ur website www.jaypeebrothers.com, for detailed information on critical care books, visit our website www.jaypeebrothers.com

Manual of Oxygen Therapy



Editors
Kapil Zirpe
Subhal B Dixit
Atul P Kulkarni

Associate Editors
Shilpushp Bhosale
Khalid Ismail Khatib

Forewords
Ashish K Khanna
BD Kadam

JAYPEE

Contents

SECTION 1: Basic Facts of Oxygen

1. **Industrial and Medical Oxygen Production and Differences 3**
   Balkrishna Nimavat, Abhijit Deshmukh, Kapil Zirpe
2. **Medical Piped Gas Structure, Design, and Safety Systems 8**
   Prajakta Pote, Kapil Zirpe
3. **Medical Compressed Gas Cylinder: Handling and Use 16**
   Vikas Marwah, Deepu K Peter, Robin Choudhary
4. **Cryogenic Liquid Medical Oxygen..... 22**
   Shikha Sahi, Apoorva Tiwari, Jeetendra Sharma
5. **Oxygen Concentrators..... 32**
   Khalid Ismail Khatib, Sameer V Kulkarni, Subhal B Dixit
6. **Oxygen Hazards and Safety..... 35**
   Deven Juneja, Prashant Nasa, Sahil Kataria
7. **Oxygen Audit 40**
   Rahul Pandit

SECTION 2: Physiology and Monitoring of Oxygen Therapy

8. **Physiology of Gas Exchange 47**
   Shilpushp Bhosale, Malini Joshi, Atul P Kulkarni
9. **Goals of Oxygen Therapy 51**
   Vikram Damaraju, Inderpaul Sehgal
10. **Drive to Breathe and Carbon Dioxide Retention..... 55**
    Prashant Nasa, Deven Juneja
11. **Oxygen Transport 59**
    Ujwala Mhatre Ahluwalia, Kapil Borawake
12. **Oxyhemoglobin Dissociation Curve..... 64**
    Srinivas Samavedam, Shabeer Ahmed Khan
13. **Diffusion of Oxygen and its Applied Physiology 69**
    Srinivas Samavedam, Kiran Raghavendra Asrnanna

14. Pulse Oximetry: Understanding and Limitations 73
Kanwalpreet Sodhi, Manender Kumar

15. Venous and Arterial Blood Gas Analysis 80
Rajesh Pande, Maitree Pandey, Jitin Sharma

SECTION 3: Oxygen Delivery Systems for the Individual Patients

16. Oxygen-Delivery Devices 91
Tapas Kumar Sahoo, Santanu Bagchi, Rajesh Chandra

17. Humidification 99
Vikram Damaraju, Inderpaul Sehgal

18. High-Flow Nasal Cannula 103
Harjit Dumra, Mansi Dandnaik

19. Hyperbaric Oxygen Therapy 109
Gunjan Chanchalani, Sunil Amin, Kanwalpreet Sodhi

20. Oxygen Toxicity 115
Shrikant Sahasrabudhe, Beena Daniel

SECTION 4: Oxygen Targets

21. Effects of Hypoxia and Hypoxemia 123
Supradip Ghosh, Sonali Ghosh

22. How does Oxygen Therapy Work? 128
Deepak Govil, Divya Pal

23. Oxygen Therapy and Targets in Disease Specifics 134
Sachin Gupta, Deeksha Singh Tomar

Index 139

3 Medical Compressed Gas Cylinder: Handling and Use

CHAPTER

Vikas Marwah, Deepu K Peter, Robin Choudhary

INTRODUCTION

Medical gas cylinders have been used for the treatment of millions of patients at healthcare centers and at homes. They comprise oxygen, nitrous oxide, carbon dioxide, air, entonox, and helium. These are compressed and stored in cylinders in liquid or gaseous form. These gases are predominantly used in medical procedures, some for inducing anesthesia and others for driving devices like ventilators, cryoprobe, etc. Improper storage, handling, and use of gas cylinders can pose a physical and chemical threat to both staff and patients. Many patients with diseases like chronic obstructive pulmonary disease with respiratory failure were already on domiciliary oxygen. The recent COVID-19 pandemic left many patients fighting for their lives and in those who survived, the residual pulmonary damage led to increased prescription of domiciliary oxygen therapy.

