Case Report

Penetrating Missile Injury by Sudden Oxygen Release From Compressed Oxygen Cylinder: A Case Report

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Abstract
This is an interesting case report to show how devastating and fatal could be the pressure effect of oxygen gas. A 25 years man, a lorry driver was loading a large completely filled oxygen cylinder to his lorry along with two other at an oxygen cylinder production factory. He was rolling the cylinder keeping it slant with the pressure valve facing to his abdomen. All off a sudden the pressure valve came off and the compressed oxygen within the cylinder burst out through the outlet and hit his abdomen directly. He flew 20 feet far and died at the spot. An autopsy was conducted which revealed extensive fatal abdominal injury along with fracture of T11, T12 & L1 vertebrae. Death due to oxygen cylinder is a rare but dangerous entity and in this paper we have discussed on various injuries associated with it. We have also highlighted on the various groups of people who could be in danger and safety measures to be taken to prevent them.

Key Words: Compressed Air, Penetrating Missile Injury, Oxygen Cylinder, Pressure Valve

Introduction:
Oxygen is the life gas of all the living organisms on this earth except few anaerobes. The atmosphere is made up of about 21 parts of oxygen and 78 percent of nitrogen, the remainder being other rare gases. Oxygen is commercially manufactured and marketed in two forms i.e. compressed oxygen and Liquid oxygen. It has become a part and parcel in functioning of all hospitals, medical laboratories, research laboratories and many industries. There is hardly any medical field in which oxygen has not found some use.

Oxygen is used both at high atmospheric as well as ordinary pressure to treat many medical conditions like chronic respiratory diseases, anaerobic bacterial infections, cardiac diseases, in anesthetic practices etc.

It has been used by many respiratory and cardiac patients used at their homes as part of their treatment. It also plays an emergency resuscitative role in aircrafts, military bases, trekking camps, etc. Since it has been widely used in our daily life, the dangers connected with the use of oxygen have also increased. [1]

The storage, handling and transportation are a very crucial issue. Most of the medical personnel are generally not sufficiently familiar with safety measures related to the handling of oxygen cylinders.

Any problem associated with the oxygen cylinder is life threatening be it a malfunctioning of pressure valve, explosion of the cylinder or a simple wrong labeling of cylinder. [1-3]

Therefore it is very important to impart knowledge regarding the safety in handling oxygen cylinder, which is the prime aim of this article.

Case Report:
A 25 years man, a lorry driver was loading the large completely filled compressed oxygen cylinder to his lorry along with two others at an oxygen manufacturing factory. He was loading the cylinder manually neither using any hand trolley nor any safety technique. He was rolling the cylinder keeping it slant with the pressure valve of cylinder facing to his abdomen. All off a sudden the pressure valve came off and compressed oxygen within the cylinder burst out through the outlet and hit his abdomen region directly.

He was thrown about 20 feet away by the pressure of compressed oxygen gas and he died on the spot. There was no fire during this explosion. The oxygen cylinder was intact except for the pressure valve which was detached and lying separately.
This incidence took place at an oxygen manufacturing factory. The place where this happened was an oxygen cylinder storing unit of the factory having concrete wall on three sides and on the remaining side there was shutter door. The room contained many fully filled oxygen cylinders. The oxygen cylinder which gave up was 4.5 ft in length made up of steel. The wall of this cylinder was intact; the pressure valve was detached from it and was lying at a distance of 4 ft from this cylinder. (Fig. 1)

The dead body was lying between two cylinders at a distance of 20ft from the cylinder which gave up. The dead body was in completely flexed position at its abdomen region (Fig. 2) with a large laceration wound back of abdomen and loops of intestine visible through this laceration. Blood stains were present all around the body. (Fig. 3)

**Autopsy Findings:**

Postmortem was conducted in the Department of Forensic Medicine at AIIMS, New Delhi on the request of the police.

**External Examination:**

He was wearing a grey colored pant and white colored full arm shirt, both were blood stained. Lower three button of the shirt were broken. Deceased was moderately built and moderately nourished, 5 feet 4 inches with 62 Kg weight. The rigor mortis was well developed in all the four limbs and postmortem lividity seen on the back side and dependent parts of the body. Both the eyes were partially open. Blood was present at the angle of mouth.

There was a lacerated wound of size 10x8cm on left side of abdomen extending to left flank, triangular in shape, with underlying soft tissues and coils of intestine visible externally through it; surrounded by contusions and contused-abrasions. (Fig. 3) An elliptical shaped laceration was present on left lower abdomen over left iliac crest region of pelvic bone.

