist job satisfaction and reduce turnover intentions[3].

> For more information on respiratory therapy protocols visit the AARC's Statement of Respiratory Therapy Protocols.

1. Ford, R. M. (2015). Therapist-driven protocols: New incentives for change. *Respiratory care*, *60*(5), 757–759. https://doi.org/10.4187/respcare.04123
2. Dubois, R., Sorensen, R., Buell, B., Telenko, T., & West, A. (2021). The respiratory therapy practice-based outcomes initiative (RT-PBOI): Developing a framework to explore the value added by respiratory therapists to health care in Alberta. *Canadian Journal of Respiratory Therapy, 57*, 99–104. https://doi.org/10.29390/cjrt-2021-010
3. Metcalf, A. Y., Stoller, J. K., Habermann, M., & Fry, T. D. (2015). Respiratory therapist job perceptions: The impact of protocol use. *Respiratory Care*, *60*(11), 1556–1559. https://doi.org/10.4187/respcare.04156

7.1 Evidenced-Based Medicine

According to an article written by Dean Hess, PhD, RRT, FAARC, FCCM, FCCP, evidence-based medicine (EBM) is the integration of individual clinical expertise with the best available evidence from systematic research and the patient's values and expectations. The best evidence is extrapolated to the patient's unique pathophysiology. EBM does not devalue clinical skills and clinical judgment. Rather, EBM demands a skilled clinician to inform its judicious application. The practice of EBM requires us to apply the evidence to the right patient, at the right time, in the right place, at the right dose, and using the right resources.

Clinical evidence comes from real clinical research among intact patients. Bench studies, simulations, animal studies, and other types of physiologic studies can support human studies. However, we should recognize that these are low levels of evidence, and we need to be cautious about extrapolating these data to patient care. The best clinical evidence is not static, but changes when new and better evidence becomes available.

The practice of EBM does not discount patient values and expectations. For example, a compelling body of high-level clinical evidence supports the use of noninvasive ventilation (NIV) in patients with COPD exacerbation, yet some patients prefer not to receive NIV. As another example, clinician bias might suggest the use of a pressurized metered-dose inhaler (pMDI) rather than a nebulizer for delivery of an inhaled bronchodilator; however, evidence suggests that the two approaches yield similar outcomes. If a patient prefers to use a nebulizer rather than a pMDI, the patient's choice should be respected.[1]

View the following supplementary YouTube Video[2] that describes EBM in more detail: Evidence-Based Respiratory Care – Current Topics 2021

View the following supplementary YouTube Video[3] that describes delivering evidence-based respiratory care: Delivering Evidence-Based Respiratory Care [OVERVIEW]

1. Hess, D. R. (2021). Evidence-based respiratory care. *Respiratory Care*, *66*(7), 1105–1119. https://doi.org/10.4187/respcare.08950

2. aarccenter. (2021, July 23). *Evidence-Based Respiratory Care – Current Topics 2021* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=-xanUfofBgk

3. Respiratory Therapy Zone. (2022, May 21). *Delivering Evidence-Based Respiratory Care [OVERVIEW]* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=9EQ2pzBH9h0

Skills Assessments

[Incentive Spirometry](#)
- [Hyperinflation](#)
- [CPT Manual and HFCWO](#)
- [Bronchial Hygiene Adjuncts](#)
- [Arterial Blood Gas](#)

PART IV

AIRWAY MANAGEMENT

Learning Objectives

- Describe the components and function of manual resuscitators.
- Demonstrate proper technique for delivering effective manual ventilation to patients in respiratory distress or arrest.
- Identify potential complications of manual ventilation and strategies to mitigate them.
- Explain the indications, contraindications, and demonstrate proper insertion techniques for nasopharyngeal airways (NPA) and oropharyngeal airways (OPA).
- Demonstrate the correct placement of laryngeal mask airways (LMA) and discuss their clinical applications.
- Describe the structure, function, and indications for endotracheal intubation.
- Compare and contrast the Combitube and King Tube in terms of indications, placement, and limitations.
- Identify the types of laryngoscopes (e.g., direct and video laryngoscopes) and their appropriate uses.
- Perform a systematic assessment of the airway to evaluate difficulty for intubation, including the Mallampati score and other predictors.
- Demonstrate the proper technique for performing endotracheal intubation, including equipment preparation, patient positioning, and tube placement.
- Demonstrate proper oral suctioning technique to maintain airway patency.
- Identify indications and contraindications for oral suctioning.
- Perform suctioning using sterile technique, including preparation, insertion, and withdrawal of the suction catheter.
- Recognize complications associated with suctioning and how to prevent them.
- Explain the indications, types, and components of tracheostomies.
- Demonstrate proper tracheostomy care, including cleaning, dressing changes, and securing the tracheostomy tube.

1.1 Manual Resuscitators and Manual Ventilation

Bag Valve Mask (BVM)

Respiratory therapists must understand manual resuscitators and manual ventilation. They must not only how to use them, but also when to use them. In addition, they must be able to troubleshoot any problems that may arise.

A bag valve mask (BVM), commonly known as a "bag" or "ambu bag," is a handheld device used in emergency situations for patients who are not breathing (respiratory arrest) or who are not breathing adequately (respiratory failure). See Figure 1.[1] This device is different from the other oxygen devices because it assists with ventilation, the movement of air into and out of the lungs, as well as oxygenation.

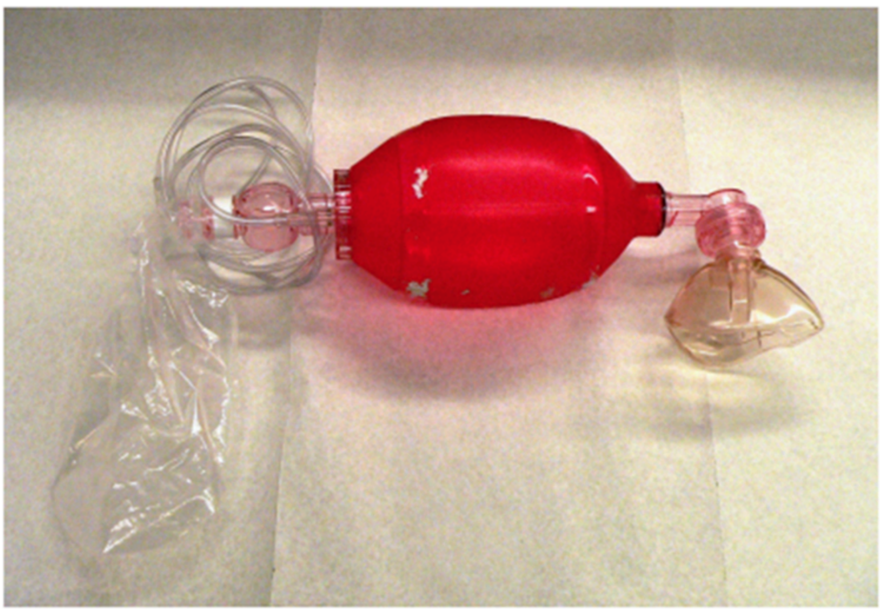

Figure 1. Self-inflating bag valve mask.

Self-inflating bag valve masks are produced in different sizes for infants, children, and adults to prevent lung injury, so it is important to use the correct size for the patient. When using a self-inflating bag mask valve, the rescuer manually compresses the bag to force air into the lungs. Squeezing the bag once every 5–6 seconds for an adult or once every 3 seconds for an infant or child provides an adequate respiratory rate. In inpatient settings, the bag mask valve is attached to an oxygen supply to increase the concentration of oxygenation provided with each breath. Self-inflating bags can be used with or without oxygen and must be squeezed in order to deliver oxygen to the patient.

1. "Ballon ventilation 1.jpg" by Rama is licensed under CC BY-SA 2.0 FR

Flow-inflating bags also come in different sizes, but unlike a self-inflating bag, the flow-inflating bag requires a constant flow of oxygen into the bag, and you must maintain a good seal with the mask. Otherwise, the bag deflates. Flow-inflating bags are typically used in anesthesia and pediatric units because they offer better control of pressure and volume delivered to the patient. A clinician can also easily feel lung compliance and resistance when compressed.

View the following supplementary YouTube video[2] that demonstrates the difference between self-inflating bags and flow-inflating bags: 5-3. Self-Inflating Bags vs. Free Flow Inflating Bags

It is vital to obtain a tight seal of the mask to the patient's face, but this is difficult for a single rescuer to achieve. Therefore, two rescuers are recommended; one rescuer performs a jaw thrust maneuver, secures the mask to the patient's face with both hands, and focuses on maintaining a leak-proof mask seal, while the other rescuer squeezes the bag and focuses on the amount and the timing.

Flow Rate: The flow rate for a bag valve mask attached to an oxygen source should be set to 15 L/min, resulting in FiO2 of approximately 100%.

Advantages: A bag valve mask is portable and provides immediate assistance to patients in respiratory failure or respiratory arrest. It also can be used to hyperoxygenate patients before procedures that can cause hypoxia, such as tracheal suctioning. These can also be used with or without a gas source.

Disadvantages: The rate and depth of compression of the bag must be closely monitored to prevent injury to the patient. In the event of respiratory failure when the patient is still breathing, the bag compressions must be coordinated with the patient's inhalations to ensure that oxygen is delivered, and asynchrony of breaths is prevented. Complications may also result from overinflating or overpressurizing the patient. Complications include lung injury or the inflation of the stomach that can lead to aspiration of stomach contents. Additionally, rescuers may tire after a few minutes of manually compressing the bag, resulting in less-than-optimal ventilation. Alternatively, an endotracheal tube (ET) can be inserted by an advanced practitioner to substitute for the mask portion of this device.

Below are the proper techniques for operating a bag valve mask:

1. Select the appropriate size mask and bag for the patient.
2. Connect the BVM to oxygen at a flow rate of 15 L/min.
3. If available, attach a filter to the exhaust port to reduce the spread of COVID and other airborne infectious diseases.
4. Place the patient in the supine position on a firm surface.
5. Position yourself at their head with your shoulders square with the patient.
6. Place the mask in your nondominant hand.
7. Use your thumb and index finger in "C" technique (see Figure 2[3]). Be sure to keep your fingers on the hard plastic to create a good face seal. Place the nose of the mask on the bridge of the patient's nose.

2. Mooncat Publications. (2017, October 31). *5-3. Self-Inflating Bags vs. Free Flow Inflating Bags* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=lBmLm0g_4fM

3. "Resuscitator 3 – Operation (PSF).png" by Pearson Scott Foresman is in the Public Domain.

8. Lower the mask over the patient's mouth.
9. Using the middle, ring, and pinky finger in the "E" technique, along the bottom of the jawbone, lock your elbow and lean back, bringing the patient's face "up" into the mask (see Figure 3[4]).
10. In your dominant hand, hold the oxygen bag out to the side of the patient.
11. With the head remaining tilted into the sniffing position, gently squeeze the bag until you see the chest rise. The goal is to deliver each breath over 1 second to minimize gastric distention or lung trauma. Deliver breaths for an adult once every 5–6 seconds or children every 2–3 seconds.
12. If resources exist, use a two-person BVM technique:

- One rescuer holds the mask with both hands in the "E / C" technique or thumb-down technique.
- The other rescuer squeezes the bag at the above-mentioned rates, just enough to see the chest rise.

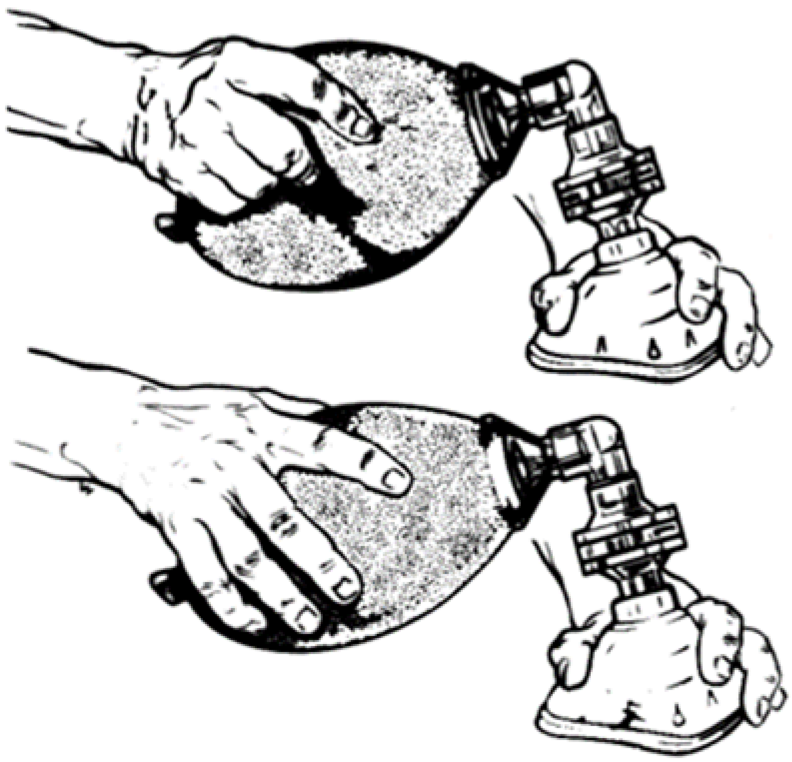

Figure 2. Operation of a self-inflating bag valve mask and the E / C hand placement technique.