Reckless use of cylinders is associated with high chances of accidents. We must be aware and also impart knowledge regarding the handling of cylinders to our patients. In this chapter, the basics of medical gas cylinders will be dealt with and we will also learn how to store these cylinders safely at hospitals and home.

COMPONENTS OF A CYLINDER

Medical gas cylinders were previously constructed using steel. Each cylinder has three components: body, shoulder, and neck. The upper part of the body, known as the shoulder, is curved and narrows down to the neck. The neck harbors a screw thread which attaches to the valve. Manufacturers have since moved onto use aluminium, chrome molybdenum steel, or composite materials to make cylinders lighter and can hold a larger volume of gas. Cylinders made of aluminium are considerably lightweight and nonmagnetic and these properties make them ideal for magnetic resonance imaging (MRI) suites and onboard helicopter ambulances. Composite cylinders are made up of lightweight steel or aluminium and encased with Kevlar, Twaron, glass fiber, and polypropylene jacket. These cylinders have the added advantage of being highly durable and can withstand pressures up to 4,000 kPa. Newer cylinders come equipped with flow meters to ensure adequate flow.

To the neck of each cylinder is attached a valve through which gas is filled and discharged. A stem or shaft is connected to each valve. Opening the valve will move the stem upward and closing of valve leads to the stem sealing against the valve thereby moving the gas in and out of the cylinder, respectively. Gas exits from the cylinder through its port. Care should be taken to avoid confusion with the conical depression opposite to the valve as any attempt to screw the retaining screw into the port can cause damage. A packed valve or direct-acting valve is commonly seen in

JAYPEE BROTHERS

medical gas cylinders and in this system the seat turns when the stem is turned. They can withstand high pressures and prevents leaks through the sealing of the stem with materials like Teflon. The diaphragm valve however has a metal seal and a disk or diaphragm separates the upper and lower stem. These stems may be permanently sealed to the diaphragm. The diaphragm is effective in preventing leakage from the stem. Only a one-half to three-quarter turn can open this valve and since the seat does not turn there is minimal chance of a leak. These properties make it ideal for low pressures and flammable gases.

A cylinder can be opened or closed using a handwheel or handle. Large cylinders usually have a handle attached to it permanently. Smaller cylinders have valve handles of different sizes and shapes. Some handles contain hexagonal opening which can be used to tighten the packing nut. Untrained personnel may use this hexagonal handle, in an attempt to open the valve, might accidentally loosen the packing nut causing the rapid release of compressed gas with force.

The cylinder pressure for oxygen is around 1,800–2,200 psi, for N_2O is 750 psi, and for CO_2 is around 850 psi (5000 kPa). The critical temperature of the gas is the temperature above which a substance cannot be liquefied no matter how much pressure is applied. The critical temperature for oxygen is 118°C and for N_2O is 36.5°C. Gases exists in the gaseous state at room temperature as it is above its critical temperature and hence liquefaction at room temperature cannot occur.

The filling ratio of the cylinder is the weight of the fluid in the cylinder divided by the weight of water required to fill the cylinder.

The service pressure is the maximum pressure up to which the cylinder can be filled at 70°F and testing pressure is usually 1.66 times the working pressure.

Avagadro's law can be used to calculate the quantity of gas in the cylinder. The law states that 1 g molecular weight of any substance will give rise to 22.4 L of gas. The molecular weight of oxygen is 32 and N_2O is 44. Thus the quantity of gas can be calculated by weighing the cylinder to its TARE weight.

TESTING OF CYLINDERS

There are various methods for testing the quality of cylinders such as the Hydraulic test which is the measure of cylinders elasticity. The cylinder is connected by a thread to testing unit, filled with water and the water level is measured by gauge. The gauge is isolated and cylinder pressurized to 240 atmospheres. The pressure is released and the gauge is opened. The cylinder should stretch <0.02%. In the flattening test the cylinder is kept between two compression blocks and pressure is applied from both sides until the distance between blocks remains six times the thickness of the wall of cylinder. The walls should not crack. The tensile test is done in 1 in 100 cylinders and the yield point should not be <15 tons per square inch. In the impact test three longitudinal and three transverse stripes are taken from a finished cylinder and struck by a mechanical hammer. The mean energy to produce the crack should not be <5 and 10 lb/ft for transverse and longitudinal strips, respectively.