On the middle region of back of the abdomen there was a laceration of size 11x10 cm, oval in shape, with coils of intestine along with left kidney protruding through it. There was twisting of left arm at its lower region with compound fracture of humerus, with sharp fractured end protruding out through a laceration of size 3.5x2.5 cm over lateral aspect of lower part of left arm. There was open compound fracture of lower 1/3rd of tibia on both right and left side of legs. Contusions of size 2x3 cm and 2x2 cm were present on left side of forehead.

**Internal Examination:**

There was fracture of ribs on both side involving 3rd to 5th on right side and 3rd to 7th on left side of chest. There were sub pleural hemorrhagic patches on both the lungs. Abdomen cavity showed blood clots of 500cc. Multiple contusions and lacerations were present on the wall of large and small intestine.

Laceration of size 3x4x2 cm was present on the anterior surface of left kidney and it was protruding through the laceration on the back of abdomen. Spleen was completely transected at its hilar region and it was lying free in the abdominal cavity. Contusion of size 4x5 cm was present on anterior surface of left and adjacent right lobe of liver.

Abdominal aorta, inferior vena-cava and adjacent large vessels were lacerated. Fracture dislocation of T11, T12 and L1 vertebrae at inter vertebral joints were present. The abdominal injury and injury on the back of abdomen was through and through. Compound fracture of lower 1/3rd of both tibia and lower end of left humerus was present. Sub-scalp hematoma in an area of 4x3 cm was present on left side of fronto-parietal region of skull.

The cause of death was ascertained as “shock and hemorrhage due to above mentioned injuries caused by blunt external force which could be possible in explosion of oxygen cylinder.”

**Discussion:**

The cylinder involved in the above mentioned case contained compressed oxygen. The compressed oxygen cylinder has a pressure of 1880-2200 psi [4] or 140-151Atm 1 or 200 bars. The two main reasons for explosion of an oxygen cylinder are weakening of the cylinder from chance defects or by corrosion and failure to observe some of the rules for the safe handling of cylinders. [1] The other factors which increase the risk of oxygen cylinder accidents are heat and vibration. [2, 4]

In the above mentioned case, corrosion at the outlet of cylinder was present which in turn rendered the pressure valve viable for detachment. Also since no trolley was used to shift the cylinder causing the cylinder to undergo lot of manhandling which in turn resulted in detachment of already weakened pressure valve due to corrosion of outlet.

In the present case the deceased was rolling the cylinder towards his lorry by keeping it in a slant position; pressure valve of cylinder directing towards his anterior abdomen wall. The valve gave up and the valve along with the high pressure of compressed oxygen struck his abdomen like missile. The deceased was thrown away from the cylinder against the other cylinders which were kept in the same room.
He died on the spot and blood was spattered all around the body. On postmortem examination we found lacerations, contusions, abrasions and also fracture of bones. There were no burns anywhere on the body which excluded the chances of fire at the time of explosion. There was one large laceration on left side of anterior abdominal wall which was cavity deep and another large laceration on back of the abdomen. These two injuries where through and through penetrating injuries, but caused by a blunt external force. The high pressure (1800-2200 psi) of compressed gas could have acted as a high intensity missile causing this perforation of abdomen, lacerating the intra abdominal structures. The pressure waves and the vibrations generated during this explosion might have caused the high impact injuries such as fractures and thoracic injuries.

The pattern of injuries on the victims of explosion of cylinders varies widely depending upon the nature of explosion. [5] They could be any sort of injuries like abrasions, contusions, lacerations, incisions, and crush or could be burns and fractures. Also pattern of distribution and management of injuries varies widely with the nature of the explosive material. [1]

Several different factors cause injury following an explosion, and the relative importance of each varies considerably with the type of detonation. For example, pure blast effects are far more important than with the home-made terrorist bombs, the lethality of which may be primarily caused by flying fragments. [6]

The causes of injuries in blasts can be categorized as-[7-8]
1. Primary blast injuries caused by a) force of explosion gases, b) wave of pressure called shock wave c) fire during blast resulting in burns
2. Secondary blast injuries caused by flying debris striking the victims
3. Tertiary blast injuries caused by victim impacted against the stationary objects or fall of stationary objects e.g., fall of wall; victim may also die of poisonous gases and fumes during an explosion. [2, 8]

During the gas cylinder explosions, people involved can be thrown off their feet and injured, and this could be the cause of death in this cases. [7]

**Common Properties of Oxygen: [9]**

- It is a colorless, odourless and tasteless gas hence any leakage cannot be appreciated manually.
- It is slightly heavier than air.
- It is non-flammable but supports combustion with other elements.
- Oxidation, an important property specific to oxygen causes rusting of ferrous metals, discoloration of copper and corrosion of aluminum. This property can lead to weakening of the storage cylinders which in turns may result in leakage and explosion.