4. "49757385962_5a78324bc2_k" by Mass Communication Specialist 3rd Class Jake Greenberg, US Navy is in the Public Domain. The appearance of U.S. Department of Defense (DoD) visual information does not imply or constitute DoD endorsement.

Figure 3. Self-inflating BVM technique.

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https://wtcs.pressbooks.pub/respiratorysurvey/?p=396#h5p-62

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=396#h5p-63

1.2 Lab Activities

1.2 BVM Lab Activity

1. Explain at least three differences between self-inflating and flow-inflating resuscitation bags. When would one be used over the other?
2. Using a clear filter, breathe (and have your lab partner give you breaths while you pretend to be apneic) on both the self-inflating and flow-inflating resuscitation bags. Describe how you felt and explain the differences.
3. In a separate sheet of paper, draw a BVM (see Figure 4[1]) as shown below and label the parts of an adult self-inflating resuscitation bag using this word bank: Face Mask, Inlet Port and Pressure Release Valve, Oxygen Reservoir, Self-inflating Bag, Oxygen Connector Tubing, Expiratory Valve.

Figure 4. BVM.

4. Locate a PEEP valve and attach it to an adult self-inflating resuscitation bag. Connect a pressure manometer and measure the amount of PEEP from the valve. How does a PEEP valve work? When and why would you use it?
5. In the laboratory classroom, with a lab partner, practice the manual resuscitator competency using an

airway manikin.

1.3 Critical Thinking Assessment

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2.1 Airway Adjuncts

To become the expert at placing and utilizing nasopharyngeal (NPA) and oropharyngeal (OPA) airways, you must first understand the anatomy and physiology of the upper airway.

The pharynx is a tube that is formed by skeletal muscle and lined by a mucous membrane that is continuous with that of the nasal cavities. The pharynx is divided into three major regions: the nasopharynx, the oropharynx, and the laryngopharynx (see Figure 5[1]).

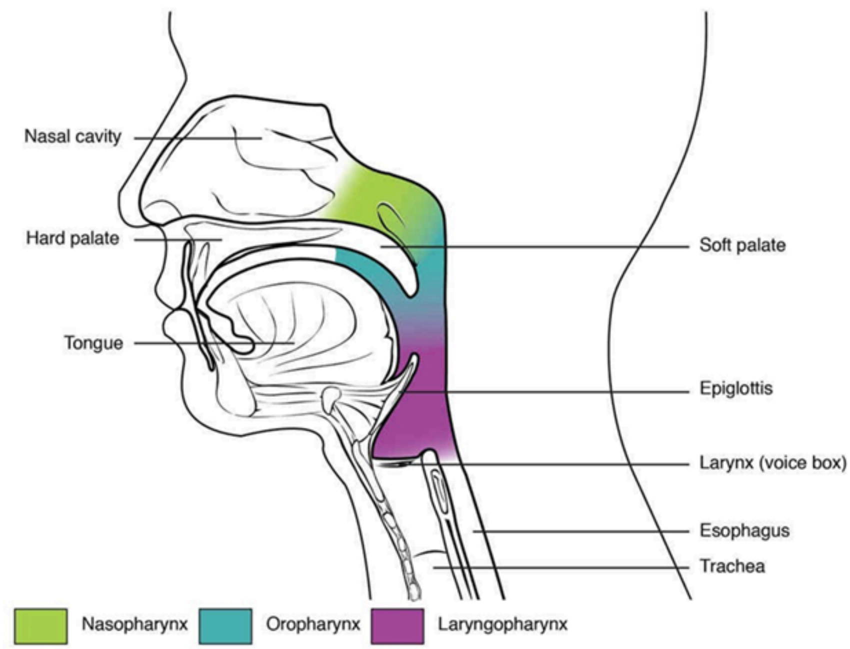

Figure 5. Pharynx.

The uppermost nasopharynx sits directly posterior to the nasal cavity, and it serves only as an airway. The nasopharynx has two openings on the lateral walls. These openings are the auditory (eustachian or pharyngotympanic) tubes, which connect the nasopharynx to each middle ear cavity. These connections are why colds often lead to ear infections. As the pharynx descends behind the oral cavity, it becomes the oropharynx, which serves as a passageway for both air and food. The uvula is a small bulbous, teardrop-shaped structure located at the apex of the soft palate that partially separates the oral cavity from this region. Both the uvula and soft palate move like a pendulum during swallowing, swinging upward to close off the nasopharynx to prevent ingested materials from entering into the nasal cavity. The most inferior portion of the pharynx is the laryngopharynx, which is located posterior to the larynx. It continues the route for ingested material and air until its inferior end, where the digestive and respiratory systems diverge. The stratified squamous epithelium of the oropharynx is continuous with the laryngopharynx. Anteriorly, the laryngopharynx opens into the larynx, whereas posteriorly, it enters the esophagus.

1. "2305_Divisions_of_the_Pharynx.jpg" by OpenStax College is licensed under CC BY 3.0

Airway adjuncts are devices used to maintain an open upper airway or relieve an obstruction. They are often used when mask ventilation is difficult. Common airway adjuncts, such as nasopharyngeal airways (NPA), laryngeal mask airways (LMA), and oropharyngeal airways (OPA), are often used in emergency situations, and a respiratory therapist needs to be able to quickly assess the patient and insert those airways.

Oropharyngeal Airway (OPA)

An oropharyngeal airway (OPA) is a short-term, easily inserted airway management device extending from the lips to the pharynx and prevents the base of the tongue from falling back and occluding the airway. A flange at the outer opening prevents the device from being inserted or pushed too far into the airway. See Figure 6[2] for an image of an oropharyngeal airway.

Figure 6. OPA.

To properly insert an OPA, first select the proper size by measuring the airway from the corner of the lip to the angle of the jaw to ensure proper length. Open the patient's mouth and insert the airway with the tip pointing toward the roof of the mouth. Observe the airway passing the uvula and rotate the OPA 180 degrees. (See Figure 7.[3])

2. "Oropharyngeal_Airways" by Hospital is licensed under CC BY-SA 3.0

3. "Sagittal-Cross-Section-w-Oral-Airway-87u1xb.png" by Open Critical Care is licensed under CC BY 4.0

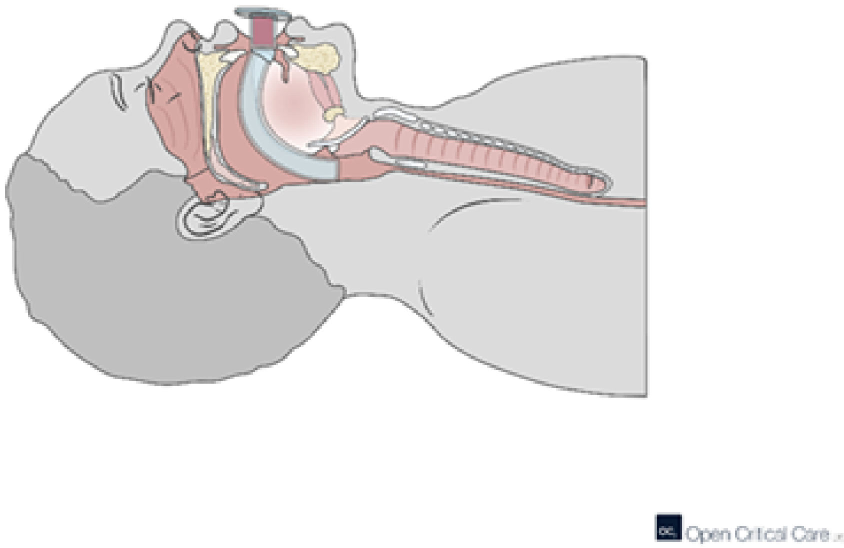

Figure 7. Proper placement of OPA.

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Nasopharyngeal Airway (NPA)

A nasopharyngeal airway (NPA) is a soft, anatomically designed airway adjunct that is inserted into the nasal passageway to provide airway patency (see Figure 8[4]). The flared distal end prevents the device from becoming lost within the nares. The NPA has advantages over the oropharyngeal airway as it can be used in patients with intact gag reflex, trismus, and oral trauma.

4. "Nasopharyngeal_Airway_2" by ICUnurses is licensed under CC BY-SA 4.0

Figure 8. NPA.

To properly insert an NPA, first select the proper size by measuring the airway from the tip of the nose to the earlobe. The outside diameter of the airway should be equal to the inside diameter of the patient's internal nares. Lubricate the airway with a water-soluble gel and insert it into the patient's nostril. The flanged end should rest against the nose, and the distal tip should rest behind the uvula. (See Figure 9.[5])

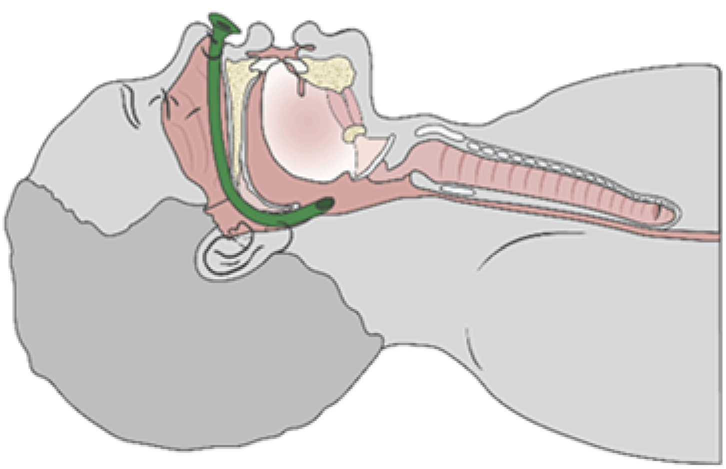

Figure 9. Proper NPA placement.

5. "Sagittal-cross-section-view-of-nasopharyngeal-airway-placement.png" by Open Critical Care is licensed under CC BY 4.0

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https://wtcs.pressbooks.pub/respiratorysurvey/?p=411#h5p-66

Laryngeal Mask Airway (LMA)

A laryngeal mask airway (LMA) is a supraglottic airway device that sits abutting the larynx, above the vocal cords. It is typically used as an alternative to endotracheal airways in short or low-risk anesthetic cases and can also be used in prehospital and cardiac arrest settings to achieve a more secure airway without endotracheal intubation.

An LMA is inserted through the mouth and into the pharynx after being lubricated with a water-soluble gel. The device is advanced until resistance is met. Then, the mask of the device is inflated, providing a low-pressure seal around the laryngeal inlet. The posterior of the tube is marked with a black line, which should be seen midline against the patient's upper lip when the airway is placed properly. (See Figure 10.[6])

6. "Sagittal-Cross-Section-LMA-091122-0g4du1-1280×989" by Open Critical Care is licensed under CC BY 4.0

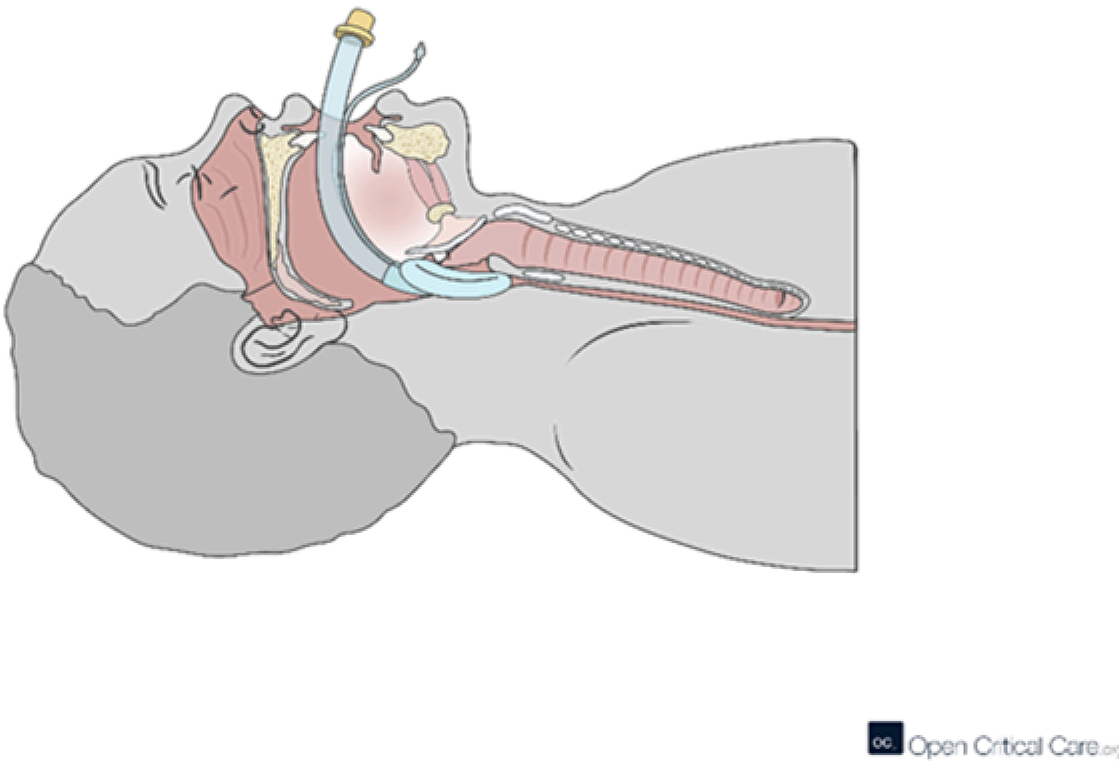

Figure 10. Proper LMA placement.