PIN INDEX SAFETY SYSTEM

To facilitate the connection of appropriate gas to its valve there is a specific arrangement of pins on each medical gas cylinder. This system is known as the Pin Index Safety System (PISS) and consists of pins protruding from the gas cylinder tank yoke and will fit into appropriate holes in the cylinder valves. The PISS was introduced in 1917, however, its widespread institution did not happen till after World War II

JAYPEE BROTHERS

wherein a large number of surgeries led to the identification of improvement in the medical gas.

Each cylinder is provided with two pins separated by 12°. The pins are distributed in a semicircular fashion and the first one is located 30° horizontal to the yoke. The pins are designated by numbers depending on their distance in millimeters from the yoke. Over the years there have been numerous changes to improve the quality of PISS. This system should not be considered foolproof and the staff should always be vigilant while monitoring the gas delivery during anesthesia.

IDENTIFICATION OF CYLINDERS

Different compositions of gases and their combination are used for medical purposes. To ensure that the correct gas is administered safely and to prevent any confusion color coding has been prescribed. The color coding followed in our country is being depicted in **Table 1**. The color on each cylinder can vary depending on the paint used and there can be variations in color tone. Also, the color perceived by each user might be different. Hence color alone should not be used for identification and the identity should be confirmed with the label before putting a cylinder to use. Color alone should be identified only for arranging and sorting the cylinders.

Cylinders come in various sizes and each size is designated a letter based on the capacity. The sizes of commonly used cylinders are given in **Table 2**. Size ranges from 1.2 to 6,550 L. Size E cylinders are most commonly used on anesthesia machines.

STORAGE

All medical gas cylinders should be stored in a dry, cool, and clean area which has been designated as "storage area". This area should be away from the operating room and should be adequately ventilated and covered and away from boilers, open flames, steam pipes, and any source of heat and fire. As most gas cylinders are prone to catch fire easily, storage area should be made of fire-resistant

TABLE 1: Color coding used for identification of medical gas cylinders.

Name of gas	*Color*
Air	White and black
Carbon dioxide	Grey
Cyclopropane	Orange
Ethylene	Violet
Helium	Brown
Mixture of oxygen and carbon dioxide	White and grey
Mixture of oxygen and helium	White and brown
Nitrogen	Black
Nitrous oxide	Blue
Oxygen	White

Source: Srivastava U. Anaesthesia gas supply: gas cylinders. Indian J Anaesth. 2013;57(5):500-6.

TABLE 2: Various sizes of oxygen gas cylinders available.

Size	*Capacity (L)*	*Pressure (psi)*	*Tare weight (kg)*	*Valve type*
B	200	1,900	2.27	Pin
D	400	1,900	3.4	Pin
E	660	1,900	5.4	Pin
F	1,360	1,900	14.5	Bull nose
G	3,400	1,900	34.5	Bull nose
H	6,900	2,200	53.2	Bull nose
M	3,450	2,200	29	Bull nose

Source: Srivastava U. Anaesthesia gas supply: gas cylinders. Indian J Anaesth. 2013;57(5):500-6.

JAYPEE BROTHERS

materials and the wrappings on each cylinder should be removed prior to storing.

To prevent tampering with these cylinders, the storage areas should be accessible to only authorized trained personnel. Public access to these areas should not be allowed and smoking should be completely prohibited in premises where cylinders are stored. Cylinders should not be draped with any material as combustible materials can accumulate under the drape and can lead to a fire. Cylinders especially nitrous oxide and oxygen being highly flammable should be stored away from combustible materials. If the storage area is in the open, it should be ensured that the cylinders are not exposed to extreme heat and cold weather and the temperature of the cylinder should not go beyond 125° or below 10°.

They should not be stored in a place wherein they can become part of an electric arc and can get damaged. Care should be taken to not subject the cylinders to mechanical shock and the storage area should have a flat and strong base.

Cylinders should be arranged in such a way that the earlier supplied cylinders should be used first and the proper segregation of full and empty cylinders are done to prevent unwanted delays during an emergency. The personnel in charge should also maintain a complete inventory of the cylinders and the grouping of cylinders is also done as per content, size, and color.

HANDLING AND INSTALLATION

Each gas cylinder should be identified using its color coding and label. In case of a missing or illegible label, the cylinder should be returned to the manufacturer. Only authorized and trained personnel who understand the potential hazards should be allowed to handle cylinders. Even an unserviceable cylinder should be handled by personnel qualified to dispose off the same.

Any damage to a cylinder can pose a safety hazard and the supplier/owner should be informed about the damage. It has to be emphasized that most individuals involved in the transport and storage of cylinders are not aware of safe handling practices. Care should be taken not to drag, roll, slide or drop the cylinder or fall upon one another and that the valve is not used for lifting or moving the cylinder.

Repainting, tampering, alteration or the repair of the cylinder, pressure-relief devices, and valve should be done only by trained individuals. The valve is usually wrapped with a tamper-evident seal which has to be removed before use.

The valve cover cap of bull-nose cylinders should be retained for attachment after use. The valve should be turned off and closed except when being used. Oil, grease, and other lubricants should not be used especially in the valves, regulators, or gauges as they are easily combustible.

Excess force should not be applied while opening valves or attaching connectors. The appropriate cylinder key should be used for opening and the valve should be turned anticlockwise to its full extent followed by a quarter turn clockwise. Hammering of the valve should be avoided. While being used the valve has to be fully opened to prevent faulty delivery of the gas.

Ensure that there are no leaks by listening or by using leak detection fluid. Attempts can be made to remedy the leak by replacing the washer or by screwing the packing nut in a clockwise manner without undue force. If any leak which cannot be corrected by tightening the connections is present, the cylinder should be closed, removed from the manifold, and returned to the supplier with a faulty label attached to it. Any unexpected loss in pressure,

JAYPEE BROTHERS

despite not using the cylinder, should warrant evaluation for a slow leak.

Prior to attaching a cylinder to a machine, the regulator should also be inspected for any damages, and foreign particles. A pressure regulator ensures that the pressure of the released gas is at usable levels and can prevent accidents arising out of gas release at high pressures. Turning the valve slowly allows to prevent the rapid filling of gas in the space between the valve and yoke and thereby allowing more time for heat dissipation. If any particles of dust and grease are present in this space, rapid filling of gas can lead to fire.

After the valve is opened, the pressure has to be checked again and cylinders with very high pressure, much more than anticipated, should be returned to the supplier.

After usage, the valve has to be completely closed and the valve cap placed back. An empty cylinder should be labeled as "EMPTY" and closing the valve will prevent leakage of any leftover gas.

Dangers of Improper Handling and Storage

Despite numerous safety measures like color coding and PISS, safety hazards related to medical gas cylinders are still reported. Excessive and repeated use leads to fading of the color coding and thereby wrong identification. Color coding on a particular cylinder can itself be incorrect. Also there have been instances where a wrong gas was filled or a wrong label was attached on the cylinder. Pins on the cylinder can be broken due to poor maintenance. This can result in attachment of wrong cylinder to a regulator or yoke. Cases have also been reported in which wrong gases were administered during surgeries due to incorrectly filled cylinders.

The valve can be damaged and release its contents if the screw is incorrectly screwed into the safety relief device. Rapid release of contents of a cylinder especially nitrous oxide into a confined oxygen deficient room can result in asphyxia and death.

Cylinder fires and explosions were seen when oxygen equipment was contaminated with oil, grease, paraffin, or dirt. Overfilling of cylinders was also identified as one of the causes of explosion of gas cylinders. Placing a cylinder with a jerk on a hard surface can cause mechanical shock and an explosion. There has been instances where individuals lifted the cylinder while holding the valve which might have led to leakage of gas and placing the same cylinder on the ground with a jerk resulted in an explosion.

Non-MR compatible cylinders have accidentally become projectiles and have caused injuries to individuals and damage to the MRI machine.

If a cylinder falls and the valve breaks the pressurized gas can rapidly escape and the cylinder can become a projectile rocket and spin out of control and lead to damage to people and property.

LIQUID OXYGEN

The COVID pandemic caused widespread loss to human life, and many were left with residual lung disease and had to be placed on domiciliary oxygen. Liquid oxygen is small and compact, and was kept in many households during the pandemic. It is also used while transferring patients and for emergency use by mountaineers. While handling and storing liquid oxygen cylinders all precautions as mentioned earlier should be taken.

Spills from liquid oxygen can happen during accidents while carrying these portable cylinders. The oxygen from the spill should be given time to dissipate and no contact with the skin should be made as any contact with

JAYPEE BROTHERS

the liquid oxygen or the valves with liquid oxygen frosting can cause burns.

As seen with other gas cylinders, these cylinders should also be kept free from combustible materials like oils, grease, and foreign particles. These can lead to fires and any further spill can increase the chance of the spread of the fire. These cylinders should also not be subjected to extremes of temperature and physical damage while handling should be avoided.

CONCLUSION

Medical gas cylinders are used extensively in both hospitals and at homes. They contain gases in liquid or gaseous form and harbor numerous inbuilt safety features. Personnel should be regularly trained about the proper use of gas cylinders and the hazards involved and only trained personnel should be allowed to handle them. Identification of the cylinders through their labels and color coding will prevent operation room accidents. Our knowledge of storage, handling, and use of medical gas cylinders will help prevent accidents related to cylinders, can help deliver proper health care to patients and will help create a safe environment to work.

SUGGESTED READING

1. Colletti PM. Size "H" oxygen cylinder: accidental MR projectile at 1.5 Tesla. J Magn Reson Imaging. 2004;19(1):141-3.
2. Crombie N. Confusing and ambiguous labelling of an oxygen cylinder. Anaesthesia. 2009;64(1):98-98.
3. Gupta S, Jani CB. Oxygen cylinders: "life" or "death"? Afr Health Sci. 2009;9(1):57-60.
4. Hogg CE. Pin-indexing failures. Anesthesiology. 1973;38(1):85-7.
5. Medical gas safety. Read the labels! They're the only sure identifier of gas cylinder contents. Health Devices. 2001;30(3):87-9.
6. Menon MRB, Lett Z. Incorrectly filled cylinders. Anaesthesia. 1991;46(2):155-6.
7. Obeidat A, Andreas T, Bordas SPA, Zilian A. Simulation of gas-dynamic, pressure surges and adiabatic compression phenomena in geometrically complex respirator oxygen valves. Therm Sci Eng Prog. 2021;24.
8. Srivastava U. Anaesthesia gas supply: gas cylinders. Indian J Anaesth. 2013;57(5):500-6.
9. Tracey JA, Kennedy J, Magner J. Explosion of carbon dioxide cylinder. Anaesthesia. 1984;39(9):938-9.

JAYPEE BROTHERS

or detailed information on critical care books, visit our website www.jaypeebrothers.com, for detailed information on critical c

Manual of Oxygen Therapy

Salient Features

- Book will be a one-stop guide for oxygen therapy in a variety of disorders for physicians
- User-friendly and provides information in structured manner
- The text itself is nicely divided into four sections that range from handling medical oxygen as a gas, monitoring the use of oxygen in the context of the physiology of gas exchange, delivery devices, toxicity, and therapy for individualized disease states
- A good source of ready reference for the experienced clinicians, medical students, critical care trainees and paramedics.

Kapil Zirpe MD (Chest) FCCM FICCM
Head
Department of Neuro Critical Care
Ruby Hall Clinic, Grant Medical Foundation
Pune, Maharashtra, India

Subhal B Dixit MD (Med) IDCCM FCCM FICCM FICP
Director
Department of Critical Care
Sanjeevan Hospital
Pune, Maharashtra, India

Atul P Kulkarni MD (Anesthesiology) FISCCM PGDHHM FICCM
Professor and Head
Division of Critical Care Medicine
Department of Anesthesiology, Critical Care and Pain
Tata Memorial Hospital
Homi Bhabha National Institute
Mumbai, Maharashtra, India

Printed in India

Available at all medical bookstores
or buy online at www.jaypeebrothers.com



JAYPEE BROTHERS
Medical Publishers (P) Ltd.
EMCA House, 23/23-B, Ansari Road,
Daryaganj, New Delhi - 110 002, INDIA
www.jaypeebrothers.com

Join us on facebook.com/JaypeeMedicalPublishers

Shelving Recommendation
CRITICAL CARE