Oxygen is obtained commercially either by the liquid-air process or by the electrolyte process. [9] Oxygen is commercially marketed in the form of compressed oxygen or liquid oxygen. Persons involved in manufacturing of Oxygen and also those who are involved in its transportation should be aware of the dangers associated with and the safety measures to be employed during those processes. Hospital personnel must be familiar with the potential problems arising from medical compressed gases in order to recognize and reject unsafe cylinders. [2]

**Common Causes of Oxygen Cylinder Accidents:**

Risks associated with oxygen cylinder vary widely and the causes for these risks also vary accordingly. [2] Since accidents associated with the oxygen cylinder irrespective of minor or major, could risk the life of either the patient, doctor or other personnel who are involved in handling the cylinder. It is important that the problems and their causes in handling of oxygen cylinders are properly understood in the domestic and commercial situations. Some of the common causes of accidents are:

- Contamination of oxygen cylinders with substances like carbon dioxide, nitrogen and hydrocarbons [2] which may lead to poisoning in patients; and could lead to explosion when contaminated with fuel gases. [1]
- Overfilling of the cylinders with high pressure exceeding the tolerance capacity of cylinder could result in explosion. [10]
- Malfunctioning of pressure valve and gas regulators may lead to non-delivering of oxygen to patients, leakage, and also explosion. [10]
- Abrupt starting and stopping of oxygen flow can produce frictional heat that may ignite any contaminant that might be in the system. [10]
- Wrong identification of cylinder due to incorrect labeling, painting over the labels, wrong color coding of cylinder. [2]
- Though oxygen is a nonflammable gas, it can ignite when it comes in contact with
ignition sources like electric cautery, defibrillators, cigarette lighters, match stick or any spark or heat producing appliances. [10]

- Some organic materials such as grease, oils and petroleum products can react violently with oxygen if ignited by a hot spark. [11]

- In MRI investigation rooms, ferromagnetic oxygen cylinders may turn into missile when they are drawn into magnet. [12]

- A cylinder can also turn into a missile when there is a damage in the cylinder wall or when the pressure valve give up all of a sudden; sudden escaping of high pressure gas will propel the cylinder with a great force which could be life threatening. [2]

- Corrosion and rusting of cylinder wall due the oxidizing property of oxygen may lead to leakage resulting in fire or explosion of cylinder. [11]

- Shifting of cylinders without trolley could be dangerous since it can lead to manhandling of cylinders, dragging, rolling and sliding the cylinders. [10]

- Improper storage of cylinder e.g. ill ventilated areas, exposing the cylinder to excessive heat and friction, not placing the cylinder in upright position, storing near other flammable products, frequent falling and knocking over of cylinders. [2,10]

- Improper transportation techniques like improper padding of cylinders, not using specially designed trucks for cylinder carrying, over speeding, over loading and also failing to use safety measures like fire extinguishers in the vehicle.

- Refilling of gas cylinders at noncertified centers and by untrained non qualified personnel. Unsafe modifications to cylinder design. In some cases, the materials may appear to be compatible but the shape and configuration of components may be important in minimizing the fire risk. Only components approved by the manufacturer should be used when maintaining oxygen equipment. [10]

- Lack of regular maintenance of cylinders by not getting them tested and certified by concerned authorities.

**Precautions for Safe Handling and Use: [13, 14]**

It is essential to follow several safety guidelines to prevent the accidents related to oxygen cylinder. The users, such as hospital professionals, home care patients, laboratory personnel; and also persons who are involved in refilling of gas, shifting and transportation must be familiar with the correct use and potential risks associated with oxygen gas.

General safety measures and precautions that are to be followed during the usage of oxygen cylinder by home care patients and hospital personnel are as follows

- Never smoke nor allow visitors to smoke near you while using oxygen. Post a 'No Smoking' sign in a prominent place at the entrance of the room.

- Stay at least 5 feet away from gas stoves, candles and other heat sources while using oxygen.

- Secure oxygen cylinders to a fixed object or place in a stand. Cylinders must remain upright at all time.

- Never use the oxygen at fuel stations.

- Always operate cylinder valve slowly; and turn off the valve when not using the oxygen.

- Do not use any flammable products like aerosol sprays, paint thinner and cleaning fluids while using the cylinder.

- Use water-based lubricants on your lips and hands; and don’t use an oil based product like petroleum jelly, creams and lotions.

- Use bedding and cloths made of cotton material which will avoid sparks from static electricity which are seen with wool, nylon and other synthetic fabrics.

- Do not allow children or untrained individual to handle the cylinder.