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2.2 Lab Activities

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2.3 Critical Thinking Assessment

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3.1 Advanced Airways and Intubation

We are now advancing from basic airways to advanced airways. In particular, you will be learning to both intubate and assist with an intubation. Depending on where your career takes you, you may be called on to do either procedure. In addition, these procedures cannot be taken lightly because patients are often critically ill, and death can occur as a negative outcome of improperly performed procedures.

You need to remember back to your anatomy and physiology course so you can recall the anatomical landmarks utilized in intubation. The anatomical landmarks that you need to visualize during intubation are the trachea, glottis, epiglottis, vallecula, and vocal cords (see Figure 11[1]).

When the epiglottis is in the "closed" position, the unattached end of the epiglottis rests on the glottis. A vestibular fold, or false vocal cord, is one of a pair of folded sections of mucous membrane. A true vocal cord is one of the white, membranous folds attached by muscle to the thyroid and arytenoid cartilages of the larynx on their outer edges. The inner edges of the true vocal cords are free, allowing oscillation to produce sound.

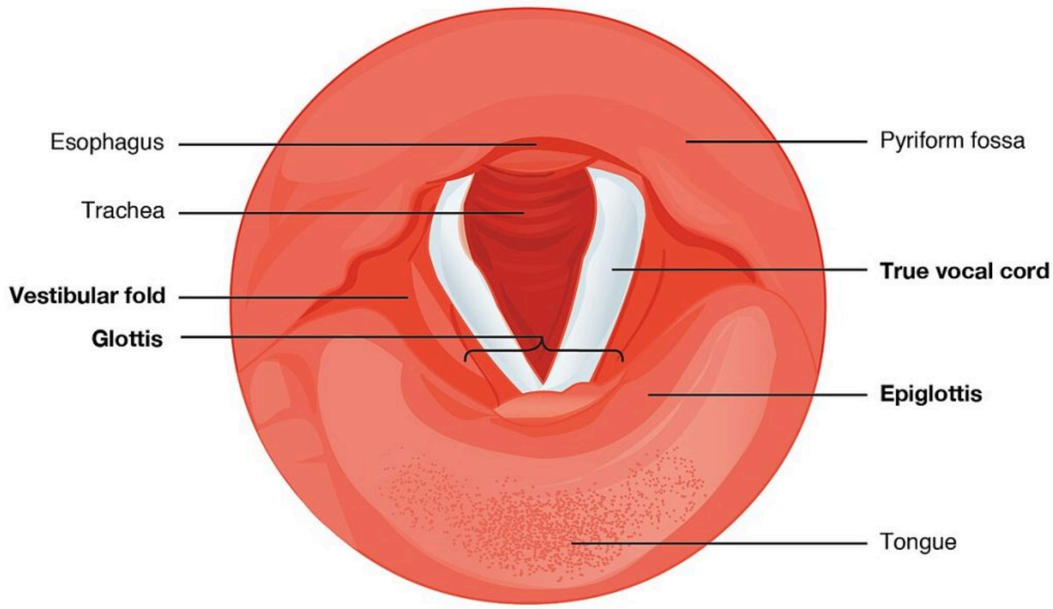

Figure 11. Airway.

Mallampati Classification

The mouth cavity should be assessed by sitting the patient upright with the head in a normal position, mouth open as wide as possible, and tongue poking out. The airway can then be given a Mallampati score, depending on how much of the oral cavity can be seen. The Mallampati score is a visual assessment of the size of the base

1. Betts, J. G., Young, K. A., Wise, J. A., Johnson, E., Poe, B., Kruse, D. H., Korol, O., Johnson, J. E., Womble, M., & DeSaix, P. (2022). Anatomy and Physiology 2e. OpenStax. https://openstax.org/books/anatomy-and-physiology-2e/pages/1-introduction

of the tongue relative to the oropharynx (see Figure 12[2]). It is used to predict how easy it will be to intubate a patient.

If the patient has a Mallampati Class 1 airway and no other airway problems, most intubations will be easy.

If the patient has a Mallampati Class 4 airway, then intubation may be difficult.

Patients with more than one airway abnormality are more likely to have a difficult intubation. For example, an obese patient with a short neck; a patient with reduced movement in the cervical spine; or a patient with large upper teeth, small mouth, and small mandible would be more difficult to intubate.

2. "Mallampati" by Jmarchn is licensed under CC BY-SA 3.0

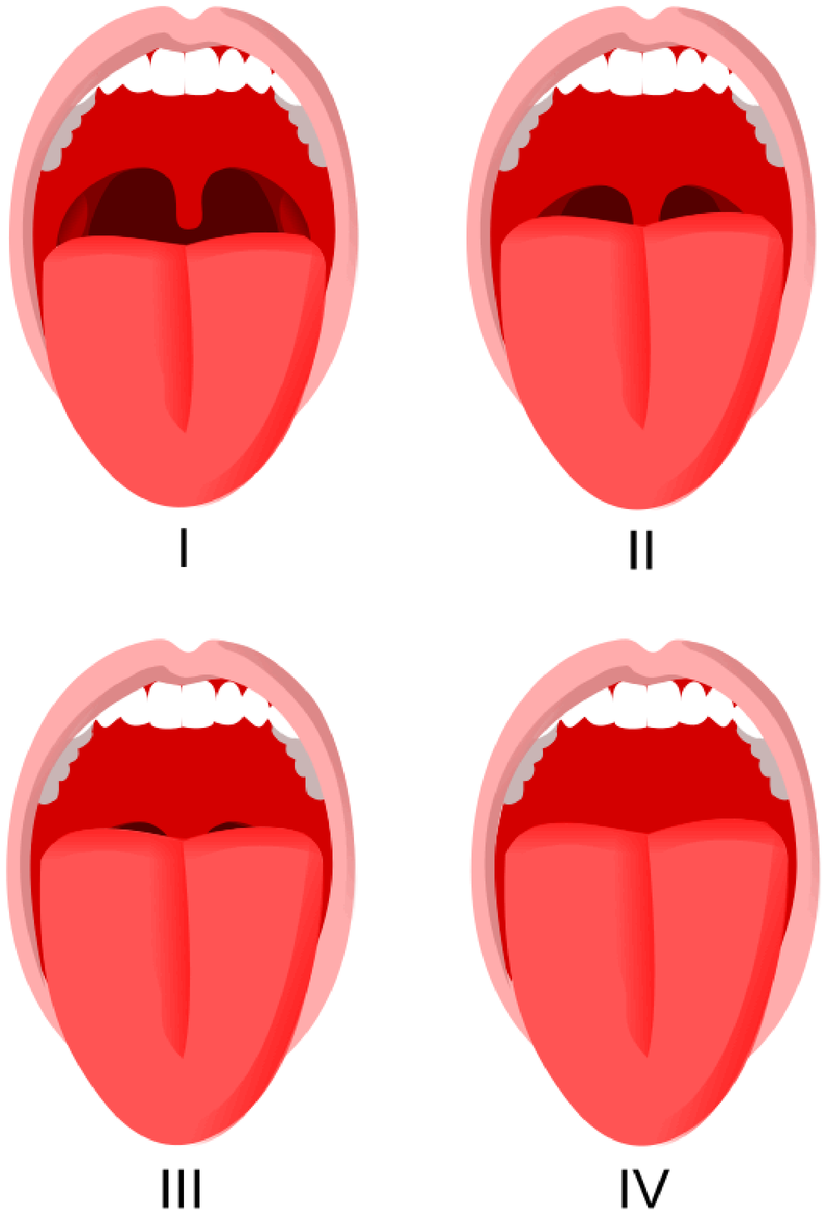

Figure 12. Mallampati classification.

Advanced Airways

The King LT (aka King Airway) and Combitube are both advanced airway management devices used in emergency and pre-hospital settings to secure a patient's airway (see Figure 13[3]). Additionally, they offer an alternative means of securing an airway when standard intubation is not feasible.

Both the King LT and Combitube are intended to have their distal tip placed in the esophagus. With the King LT, the pharyngeal balloon and esophagus balloon are inflated through a single inflation port and pilot balloon, while the Combitube has two ports and pilot balloons. There has been one case report where over-inflation of the esophageal balloon collapsed the trachea (from behind), preventing ventilation even though the tip of the device was in the esophagus.

The protocol for ventilating with the Combitube involves the following steps. First, attempt ventilation using Lumen 1 (the blue lumen). If this is unsuccessful, switch to Lumen 2 (the transparent lumen) in case the tip of the device has entered the trachea directly. If both attempts fail, advance the device slightly, as the pharyngeal balloon might be folding down the epiglottis and obstructing airflow.

For the King LT, insert the device as deeply as possible after selecting the appropriate size. Inflate the balloons and then gently withdraw the device until ventilation is successful. While tracheal insertion is possible with the King LT, it is less likely than with the Combitube due to the King LT's shorter and more flexible design. If tracheal insertion does occur, withdraw the device slightly before attempting ventilation again.[4]

3. "biad-king-airway-combitube-1936581" by kkirkemtp via Pixabay is licensed under CC0

4. Levitan, R. M. (2011). *Ems-delivered airways, part II*. Emergency Physicians Monthly. https://epmonthly.com/article/ems-delivered-airways-part-ii/


Figure 13. King LTs and Combitube airway.

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Laryngoscopes

The standard rigid laryngoscope consists of a detachable blade with a removable bulb (or fiber optic light) that attaches to a battery-containing handle. The blade has a flange on the left side for displacing the tongue. The blade may be curved (e.g., Macintosh) or straight (e.g., Miller). (See Figures 14[5] and 15.[6]) The curved blade may present more room in the mouth as the blade matches the curve of the oropharynx. The straight blade may be better when mouth opening is vertically limited, or the larynx is anterior. When laryngoscopy is difficult with one blade, the other blade may be useful. Laryngoscope blades are available in different lengths. Adults usually need a Size #3 or #4 Macintosh blade, children younger than 8 years of age usually need a Size #2 Macintosh blade, term infants usually require a Size #1 Miller blade, and premature infants usually need a Size #0 Miller blade.

Figure 14. Miller blades and laryngoscope handles.

5. "Laryngoscopes-Miller_blades.JPG" by DiverDave is licensed under CC BY 3.0

6. "Macintosh_Blades.jpg" by Sasata is licensed under CC BY 3.0

Figure 15. Macintosh blades and laryngoscope handles.

When attempting intubation, you always use your left hand (laryngoscopes are left-handed devices) and when inserting the blade into the right side of the mouth. Be careful not to pinch the lips or knock the incisor teeth. At the tonsillar pillars, sweep the tongue to the left and identify the uvula. Advance the laryngoscope blade slowly down the midline over the base of the tongue until the epiglottis is seen. A common mistake is to insert the blade too far down and into the esophagus. If unsure, withdraw the laryngoscope slowly, and the epiglottis may fall into view. A curved blade should have its tip in the vallecula. The tip of a straight blade is placed over the epiglottis. Exposure of the laryngeal inlet is improved by lifting the laryngoscope in the direction of the handle. Do not use the blade as a lever on the teeth and gums. The laryngoscope should only be moved in the direction of the handle.

In addition to traditional nondisposable laryngoscope handles and blades, video laryngoscopy offers an advanced method for airway visualization. This technique provides indirect visualization of the airway via a video screen, rather than requiring the provider to directly view the anatomical structures. Video laryngoscopy offers several benefits, including improved intubation success rates, reduced need for upper airway manipulation, and enhanced opportunities for training. Additionally, it allows for the capture of videos and photos, which can be valuable for quality improvement initiatives and case documentation.

View the following supplementary YouTube video[7] to learn more about video laryngoscopy: [Mastering Video Laryngoscopy]

Endotracheal Intubation

Endotracheal intubation is a medical procedure used to secure the airway by inserting a tube into the trachea (windpipe) through the mouth or nose. This procedure is commonly performed in emergency situations, during surgery, or in patients with respiratory failure.

The indications for intubation are relief of upper airway obstructions, protection of the airway, or the need for mechanical ventilation or tracheal suctioning.

Intubation Procedure[8]

Prepare your endotracheal tube (ETT) by testing the cuff with 10 milliliters of air, lubricating the end of the tube, and inserting a stylet. Place the person's head in a neutral position and insert a laryngoscope into their mouth to hold the tongue and pharynx out of the way (see Figure 16[9]). Then, the ETT can be inserted down the patient's throat, past the vocal cords, and into the trachea.

7. Medmastery. (2018, September 20). *Mastering video laryngoscopy* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=V6RAx8LyBOI

8. RNspeak. (2021). *Patients with endotracheal tube – Nursing roles, management & procedure*. https://rnspeak.com/endotracheal-intubation-procedure/

9. "Sagittal-Cross-Section-w-Laryngoscope-intubation-mac3091122-f0vs3p.png" by World Health Organization is licensed under CC BY-NC-SA 3.0

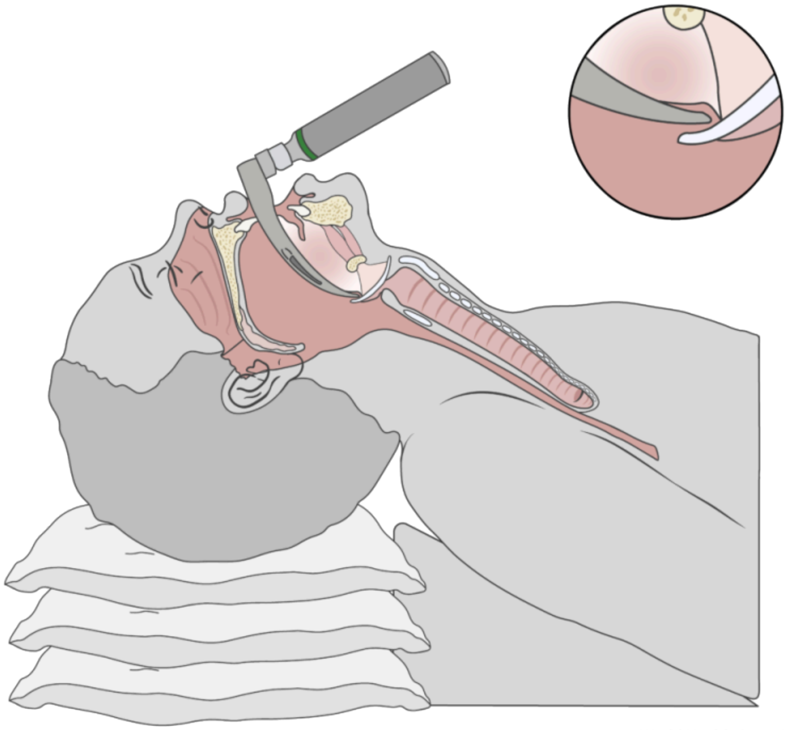

Figure 16. Macintosh blade laryngoscope positioning in preparation for intubation.

Insert the tube until the lower depth marker is at the vocal cords. As you are inserting the tube, you should be able to see where it is going until it gets past the vocal cords. At that point, you need to start watching for the marking near the end of the tube to line up with the vocal cords.

Check that the depth marker is at the opening of the mouth. There are length markers all along the length of the tube. When the tube is in place properly in an adult, it should indicate a depth of anywhere from 20 to 25 cm at the corner of the mouth.

Once you have inserted the tube to the correct depth, remove the stylet and inflate the cuff to hold the ETT in place. (See Figure 17.[10]) There is a balloon at the bottom of the ETT that holds the tube still in the trachea. It is inflated by attaching a syringe to its port and squeezing in 10 milliliters of air. In addition to holding the tube in place, the cuff keeps liquids out of the lungs. This helps minimize the chance of aspiration while the person is intubated.

10. "Sondeintubation.jpg" by bigomar2 is licensed under CC BY-SA 3.0

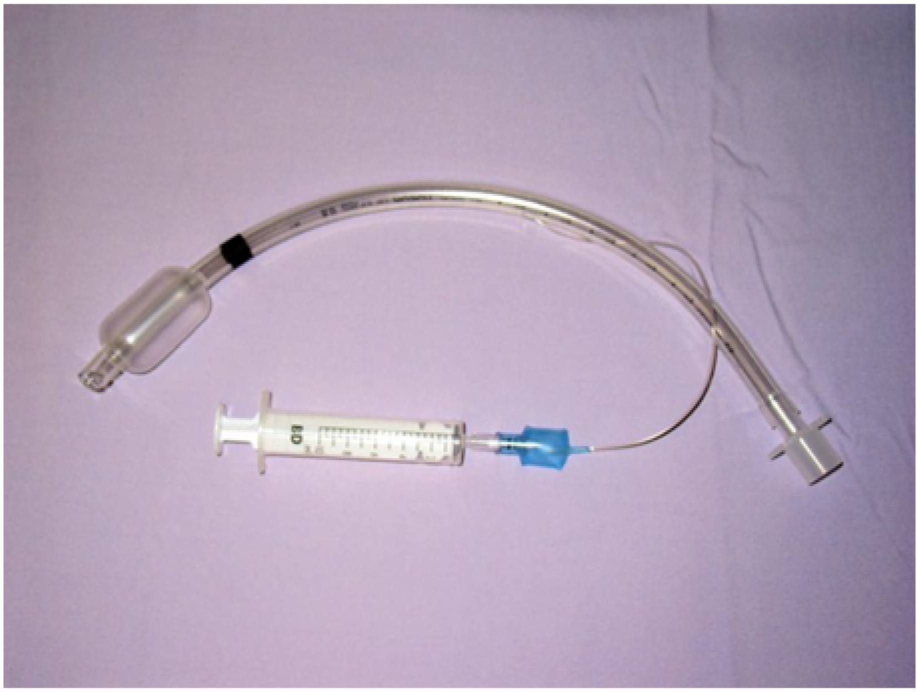

Figure 17. ETT with cuff inflated.

View the following supplementary YouTube video[11] to learn where the vallecula is located and how to visualize it when intubating: [Vallecula (Medical Definition) | Quick Explainer Video]

To ensure that the tube is inserted correctly, you should either place a colormetric device or a CO_2 detector on the 15 mm adapter end of the ETT. If the colormetric detector senses any amount of CO_2 being exhaled, it will simply change color. This shows that the patient is receiving oxygen properly, as CO_2 is a byproduct expelled only when oxygen is supplied.

Verify proper insertion. Once you have applied oxygen to the tube, make sure the chest is rising and falling. Listen to lung sounds. Make sure you can hear them bilaterally. Then, verify that the tube is in the right position and secure the ETT using a securement device. To verify proper placement, an X-ray should be taken (see Figure 18[12]).

11. Respiratory Therapy Zone. (2023, July 26). *Vallecula (Medical Definition) | Quick Explainer Video* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=6dWnS5mM-_U&t=8s

12. "A-chest-x-ray-showing-correct-endotracheal-tube-placement-and-no-acute-lung-pathology.png" by Ankit Jain is licensed under CC BY 2.0

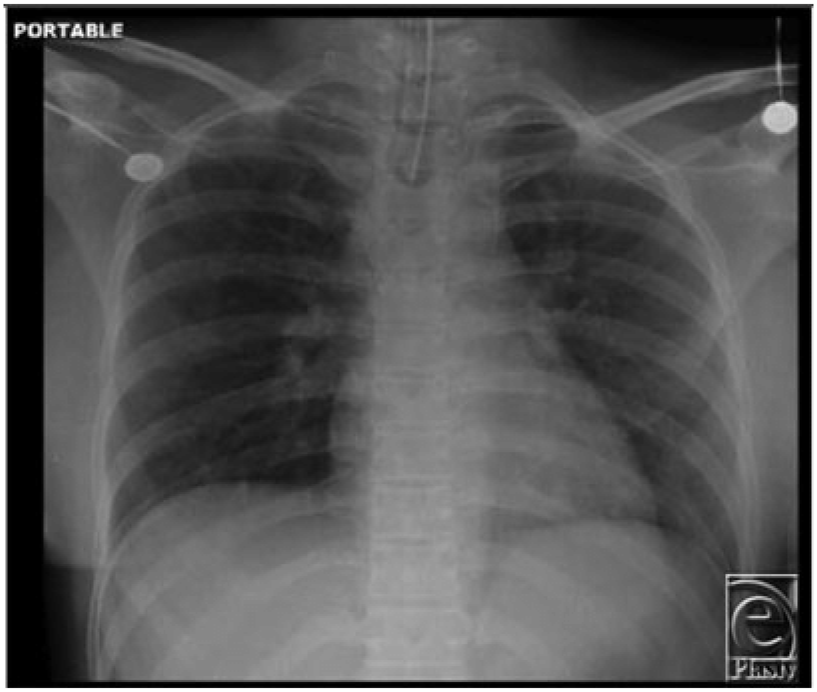

Figure 18. X-ray showing proper ETT placement.

Record the position of the ETT so movement can be identified. Recording the positioning of a tube at insertion will allow you to make sure it hasn't moved over time. Write down the measurement printed on the tube at a specific position in the mouth, such as at the front teeth or the lips. When checking on the patient later, you can ensure that the tube is still in the proper position by referencing this documentation.

Measure the air pressure in the ETT. Once the ETT is in, it's a good idea to measure the amount of pressure being created by respiration through the tube. This can be done by performing the minimal leak technique or minimal occlusion volume. Watch the video on how to perform these maneuvers.

View the following supplementary YouTube video[13] in which ETT cuff pressure and assessment are demonstrated: [ETT Cuff Pressure Check/ Assessment](https://www.youtube.com/watch?v=Yv7Fs9ljw-k)

13. George O. RRT. (2017, November 8). *ETT Cuff Pressure Check/ Assessment* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=Yv7Fs9ljw-k

An interactive H5P element has been excluded from this version of the text. You can view it online here:
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Tips and Tricks

1. When intubating someone, it is best to have several ETTs available at a moment's notice. This will allow you to use a different size if you cannot get the one you chose into the person's trachea.
2. If the person is not already unconscious, they will need to be sedated before having an ETT inserted.
3. The tip of the ETT should be between 3–7 cm (1.2–2.8 inches) from the bottom of the trachea above the carina. The carina is the point at the bottom of the trachea where it splits into the bronchi. You do not want the ETT to go this far down, as it could damage this area.
4. A rigid stylet and flexible bougie are excellent intubation aids. The rigid stylet is placed in the ETT, and the tube is bent into a more useful shape. Usually, the curve at the distal end is increased. The stylet should not extend beyond the end of the endotracheal tube because it could cause tracheal trauma. The flexible bougie (gum elastic bougie) should be 60 cm long with a "J" shape at the distal tip. It should be soft and flexible to prevent trauma to the trachea. The flexible bougie is used as a guide for the ETT.
5. Colormetric (CO_2) monitors are single use. When they sense CO_2, the face of the monitor changes color irreversibly. Because of this, they are typically used just once right after intubation.
6. Measuring the pressure of the cuff in the trachea will help prevent damage to the trachea and the lungs. A safe pressure at the cuff of the ETT is between 20 and 30 cmH_2O.

3.2 Lab Activities

An interactive H5P element has been excluded from this version of the text. You can view it online here:
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3.3 Critical Thinking Assessment

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https://wtcs.pressbooks.pub/respiratorysurvey/?p=443#h5p-72

4.1 Suctioning

Airway suctioning is routinely done in most care settings, including acute care, sub-acute care, long-term care, and home settings. Suctioning is performed when the patient is unable to effectively move secretions from the respiratory tract or the oropharynx. (See Figure 19.[1]) A respiratory therapist should be skilled and knowledgeable about all aspects of airway suctioning.

Airways suctioning is indicated for multiple reasons. Most commonly, suctioning is done for the removal of secretions from the respiratory tract, but sometimes also for the removal of blood or other materials like meconium in neonates. Airway suctioning is also performed for diagnostic purposes. For example, airway secretions may be sent for microbiological and histological review. Additionally, suctioning is performed to maintain the patency of artificial airways such as an endotracheal tube or a tracheostomy tube.

Figure 19. Health care worker suctioning patient's oral airway.

Multiple studies have shown that airway suctioning should be done as needed or based on clinical parameters, including pulse oximetry levels, respiratory rate, or visible secretions in the airway. Optimal suctioning helps reduce airway obstruction and the incidence of atelectasis, which leads to hypoxemia and impaired gas exchange.

1. "DSC_0192" by BcCampus is licensed under [CC BY 4.0](). Access for free at https://opentextbc.ca/clinicalskills/

Oral and Nasotracheal Suctioning (Open Suctioning)

Suctioning via the oropharyngeal (mouth) and nasopharyngeal (nasal) routes is performed to remove accumulated saliva, pulmonary secretions, blood, vomitus, and other foreign material from these areas that cannot be removed by the patient's spontaneous cough or other less invasive procedures. Nasal and pharyngeal suctioning are performed in a wide variety of settings, including critical care units, emergency departments, inpatient acute care, skilled nursing facility care, home care, and outpatient/ambulatory care. Suctioning is indicated when the patient is unable to clear secretions and/or when there is audible or visible evidence of secretions in the large/central airways that persist in spite of the patient's best cough effort.

For oropharyngeal suctioning, a device called a Yankauer suction tip is typically used for suctioning mouth secretions (see Figure 20[2]). A Yankauer device is rigid and has several holes for suctioning secretions that are commonly thick and difficult for the patient to clear.

Figure 20. Yankauer suctioning device.

Nasopharyngeal and nasotracheal suctioning removes secretions from the nasal cavity, pharynx, and throat by inserting a flexible, soft suction catheter through the nares. This type of suctioning is performed when oral suctioning with a Yankauer is ineffective. For nasopharyngeal/nasotracheal suctioning, it is important to use a sterile open suction catheter and use sterile technique when handling the catheter (see Figure 21[3]). When performing nasal suctioning, have the patient lean their head backwards to open the airway. This helps guide the catheter toward the trachea rather than the esophagus.

Figure 21. Open suction catheter.

View the following supplementary YouTube video[4] that demonstrates the technique for nasopharyngeal/nasotracheal suctioning: Performing Nasotracheal and Nasopharyngeal Suctioning

3. "DSC_0210" by BcCampus is licensed under CC BY 4.0. Access for free at https://opentextbc.ca/clinicalskills/

4. Ashraf Z Qotmosh. (2020, June 23). *Performing Nasotracheal and Nasopharyngeal Suctioning* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=AjVw7HZ1YCk

Sterile Technique for Open and Nasotracheal Suctioning

Sterile technique (also called surgical asepsis) seeks to eliminate every potential microorganism in and around a sterile field while also maintaining objects as free from microorganisms as possible. It is the standard of care for open suctioning. Sterile technique for open suctioning requires a combination of meticulous handwashing and donning sterile gloves (see Figure 22[5]).

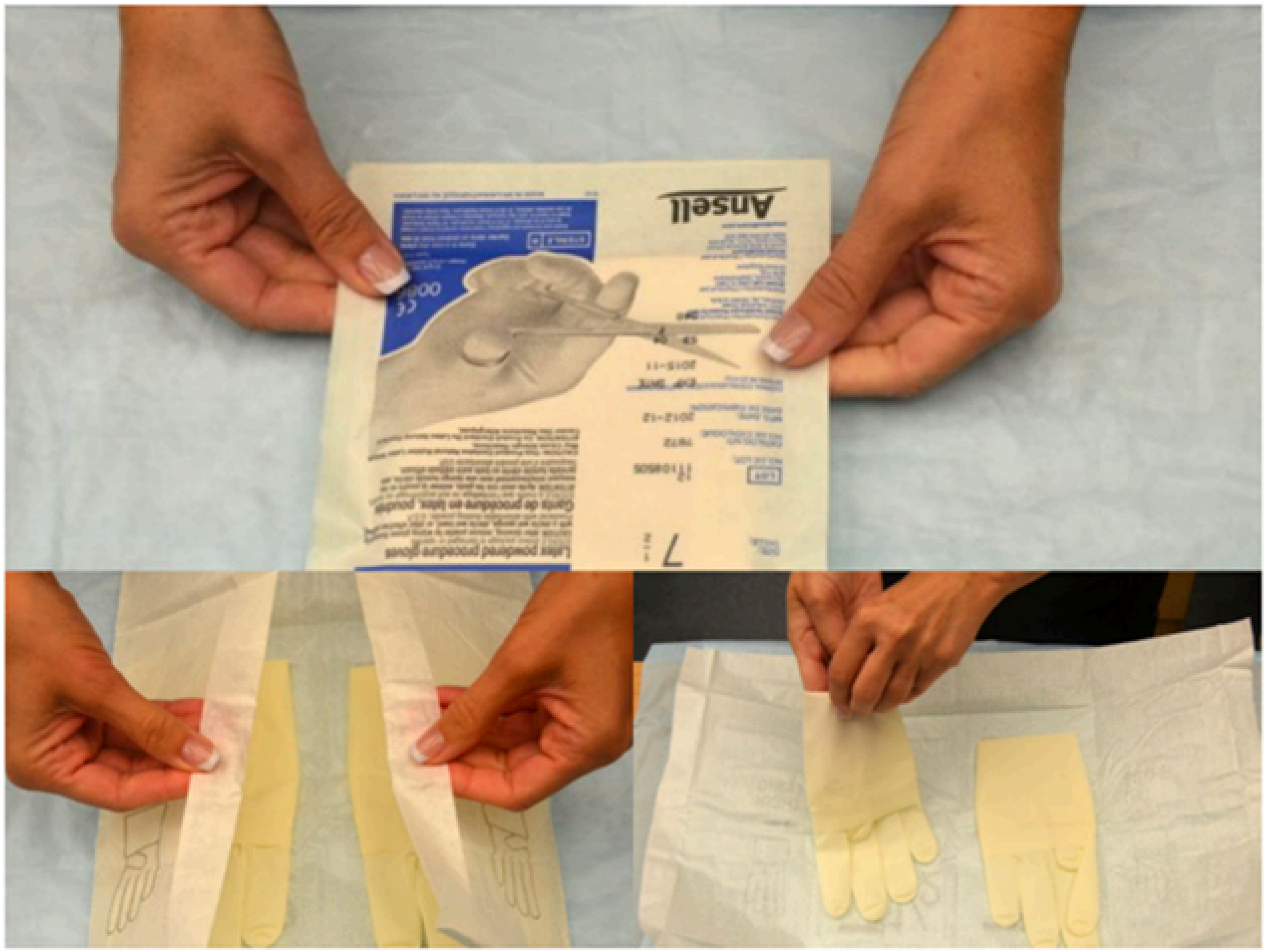

Figure 22. Sterile gloves.

Closed Suctioning

Closed suction catheters are preferable with ventilated patients to reduce the occurrence of airway collapse that may occur when a patient is disconnected from the ventilator. Closed suctioning is considered safer and is

5. This image is derivative of "Book-pictures-2015-199-001", "Book-pictures-2015-215", and "Book-pictures-2015-220" by BcCampus is licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/). Access for free at https://opentextbc.ca/clinicalskills/

associated with fewer adverse events. In-line suctioning, as the name implies, includes a suction catheter that is attached as a part of the ventilator circuit connected to the patient.

Superficial suctioning implies going down with the suction catheter only up to the end of the artificial airway (endotracheal or tracheostomy tube), whereas deep suctioning implies going down with the catheter until resistance is met, which can theoretically be until the carina or primary bronchi are reached. Superficial suctioning is the most advisable to avoid mucosal injury and trauma.

View the following supplementary YouTube video[6] that demonstrates the proper technique for closed suctioning and artificial airway: [Suctioning the endotracheal tube – medical animation](https://www.youtube.com/watch?v=pN6-EYoeh3g)

Procedure

The patient should be educated about the procedure (if awake and interactive) and the possibility of discomfort. Ensure preoxygenation with 100% FiO2 was done with adequate pulse oximetry measurements. Preoxygenation is required because an airway suctioning procedure may be associated with significant hypoxemia. Suctioning of the lower airways should be done in a sterile manner with single-use gloves and suction catheters to prevent contamination and secondary infection.

After preparation with appropriate equipment at the bedside, vitals should be monitored continuously, including heart rate, oxygen saturation, and intracranial pressure if transduced. Once the patient is preoxygenated, the patient should be suctioned with the appropriately sized equipment for their airway. The catheter should be introduced to a depth no more than the tip of the artificial airway to prevent trauma and bleeding from airway mucosa. Suction pressure should be set at -100 to -120 mmHG for adults, -80 to -100 mmHG for children, and -60 to -80 mmHG for infants. The catheter size used for suction should be less than 50% of the internal diameter of the endotracheal tube.

Each pass should be less than 15 seconds in duration, and the patient should be allowed to recover for at least 30 seconds to 1 minute between suction passes. Routine use of saline down the endotracheal tube is not recommended while suctioning.

Specimen Collection

A variety of specimen collectors (commonly called Lukens traps) are available. They are packaged as sterile so that no contamination of the sputum sample occurs with nonpatient organisms. A properly working specimen collection system provides a vacuum to the tip of the suction catheter when the thumb control valve or mouthpiece is sealed, and vacuum is applied.

6. Amerra Medical. (2022, May 7). *Suctioning the endotracheal tube – medical animation* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=pN6-EYoeh3g

View the following supplementary YouTube video[7] that shows how to collect as sputum sample: [Collecting a Suction Sample](https://www.youtube.com/watch?v=5pM5ZYngxnk)

7. Pediatric Home Service. (2018, August 30). *Collecting a Suction Sample* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=5pM5ZYngxnk

4.2 Lab Activities

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=454#h5p-73

4.3 Critical Thinking Assessment

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5.1 Tracheostomy and Tracheostomy Cares

A tracheostomy (aka trach) provides a secure, durable airway for prolonged mechanical ventilatory support in patients. (See Figure 23.[1]) Quality-of-life issues, as well as end-of-life issues, should be addressed preoperatively with the patient or family members/guardians before proceeding, especially in the terminally ill and elderly. Tracheostomy is a safe, effective procedure that can be performed via an open or percutaneous technique. Indications include relief of airway obstruction, secretion management, and secure access for prolonged mechanical ventilation. The precise timing of placing a tracheostomy remains controversial, but most centers proceed within 5–14 days, depending on the prognosis of the patient and the cause of initial intubation. Complications can be categorized as intraoperative, early, and late. Postoperative management is best carried out by a multidisciplinary team that includes respiratory therapists.[2]

Figure 23. Cuffed tracheostomy with disposable inner cannula and obturator.

1. "Tracheostomy_tube.jpg" by Klaus D. Peter, Wiehl, Germany is licensed under CC BY 3.0

2. Raimonde, A. J., Westhoven, N., & Winters, R. (2023). *Tracheostomy*. StatPearls [Internet]. https://www.ncbi.nlm.nih.gov/books/NBK559124/

Tracheostomy care is provided on a routine basis to keep the tracheostomy tube's flange, inner cannula, and surrounding area clean to reduce the number of bacteria entering the artificial airway and lungs. Typically, health care facilities use tracheostomy care kits to clean a tracheostomy (see Figure 24[3]).

The primary purpose of the inner cannula is to prevent tracheostomy tube obstruction. Many sources of obstruction can be prevented if the inner cannula is regularly cleaned and replaced. Some inner cannulas are designed to be disposable, while others are reusable for a number of days. Follow policies for inner cannula replacement or cleaning, but as a rule of thumb, inner cannula cleaning should be performed every 12–24 hours at a minimum. Cleaning may be needed more frequently depending on the type of equipment, the amount and thickness of secretions, and the patient's ability to cough up the secretions.

Changing the inner cannula may encourage the patient to cough and bring mucus out of the tracheostomy. For this reason, the inner cannula should be replaced prior to changing the tracheostomy dressing to prevent secretions from soiling the new dressing. If the inner cannula is disposable, no cleaning is required.

The stoma site should be assessed, and a clean dressing applied at least once per shift. Wet or soiled dressings should be changed immediately.

Figure 24. Tracheostomy care kit.

3. "Sterile Tracheostomy Care Kit" by Julie Teeter at Gateway Technical College is licensed under CC BY 4.0

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5.2 Lab Activities

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5.3 Critical Thinking Assessment

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Skills Assessment

[Manual Ventilation with a BVM]
- [Intubation Assist]
- [Manage Artificial Airway / ETT Care]
- [Closed Suctioning]
- [Open/NT Suctioning]
- [Tracheostomy Care]

PART V

LIFE SUPPORT

Learning Objectives

- Explain the principles and clinical applications of NIPPV.
- Demonstrate the proper application of NIPPV, including patient assessment and monitoring.
- Select and fit appropriate masks for NIPPV to ensure patient comfort and minimize air leaks.
- Differentiate between volume control and pressure control ventilation modes, including their indications and limitations.
- Configure ventilators for both modes based on patient-specific needs.
- Describe the role of pressure support and SIMV ventilation in augmenting spontaneous breathing.
- Adjust PSV and SIMV settings to optimize patient comfort and ventilation support.
- Identify key ventilator parameters (e.g., FiO2, PEEP, respiratory rate, tidal volume) and their impact on oxygenation and ventilation.
- Make appropriate ventilator adjustments to address issues such as hypoxemia or hypercapnia.
- Define ventilator-associated events and recognize their potential causes.
- Analyze ventilator waveforms (e.g., pressure, flow, and volume curves) to assess patient-ventilator interaction.
- Use ventilator graphics to identify common issues such as air trapping, patient effort, and asynchrony.
- Explain the criteria and methods for assessing readiness for weaning.
- Develop strategies to gradually reduce ventilatory support while monitoring patient response.
- Describe the steps involved in safe extubation, including pre-extubation assessment and post-extubation care.
- Recognize complications that may arise during or after extubation and implement appropriate interventions.

1.1 Noninvasive Positive Pressure Ventilation (NIPPV)

Noninvasive positive pressure ventilation (NIPPV) – sometimes just called noninvasive ventilation (NIV) – is a common therapy in critical care medicine. In the right patient population, it can be used instead of invasive ventilation and keep patients off mechanical ventilators. Selecting the appropriate patient for NIPPV is crucial, as using this intervention in an unsuitable setting can lead to treatment failure and increase the risk of patient aspiration. The classic NIPPV patient is alert with an intact drive to breathe (see Figure 1[1]). They either need some help with distending pressure or assistance with augmenting their tidal volumes with some extra support. Choosing initial settings on NIPPV is straightforward once you identify the therapy that is most beneficial to the patient.

NIPPV is the application of two different levels of pressure. There is a lower pressure that is there during expiration (EPAP), and then the pressure increases to a higher level during inspiration (IPAP). These two pressures remain constant and vary up and down based on the ventilator sensing inspiration and expiration. The IPAP and EPAP will not change unless the clinician increases or decreases the pressure settings. The EPAP may help oxygenation by methods of lung recruitment or opening collapsed airways. The IPAP is able to help improve the clearance of CO2 by augmenting each breath the patient is taking and by increasing the tidal volume, allowing more CO2 clearance with every breath.

When initiating noninvasive ventilation for a spontaneous breathing patient, there are three main settings that need to be adjusted, as well as one additional "back-up" setting. First, you will set the oxygen delivery (FiO2), a distending pressure to help recruit alveoli (EPAP), and a high pressure to augment the patient's normal breath (IPAP). The back-up setting is a basic respiratory rate (RR). (Remember that this setting does not replace the patient spontaneously breathing.) Then, the efficacy of NIPPV is checked after 30 minutes, sometimes with an arterial blood gas or by reassessing the patient's response to the treatment.[2]

1. "BIPAP.JPG" by James Heilman, MD is licensed under CC BY-SA 4.0

2. Bishop, M. (2022). *Basic principles of mechanical ventilation*. Sault College. https://ecampusontario.pressbooks.pub/mechanicalventilators/front-matter/introduction/

Figure 1. Person on NIPPV.

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1.2 Lab Activities

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1.3 Critical Thinking Assessment

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https://wtcs.pressbooks.pub/respiratorysurvey/?p=469#h5p-86

2.1 Invasive Mechanical Ventilation

Volume Control

Invasive mechanical ventilation is the primary usage of the volume control. (See Figure 2.[1]) This requires an invasive airway, whether a surgical or mechanically placed airway. The airway considerations are considered elsewhere in this laboratory resource. Volume control is a mode of ventilation, which, in simple terms, is the way that a mechanical ventilator interacts with a patient. Volume control is the name that gives the best way to understand the nature of this mode of ventilation. As you will see, there are multiple ways that this form of mechanical ventilation is referred to, such as assist-control volume control, volume control, or continuous mechanical ventilation-volume control (ACVC, VC, CMV-VC), all of which refer to the same mode of ventilation.

Volume control is typically a straightforward and easy-to-understand mode for respiratory therapists. This mode mimics normal breathing, as minute volume is determined by tidal volume (Vt) multiplied by the number of breaths. In this case, the machine selects both the breath size and the minimum breath rate. The clinician sets the tidal volume (the size of each breath based on the height of the patient) and the respiratory rate (how often a breath is delivered). The breath initiation is called the trigger or the start of a mechanical breath. The ventilator then ensures that the same volume is delivered with each breath, maintaining consistency regardless of the pressure needed to achieve this within the designated timeframe. However, the pressure will vary depending on the resistance of the patient's airways and the compliance of the patient's lungs. The patient effort can also trigger a breath; this would be considered non-initiated by the mechanical ventilator.

In most cases, volume control involves managing the set time through a specified flow rate, which is the rate at which the gas comes out of the ventilator into the lungs of the patient. The clinician determines the amount of air to be delivered and how many times the lungs will inflate per minute. However, some ventilators allow the option to set an inspiratory time, or I-time, directly. The inspiratory time is the length of time that it takes for the gas to enter the lungs of the patient. It is helpful to remember that as the flow rate increases, the time of inspiration (or I-time) decreases. Additionally, the maximum flow rate, or the "speed" of air delivery, is set. The I-time is influenced by the chosen flow rate: a higher flow rate results in a shorter I-time to deliver the set volume. These two parameters are inverse of each other.

1. "Ventilator control panel" by quinn.anya is licensed under a CC BY-SA 4.0. Access for free at https://ecampusontario.pressbooks.pub/mechanicalventilators/chapter/settings-and-definitions/

Figure 2. Ventilator interface screen.

In assist-control volume control, you will directly set the following:

- Respiratory rate (RR or f)
- Tidal volume (Vt)
- Max flow rate (V) or inspiratory time (I-time)
- PEEP (every ventilator, every mode)
- FiO2 (every ventilator, every mode)

In assist-control volume control, you will observe but not directly set the following:

- Inspiratory pressure
- Peak inspiratory pressure (PIP)
- Inspiratory time (I-time) would not be set if the ventilator lets you set flow. In this case, observe I-time.

In volume control, the volume delivered is constant, but there will be changes in peak pressures (PIP or Ppeak, which refers to the highest pressure experienced by the alveoli during a breath) to achieve the set volume for both the following situations:

1. The clinician changing the set parameters (volume, flow/time)
2. Breath-to-breath changes based on the compliance and resistance of the lungs

Impacts to peak pressures should be considered by the clinician when making changes, and lung pathology should be considered if changes are noted in the pressure when no adjustments to settings are made. (See Figure 3.[2]) Peak pressures should not be allowed to go too high. Remember that high pressures can cause

2. "Pressure time" by Kirsten Holbrook, Chippewa Valley Technical College is licensed under [CC BY-NC 4.0](https://creativecommons.org/licenses/by-nc/4.0/)

damage to the alveoli of the lungs. Ideally, plateau pressures should be kept below 30 cmH20, with a maximum of 35 cmH20, to ensure the alveoli do not get damaged.

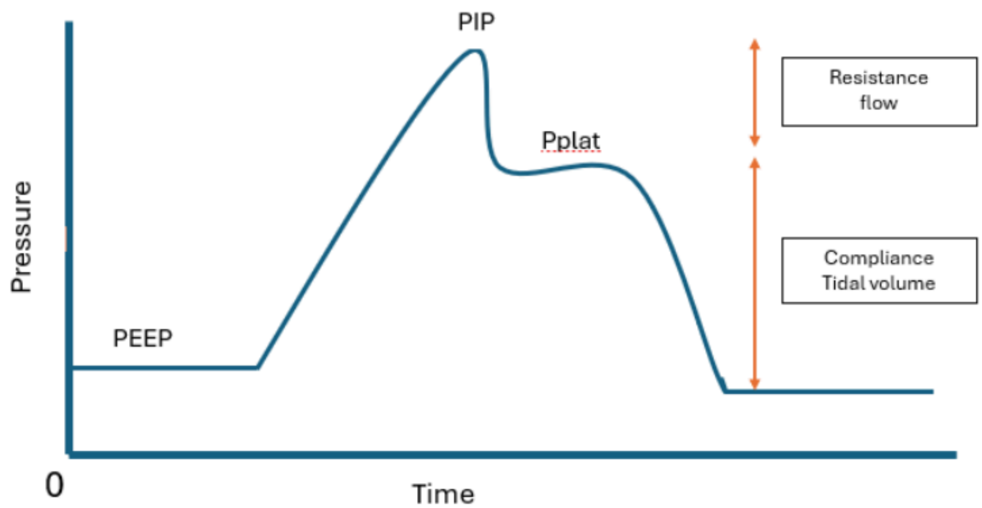

Figure 3. Pressure Time waveform.

View the following supplementary YouTube video[3] that shows the parameters that should be set when using the volume control mode of mechanical ventilation: [Mechanical Ventilation Series: #3 Explanation of Settings (AC Colume Control)]

Pressure Control

Pressure control ventilation or assist-control pressure control, pressure control, or continuous mechanical ventilation-pressure control (ACPC, PCV, CMV-PC) is a full control mode of ventilation – the ventilator will control all phases of the breath delivered based on the set parameters. Exhalation is still passive. The clinician sets a minimum of how often breaths will be delivered and sets the positive pressure applied (pressure control) to the lungs that causes the lungs to inflate with volume. The pressure delivered is constant and does not change breath to breath unless the clinician changes it. In contrast to volume control, the control here is the

3. RespTherapy. (2016, March 8). *Mechanical ventilation series: #3 explanation of settings (AC volume control)* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=UkSfJI9zGEk

pressure set, and the volume that the patient receives varies according to their pulmonary compliance and airway resistance.

In pressure control, the volume being delivered over time is something that you can trend to see whether the lungs are improving or getting worse. Volumes must be continuously monitored to ensure they are enough to effectively ventilate the patient, but not too high that they cause damage. Pressure control (inspiratory pressure) should be limited to deliver tidal volumes within a safe range for the patient's lungs.[4]

In PC, you will directly set each of the following:

- Respiratory rate (RR or f)
- Pressure control (PC)
- Inspiratory time (I-time)
- PEEP (every ventilator, every time)
- FiO2 (every ventilator, every time)

In PC pressure control, you will observe but not directly set the following:

- Tidal volume (Vt)
- Inspiratory flow (V)
- I:E

View the following supplementary YouTube video[5] you will differentiate between volume control and pressure control modes of ventilation: Volume versus pressure control

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https://wtcs.pressbooks.pub/respiratorysurvey/?p=471#h5p-109

4. Bishop, M. (2022). *Basic principles of mechanical ventilation*. Sault College. https://ecampusontario.pressbooks.pub/mechanicalventilators/front-matter/introduction/

5. Medmastery. (2017, January 30). *Volume versus pressure control* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=TJf0tPjIK4Q

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2.2 Lab Activities

2.2a Volume Control Activity

Utilize the Data Recording Sheet that your laboratory instructor provides.

1. Setup:

- Connect the ventilator to the test lung or lung simulator using the ventilator circuit.
- Ensure all connections are secure and there are no leaks.
- Turn on the ventilator and set it to volume control (VC) mode.

2. Initial Settings:

- Set the tidal volume (Vt) to 500 mL.
- Set the respiratory rate (RR) to 12 breaths per minute.
- Set the PEEP (Positive End-Expiratory Pressure) to 5 cmH2O.
- Set the FiO2 (Fraction of Inspired Oxygen) to 21%.
- Set the I:E ratio to 1:2.

3. Baseline Measurements:

- Record the baseline peak inspiratory pressure (PIP), plateau pressure (Pplat), and compliance.
- Calculate the initial I-time.

4. Compliance Changes:

- Simulate a decrease in lung compliance by adjusting the settings on the test lung.
- Observe and record the changes in PIP, Pplat, and compliance.
- Calculate the new I-time.
- Repeat the above steps by increasing lung compliance and record the results.

5. Resistance Changes:

- Simulate an increase in airway resistance by adjusting the test lung or adding an obstruction in the ventilator circuit.
- Observe and record the changes in PIP and Pplat.
- Calculate the new I-time.
- Repeat the above steps by decreasing airway resistance and record the results.

6. I-time Calculations:

- Adjust the respiratory rate to 20 breaths per minute and keep the I:E ratio constant at 1:2. Calculate the new I-time.
- Adjust the I:E ratio to 1:1 while keeping the respiratory rate at 12 breaths per minute. Calculate the I-time.
- Observe the changes in PIP and Pplat with these different I-time settings.

Analysis and Discussion:

- Discuss how compliance and resistance impact ventilator settings and patient care.
- Explain the importance of calculating and adjusting I-time in different clinical scenarios.
- Reflect on the observed changes and how they would guide ventilator management in real patients.

2.2b Pressure Control Activity

Utilize the Data Recording Sheet that your laboratory instructor provides.

1. Setup:

- Connect the ventilator to the test lung or lung simulator using the ventilator circuit.
- Ensure all connections are secure and there are no leaks.
- Turn on the ventilator and set it to pressure control (PC) mode.

2. Initial Settings:

- Set the PIP to 15 cmH2O.
- Set the respiratory rate (RR) to 12 breaths per minute.
- Set the PEEP (Positive End-Expiratory Pressure) to 0 cmH2O.
- Set the FiO2 (Fraction of Inspired Oxygen) to 21%.
- Set the I-time to 1.0 sec.

3. Baseline Measurements:

- Record the baseline tidal volume, plateau pressure (Pplat), and compliance.
- Calculate the initial I:E ratio.

4. Compliance Changes:

- Simulate a decrease in lung compliance by adjusting the settings on the test lung.
- Observe and record the changes in PIP, Pplat, and compliance.
- Calculate the new I:E ratio.
- Repeat the above steps by increasing lung compliance and record the results.

5. Resistance Changes:

- Simulate an increase in airway resistance by adjusting the test lung or adding an obstruction in the ventilator circuit.
- Observe and record the changes in PIP and Pplat.
- Calculate the new I:E ratio.
- Repeat the above steps by decreasing airway resistance and record the results.

6. I-time Calculations:

- Adjust the respiratory rate to 20 breaths per minute and keep the I:E ratio constant at 1:2. Calculate the new I-time.

- Adjust the I:E ratio to 1:1 while keeping the respiratory rate at 12 breaths per minute. Calculate the I-time.
- Observe the changes in tidal volume and Pplat with these different I-time settings.

2.3 Critical Thinking Assessment

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=475#h5p-87

3.1 Pressure Support (PS) / Synchronized Intermittent Mechanical Ventilation (SIMV)

Spontaneous breathing modes, which include synchronized intermittent mechanical ventilation (SIMV) and various implementations of pressure support (PS), allow for the patient to breathe spontaneously either in between machine breaths with or without support or "augmentation" for that breath. SIMV allows for spontaneous breaths with pressure support that augments or supports each spontaneous breath. PS is an inspiratory pressure that is initiated when the patient takes a spontaneous breath.

Pressure Support (PS)

In PS ventilation, each time a patient initiates a breath, the ventilator delivers a set level of pressure to assist the patient as they breathe in. The patient controls the frequency and volume of their breaths, allowing them to take long, deep breaths or shorter, more rapid ones as needed. The only constant is the set level of pressure provided by the ventilator, which will not change unless adjusted by a clinician.

The primary setting in PS ventilation that the clinician must determine is the amount of pressure support. This level should be sufficient to keep the patient's work of breathing within normal limits. If the patient's condition worsens and they are unable to maintain adequate breathing effort, they may be considered "failing" and could require additional support or a switch back to a controlled ventilation mode.

In PS, you will directly set the following:

- Pressure support (PS)
- PEEP (every ventilator, every time)
- FiO2 (every ventilator, every time)

In PS, you will observe but not directly set the following:

- Tidal volume (Vt)
- Inspiratory flow or I-time (V or TI)
- RR (patient must trigger all breaths)
- Peak inspiratory pressure (PIP or Ppeak)
- I:E

Patients can take air in at whatever speed they want and end the breath when they want to. The mechanical ventilator will sense when inspiration and expiration start.[1]

1. Bishop, M. (2022). *Basic principles of mechanical ventilation*. Sault College. https://ecampusontario.pressbooks.pub/mechanicalventilators/front-matter/introduction/

View the following supplementary video[2] that explains the mode of PS (aka CPAP): [Respiratory Therapist – Mechanical Ventilation – CPAP vs CPAP w/ Pressure Support]

Synchronized Intermittent-Mandatory Ventilation (SIMV)[3]

This mode guarantees a certain number of breaths, but unlike AC/VC, patient breaths are partially their own, reducing the risk of hyperinflation or alkalosis. Mandatory breaths are synchronized to coincide with spontaneous respirations. Disadvantages of SIMV are increased work of breathing and a tendency to reduce cardiac output, which may prolong ventilator dependency. The addition of pressure support on top of spontaneous breaths can reduce some of the work of breathing.

In SIMV, you will directly set the following:

- Respiratory rate (RR or f)
- Tidal volume (Vt) or Inspiratory pressure (PC)
- PEEP (every ventilator, every mode)
- FiO2 (every ventilator, every mode)
- Pressure support (PS)

In SIMV, you will observe but not directly set the following:

- Peak inspiratory pressure (PIP)
- Inspiratory time (I-time) would not be set if the ventilator lets you set flow. In this case, observe I-time.

The ventilator establishes a time window, equal to the total cycle time for each respiratory cycle established by the set respiratory rate. At the start of each window, the ventilator assesses whether the patient is making an inspiratory effort. If the ventilator does not feel any inspiratory effort, it will provide a controlled breath. If the ventilator feels an inspiratory effort at the start of the window, it will provide an assisted breath. If the patient breathes spontaneously after the obligatory or assisted breath has been given, the patient will receive spontaneous type breaths for the remainder of the respiratory cycle.

Therefore, for mandatory or assisted breaths, the operator can choose to control the breaths either by pressure or flow/volume. For spontaneous breaths, the support is controlled by setting a support pressure.

An advantage of using SIMV mode is that it allows the patient to breathe spontaneously (with supportive pressure).

Despite this advantage, these are disadvantages of using SIMV mode:

2. Respiratory Coach. (2022, September 23). *Respiratory therapist – mechanical ventilation – CPAP vs CPAP w/ pressure support* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=fiaRjq0t_1I

3. OpenAnesthesia. (2024). *Modes of mechanical ventilation*. https://www.openanesthesia.org/keywords/modes-of-mechanical-ventilation/

- The mode was designed to improve removal or weaning of a patient from a ventilator. This has subsequently been shown to be an error, and some form of a spontaneous breathing trial with spontaneous breath assistance or support has been found to be superior.
- It may lead to increased work of breathing if controlled and spontaneous breaths are not synchronized (frequently observed when the patient suffers from an increased respiratory rate).

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=477#h5p-112

3.2 Lab Activities

3.2a SIMV

Utilize the Data Recording Sheet that your laboratory instructor provides.

1. Setting Up the Circuit:
    - Assemble the ventilator circuit according to the simulator's instructions. This typically involves connecting the ventilator to the artificial lung model (if used) or the syringe (simulating lung compliance) through tubing and valves.
    - Connect the manometer to the circuit to measure airway pressure.
2. Initial Settings:
    - Set the ventilator mode to SIMV.
    - Set the following initial parameters:
        - Tidal volume (Vt): 500 mL
        - Respiratory rate (RR): 12 breaths/minute
        - PEEP (Positive End-Expiratory Pressure): 5 cmH2O
        - Pressure Support: 5-8 cmH2O
    - Turn on the ventilator and observe the simulated ventilation cycles.

Data Collection and Analysis:
1. Effect of Respiratory Rate:
    - Increase the respiratory rate on the ventilator to 16 breaths/minute while keeping all other settings constant.
    - Record the following data:
        - Peak inspiratory pressure (PIP)
        - Plateau pressure (Pplat)
        - Minute ventilation (Ve)
    - Repeat this step by decreasing the respiratory rate to 8 breaths/minute.

Question 1: How did the change in respiratory rate affect PIP, Pplat, and Ve? Explain why this happened.
2. Effect of Tidal Volume:
    - Set the respiratory rate back to 12 breaths/minute.
    - Increase the tidal volume to 700 mL while keeping all other settings constant.
    - Record the same data points as in Step 1 (PIP, Pplat, Ve).
    - Repeat this step by decreasing the tidal volume to 300 mL.

Question 2: How did the change in tidal volume affect PIP, Pplat, and Ve? Explain the relationship between tidal volume and airway pressures.
3. Effect of PEEP:

- Set the tidal volume back to 500 mL and respiratory rate to 12 breaths/minute.
- Increase the PEEP setting to 10 cmH2O while keeping all other settings constant.
- Record the same data points as in Step 1 (PIP, Pplat, Ve).
- Repeat this step by decreasing the PEEP to 0 cmH2O.

Question 3: How did the change in PEEP affect PIP, Pplat, and Ve? Explain the rationale behind using PEEP in ventilator management.

3.2b PS

Utilize the Data Recording Sheet that your laboratory instructor provides.

1. Setting Up the Circuit:
    - Assemble the ventilator circuit according to the simulator's instructions. Connect the manometer to the circuit to measure airway pressure.
    - For an advanced setup, connect the flow simulator to represent patient inspiratory effort or breathe for the the vent by triggering an artificial lung.
2. Initial Settings:
    - Set the ventilator mode to PS.
    - Set the following initial parameters:
        - Pressure support (PS): 5 cmH2O
        - PEEP (Positive End-Expiratory Pressure): 5 cmH2O
        - Respiratory rate (RR): Backup rate set to 12 breaths/minute (ventilator will deliver breaths only if patient doesn't initiate their own)
    - Turn on the ventilator and observe the simulated ventilation cycles.

Data Collection and Analysis:

1. Effect of Pressure Support:
    - Increase the pressure support level on the ventilator to 10 cmH2O while keeping all other settings constant.
    - Record the following data:
        - Peak inspiratory pressure (PIP)
        - Plateau pressure (Pplat)
        - Tidal volume (Vt)
    - Repeat this step by decreasing the pressure support to 2 cmH2O.

Question 1: How did the change in pressure support affect PIP, Pplat, and Vt? Explain the relationship between pressure support and lung inflation.

2. Effect of PEEP:

- Set the pressure support level back to 5 cmH2O.
- Increase the PEEP setting to 10 cmH2O while keeping all other settings constant.
- Record the same data points as in Step 1 (PIP, Pplat, Vt).
- Repeat this step by decreasing the PEEP to 0 cmH2O.

Question 2: How did the change in PEEP affect PIP, Pplat, and Vt? Explain how PEEP influences work of breathing in PS.

3. Simulating Patient Effort (Optional):

- If your simulator allows, connect the flow simulator to represent patient inspiratory effort.
- Observe the ventilator's response to increased and decreased flow rates.

Question 3: How does patient effort (increased flow) affect ventilator cycling in PSV? Explain the concept of patient-ventilator synchrony.

3.3 Critical Thinking Assessment

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=481#h5p-88

4.1 Parameter Adjustments

The terms ventilation (the exchange of pCO2) and oxygenation (pO2) are probably very familiar to you. Remember, pCO2 and pO2 are values in an ABG reading. Let's relate these concepts to settings on the ventilator and learn which specific setting affects ventilation or oxygenation.

Ventilation refers specifically to the movement of air in and out of the lungs. In terms of blood gas effects, ventilation directly refers to the removal of CO2. Therefore, what ventilator settings would affect this? What settings directly impact the amount of air going in and out of the lungs? If you guessed the tidal volume, you are correct! The size of breath will directly impact the amount of air going in and CO2 coming out of the lungs.

There is another setting that will impact the amount of CO2 clearance. What do the chemoreceptors in the brain trigger if the CO2 levels start to rise? If you answered the respiratory rate, then you are remembering correctly! The respiratory rate also has a direct impact on the amount of CO2 leaving the lungs over time. If you breathe faster, you are getting rid of CO2 more often, and this will help drive CO2 levels down.

What about oxygenation? Which ventilator settings directly impact the patient's oxygenation status? This concept should not be new to you. We have talked extensively about FiO2 and PEEP as working together to deliver oxygen into the body. The FiO2 can be increased to deliver higher amounts of oxygen to the lungs, while PEEP expands the lung units and increases the surface area of the lung to the capillary vasculature of the lung. Please note that this is a slight simplification of these concepts. There is some crossover between the ventilator settings that affect oxygenation and ventilation. However, for beginning learners it is better to keep oxygenation and ventilation and the settings that affect them separate in their minds without crossover. With practice they will be able to see the big picture and even make predictions on what order to use ventilation settings. (See Figure 4.[1])

1. "Lt._Cmdr._Michael_Heimes_checks_on_a_patient_connected_to_a_ventilator_at_Baton_Rouge_General_Mid_City_campus.jpg" by Cpl. Daniel R. Betancourt Jr. for U.S. Navy is licensed under CC BY 2.0. The appearance of U.S. Department of Defense (DoD) visual information does not imply or constitute DoD endorsement.

Figure 4. Health care provider manipulating ventilator settings.

Take a look at the following table, which summarizes the mechanical ventilation settings that affect oxygen versus ventilation. Keep in mind that Vt can also be affected by other settings on a ventilator.

Settings That Affect Oxygenation	Settings That Affect Ventilation
FiO2	RR
PEEP	Vt

Oxygenation Issues: FiO2 or Positive End Expiratory Pressure (PEEP)

When it comes to changing either FiO2 or PEEP, you need to think about the impacts of either of these values on the body. Remember, high levels of oxygen can cause lung damage, and we are always targeting the lowest FiO2 to maintain SpO2 > 92% and a pO2 at normal ranges (80–100 mmHg). FiO2s of higher than 50% can lead to oxygen damage to the lungs.

For PEEP, a normal starting range is 4–6 cmH2O—you will rarely decrease the PEEP below that number. Conversely, increasing PEEP too high can start to negatively impact the body. PEEP can negatively impact the compliance of the lungs—just like balloons that are already inflated with pressure could lose elasticity and not be able to inflate as easily. High PEEPs will also increase the pressure in the alveoli that, when added to the additional volume or pressure applied with every breath, could increase your patient beyond safe pressure levels and put the lungs at risk of barotrauma. We need to maintain pressures of less than 35 cmH2O—and, ideally, the lower, the better.

PEEP also increases the pressure in the thorax (chest) of the patient. Other than the lungs, this cavity also houses the heart and important vessels like the aorta and vena cava. Increased intrathoracic pressure will increase the pressure on these vessels as well. This pressure could squeeze the heart, decreasing the blood flow back into the heart and the pumping effectiveness of the heart. The medical terms for these situations are venous return and ejection fraction of the heart. Both conditions will show an impact on the blood pressure of the patient.

Ventilation Issues: Respiratory Rate (RR) or Tidal Volume (Vt)

If the pH is abnormal and you are going to try to normalize it by increasing or decreasing the pCO2 level, you know Vt and RR are both options to impact the amount of CO2 being exhaled every breath—but which change is most correct?

The answer depends on your current your ventilator settings. Remember the safe ranges for respiratory rate: 10–16 breaths per minute.

Now think about your tidal volume ranges. This parameter is much more definitive with its allowances. The safe tidal volume ranges for medical providers with basic ventilator knowledge is 6–8 mL/Kg. Using the knowledge you have of ideal body weight (IBW) and calculated safe tidal volume ranges, you would compare the tidal volume your patient is getting to your calculated ranges. Do you have room to move to correct the problem? If you do, this would be an option to take. However, if you are at either limit, then changing the tidal volume would not be an option to correct the problem.

If you are at the low ends of your safe ranges for both, then either RR or Vt can be adjusted. If you are at the higher ends of either one, then use the other setting instead. If you are at the high end of both RR and Vt, remember that the Vt is typically a hard limit, while RR can still be adjusted carefully. If you are already at the low ends of Vt and RR and you need to move your patient even lower, consider a different mode of ventilation or weaning the patient [2].

Equations to utilize when changing ventilator parameters

Making Changes in FiO2

$$\text{Desired Ve} = \frac{\text{Ve (current)} \cdot \text{PaCO}_2\text{(Current)}}{\text{PaCO}_2\text{(desired)}}$$

Remember VA and PaCO2 are inversely proportional.

2. Sault College. (2022). *Basic Principles of mechanical ventilation*. Open Library. https://ecampusontario.pressbooks.pub/mechanicalventilators/front-matter/introduction/

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=483#h5p-113

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=483#h5p-114

Ventilator-Associated Events (VAE)

Studies suggest that most VAEs are caused by pneumonia, fluid overload, ARDS, and atelectasis. VAEs are associated with a doubling of the risk of death compared to patients without VAEs and compared to patients who meet traditional VAP criteria.

Risk factors for VAEs include sedation with benzodiazepines or propofol, volume overload, high tidal-volume ventilation, high inspiratory driving pressures, blood transfusions, and patient transport.

Potential strategies to prevent VAEs include minimizing sedation, paired with daily spontaneous awakening and breathing trials, early mobility, conservative fluid management, conservative transfusion thresholds, oral care with chlorhexidine, stress ulcer prophylaxis, and low tidal-volume ventilation.

4.2 Lab Activities

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=485#h5p-89

4.3 Critical Thinking Assessment

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=487#h5p-90

5.1 Waveforms

Understanding and interpreting ventilator graphics (e.g., waveforms) are important skills for clinicians to have when working with patients requiring mechanical ventilation. After initiating mechanical ventilation, waveforms should be analyzed to ensure that the patient's demand is met and whether or not they are synchronous with the ventilation.[1]

View the following supplementary YouTube video[2] to gain a better understanding of ventilator graphics: [Mechanical Ventilation Basics – Waveforms/Scalars (Press, Flow, Volume) + Loops | Clinical Medicine]

In Figure 5[3] below, **A** demonstrates curves under normal conditions, and **B** demonstrates a situation where static lung compliance is reduced. In these circumstances, the lung accepts less volume and, therefore, requires less time to fill and **C** demonstrates a situation where resistance is increased. In these circumstances the flow that can flow through the airways decreases and, therefore, more time is required to administer normal tidal volume (Vt).

1. Harrigan, D. & Verville-Fiset, J. (2023). *Reference manual: Respiratory therapy*. Open Library. https://ecampusontario.pressbooks.pub/therapielacite/chapter/chapitre-3-la-ventilation-mecanique/
2. Whiteboard Medicine. (2022, December 21). *Mechanical ventilation basics – waveforms/scalars (Press, Flow, Volume) + loops | clinical medicine* [Video}. YouTube. All rights reserved. https://www.youtube.com/watch?v=8pKZ3XYCOio&t=4s
3. "Picture8-2.png" by unknown author is licensed under CC BY-NC-SA 4.0. Access for free at https://ecampusontario.pressbooks.pub/therapielacite/chapter/chapitre-3-la-ventilation-mecanique/

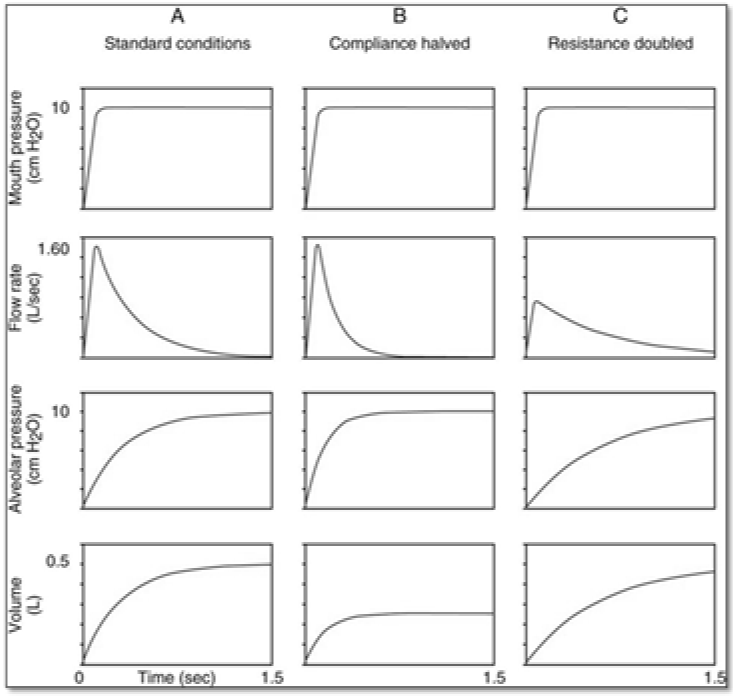

Figure 5. Wave form changes.

It is important to assess the presence of auto-PEEP in ventilated patients. Auto-PEEP increases the patient's mean airway pressure and may contribute to complications associated with mechanical ventilation, especially barotrauma, volutrauma, and hypotension. By activating the expiratory pause as shown in diagram A, the expiratory valve closes during static expiration. In the presence of auto-PEEP the airway flow continues to flow into the tubing. An equilibrium occurs between the lung and the ventilator and the measured pressure estimates the patient's auto-PEEP. (See Figure 6.[4])

4. "Picture10-2.jpg" by unknown author is licensed under [CC BY-NC-SA 4.0](). Access for free at https://ecampusontario.pressbooks.pub/therapielacite/chapter/chapitre-3-la-ventilation-mecanique/

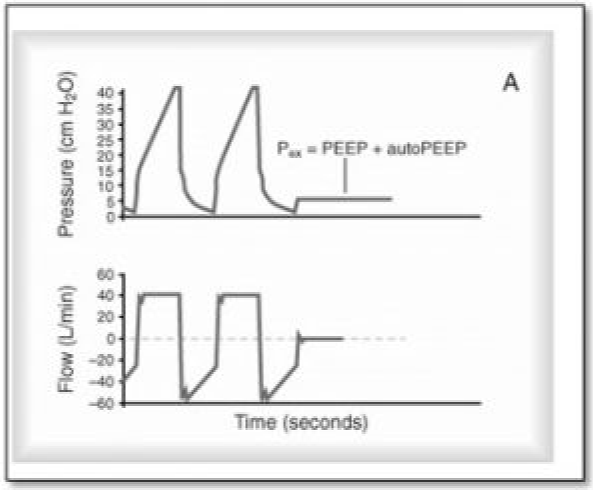

Figure 6. Expiratory pause showing auto-PEEP.

If the I-time is too long for the patient and they want to exhale before the expiratory valve opens you will see asynchrony. (See Figure 7.[5])

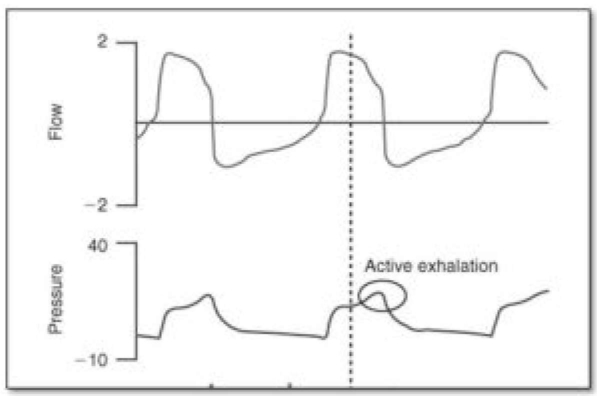

Figure 7. Active exhalation by evaluating the pressure curve waveform.

When two breaths are observed very close together, this may be an indication that the exhalation occurred too early. Therefore, the patient triggers a second breath immediately afterwards, producing almost "breath stacking." During ventilation, the ventilator-set I-time concludes, but the patient's inspiratory muscles are still contracting, resulting in a drop in pressure. Should this drop in pressure reach the trigger sensitivity level, it will prompt the ventilator to deliver another breath, causing the appearance of double triggering.

5. "Picture12-1.jpg" by unknown author is licensed under CC BY-NC-SA 4.0. Access for free at https://ecampusontario.pressbooks.pub/therapielacite/chapter/chapitre-3-la-ventilation-mecanique/

View the following supplementary YouTube video[6] that shows double triggering: Patient Ventilator Asynchrony: Double trigger

6. FREMITUS. (2011, March 4). *Patient ventilator asynchrony: double trigger* [Video]. YouTube. https://www.youtube.com/watch?v=G6kUx1sRKcI

5.2 Lab Activities

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=491#h5p-91

5.3 Critical Thinking Assessment

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://wtcs.pressbooks.pub/respiratorysurvey/?p=493#h5p-92

6.1 Weaning and Extubation

Extubation is removing an endotracheal tube (ETT), which is the last step in liberating a patient from the mechanical ventilator. To discuss the actual procedure of extubation, one also needs to understand how to assess readiness for weaning and management before and after extubation.

Weaning is a gradual transition from full invasive ventilatory support to spontaneous ventilation with minimal support. Liberation, however, means the complete discontinuation of mechanical ventilation. The current trend is to use the term "liberation" as opposed to "weaning'" in intensive care unit (ICU) ventilator management because the goal is to liberate patients from the ventilator as soon as possible rather than weaning over several days to weeks. Weaning is more common in long-term, acute care settings.

If the patient has passed the spontaneous breathing trial (SBT) after weaning, they should undergo reassessment for the suitability of extubation. (See Figure 8.[1]) Many of these assessments may have been done at the start of the weaning trial or as a part of the daily assessment of the patient's readiness to wean.

Figure 8. Patient on ventilator.

The most important part of this assessment is assessing the ability of the patient to protect and maintain a patent airway.

The patient should have an adequate level of consciousness; a Glascow Coma Scale (GCS) greater than 8 suggests a higher likelihood of successful extubation. The patient should have a strong cough. Most clinicians objectively determine the presence of a moderate to strong cough before extubation, although there are other

1. "Clinicians_in_Intensive_Care_Unit.jpg" by Calleamanecer is licensed under CC BY-SA 3.0

objective measures like a MIP. The presence of a weak cough, or a MIP of more than -20 cmH2O, is a strong independent risk factor for extubation failure. Additionally, the patient should be assessed for the volume and thickness of respiratory secretions, and the cuff-leak test should be done to ensure airway patency. Clinicians must be familiar with the airway anatomy observed prior to intubation, recognize potential difficult airways, and understand the techniques used for intubation. In cases of a known difficult airway, it is essential to have all necessary equipment readily available. If extra personnel are needed, they should be informed beforehand and be available at very short notice.[2]

> View the following supplementary YouTube video[3] that describes in detail weaning parameters in mechanical ventilation: Everything you need to know about weaning parameters in mechanical ventilation

Withdrawing of Life Support for Death

One of the dilemmas that can occur when a patient is on mechanical ventilation relates to the cessation of medical interventions in patients. Sometimes these interventions range from minor, such as a non-life sustaining medication, to more complex, such as mechanical ventilation. The rationale for stopping these interventions is often based on the fact that the burdens are outweighing any benefits the patient may get from it. Sometimes life-sustaining therapies may prolong suffering at the cost of decreasing the patient's quality of life. Patients and their family often decide to stop medical interventions based on some of these factors. One of the most heart-wrenching decisions that family members often have to make is about withdrawing life-sustaining treatments (life support) from patients. This is why advance directives are so important. Advance directives are documents that enable patients to make their decisions about medical care known to their family and health care providers, in the event that they are unable to make those decisions themselves. If a family member knows for sure that their loved one would not have wanted a particular medical intervention done, it may help to alleviate some of the burden they may feel about making the decision. It also helps prevent the initiation of some life-sustaining treatments beforehand, in which case no decision will be needed to withdraw that intervention. It also can help reduce overall costs of futile medical care.[4]

2. Saeed, F. & Lasrado S. (2023). *Extubation*. StatPearls [Internet]. https://www.ncbi.nlm.nih.gov/books/NBK539804/
3. Medmastery. (2017, February 23). *Everything you need to know about weaning parameters in mechanical ventilation* [Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=aQ3i5uxDURo
4. Lowey, S. E. (2015). *Nursing care at the end of life: What every clinician should know*. Open SUNY Textbooks. https://milnepublishing.geneseo.edu/nursingcare/chapter/ethical-concerns-in-end-of-life-care/

View the following supplementary YouTube video[5] that describes advanced directives: [Introduction to Advanced Directives](https://www.youtube.com/watch?v=B9DjjqyH19Y)

5. Ochsner Health. (2024, April 8). *Introduction to advanced directives*]Video]. YouTube. All rights reserved. https://www.youtube.com/watch?v=B9DjjqyH19Y

6.2 Lab Activities

Weaning and Extubation Case Study Lab Activity

6.3 Critical Thinking Assessment

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://wtcs.pressbooks.pub/respiratorysurvey/?p=499#h5p-93

Skills Assessments

NIPPV (CPAP and BiPAP)
- Initiate Mechanical Ventilation
- Patient Ventilator Assessment and Parameter Change
- Weaning Process
- Extubation Process