- Never use the cylinder beyond expiry dates.

- Ensure that you have an all purpose fire extinguisher close by and have your gas supplier’s number handy.

- Never discard pressurized cylinders in the normal trash.

- Pressure regulators constitute a critical interface in the area of safety in the use of compressed gas pressure valve is the most vulnerable portion of the cylinder. [15] The design manufacture, operation and maintenance of these pressure regulators must be handled by suitably qualified persons with expertise and knowledge in the area concerned.

- The use of copper alloys and bronze for the body of oxygen regulators during manufacture is strongly recommended and...
the use of aluminum and plastic should be minimized. [16, 17]

- Do not use flammable organic materials such as oils, greases, cream, etc.
- Do not operate the pressure valve/regulator with dirty and greasy hands; this may lead to unregulated sudden release of gas.
- Regularly check the integrity of the pressure valve/ regulator connection, e.g.:- position of gaskets, condition of mating surface etc.
- While opening the cylinder valve, position yourself behind the valve, opposite the pressure regulator.
- Open the cylinder valve gradually and in case of adjustable regulators, ensure that the regulator screw is in “zero” position before opening the cylinder.
- In the event of impact or leak the user should not attempt to make unauthorized repairs or adjustments of regulators, remove the equipment from the service and have it repaired by an authorized person.
- Ensure that maintenance is carried out at the periods specified by manufacturer.
- The storage area should be in a cool, clean area that is constructed of fire-resistant materials. Conductive flooring must be present where flammable gases are stored but is not required where only nonflammable gases are kept.
- Adequate ventilation should be provided so that if there is a leak in a cylinder, gas will not accumulate in the room.

Easily visible signs with texts such as “GAS CYLINDERS, REMOVE TO A SAFE PLACE IN THE EVENT OF FIRE”, “NO SMOKING,” “NO OPEN FLAMES OR SPARKS,” “NO OIL OR GREASE,” and “NO COMBUSTIBLE MATERIALS” should be posted inside the room and on the door.

Knowledge regarding proper storage of the oxygen cylinder is very essential to prevent accidents. [15, 17] Cylinders should be stored in well ventilated areas. The temperature of cylinder storage area must not exceed 125°F. Direct sunlight exposure must be avoided; and precautions should be taken to not to expose the cylinders to extreme climate conditions. Cylinder should be protected from the ground to prevent bottom corrosion.

Full and empty cylinders should be stored away from other flammable products. Keep cylinders away from electrical circuits. Oxygen cylinders (empty or full) in storage should be separated from fuel-gas cylinders and combustible materials by a minimum distance of 20 feet or by a barrier at least 5 feet high having a fire-resistance rating of at least one-half hour.

Cylinders must always be kept in upright position, use stands and hand trolley should be used for their movements. Cylinders should be properly secured by using storage racks, carries and by chaining them to a fixed object to prevent them by falling and tipping.

The personnel involved in transportation, shifting, manufacturing cylinders and refilling of oxygen gas should made aware of proper techniques and safety measures.

- Personnel involved in refilling and shifting of the cylinders must use safety goggles, insulated gloves, safety shoes and protective jackets.
- Avoid dropping, knocking over, rolling and dragging of cylinders and also striking the cylinders against each other. Never carry a cylinder by the valve.
- Cylinders should be lifted by crane using the pallet.
- While loading the cylinders to the truck use trolley and Fork Lift Trucks.
- Drivers should be trained in the potential hazards and dangers, safe handling, emergency procedures and the use of fire fighting appliances.
- There should be no passengers other than driver and helper in the vehicle.
- Vehicle must be turned off while refueling and also it should be made sure that no other vehicle is present in the vicinity.
- It is imperative that all cylinders must be secured and stabilized while transportation.
- Fire extinguisher should be present.

**Gas Cylinder Disposal: [18]**

The following information applies to the disposal of compressed gas cylinders:

1. If possible, purchase compressed gas only from manufacturers that will agree to take back the empty cylinder.
2. A cylinder is considered empty when the container pressure is at atmospheric pressure.
3. Refillable cylinders should be returned to Chemistry Stores, materials handling personnel or directly to the vendor.
4. Maintain manufacturer labels and label the cylinder with an “Empty” or “MT” tag.

**Conclusion:**

Oxygen is used for various purposes in the hospitals, laboratories and industries. This case report highlights the hazardous effects of mishandling of oxygen cylinder leading to fatal blast. The high pressure effect can cause missile like injuries in the victim. The forensic
The pathologist should be aware of the pattern of injuries possible in blast injuries. It is important for the people using and handling oxygen cylinders to know the ill effects and precautions to be taken while handling the cylinder.

References: