Indian Internet Journal of Forensic Medicine & Toxicology
ISSN 0973-1970, Vol.7, No.2 (2009)

Oxygen Cylinder Blast Fatality: A Case Report and Review of Literature

S.K. Verma Professor, Dept. of Forensic Medicine University College of Medical Sciences & G.T.B. Hospital (University of Delhi) Dilshad Garden, Delhi-110095

Abstract

Fatalities related to blast are usually caused by ignition of inflammable substance(s), that may be solid, liquid or in gaseous form. A sub category of these deaths may include death by explosive devices.

Oxygen is the third most abundant element in the universe by mass after hydrogen and helium and the most abundant element by mass in the Earth's crust. Highly concentrated sources of oxygen promote rapid combustion. Fire and explosion hazards exist when concentrated oxidants and fuels are brought into close proximity; however, an ignition event, such as heat or a spark, is needed to trigger combustion.

Few cases of injury due to oxygen cylinder blast have been reported in the media reports and scientific literature. However detailed post-mortem findings and preventive strategies have not been discussed frequently. The paper is intended to focus on this aspect of such fatal eventualities.

Case report

A 26 years young adult male was working as labor to load and unload gas cylinders from the manufacturing unit to the store. He was unloading the oxygen filled cylinders from a vehicle (tempo) containing these cylinders in the afternoon of March (Fig.1). During unloading the cylinders, when he had already unloaded 3 cylinders and was unloading the 4th, the cylinder exploded and thrown the deceased about 30 feet's from the site of incident and killing the deceased instantaneously on the spot.

A medico-legal post-mortem examination was conducted next day following the incident by the author that revealed a well built male with few remnants of torn vest and underwear present over thoracic and perinial region. Bleeding from right ear was seen and rigor mortis was present all over the body with no signs of decomposition. The following ante-mortem injuries were found on external examination:

1. Both hands missing from lower one-third of both forearms, exposing the irregularly fractured radius and ulna with lacerated soft tissues.
2. Reddish laceration of size 20X9X5 cms over upper neck region parallel to the chin going deep into the pharyngeal wall.
3. Reddish laceration on the left side lower neck area of size 10X2X3 cms along with underneath fracture of thyroid cartilage.
4. Reddish contused lacerated wound of size 9X6.5X5 cms going deep into the abdominal cavity and lower right side chest.

For Correspondence :
Dr. S.K.Verma, Professor
Dept. of Forensic Medicine, University College of Medical Sciences, Delhi-110095.

Fig.1: The Vehicle (Tempo) with oxygen filled cylinders

5. Reddish contused laceration of size 12X3X4 cms over right axillary region.
6. Masonry injuries over medial aspect of left leg in an area of 17X6 cms.
7. Numerous small contusions and abrasions present over almost whole of the body.

On internal examination, following injuries were observed

1. Fracture of pubic symphysis.
2. Fracture of ribs bilaterally in anterior axillary line from 1-10th.
3. Fracture of sternum in the middle.
4. Fracture of the facial bones and jaw.
5. Tear of the pericardium with stomach herniating into it.
6. Multiple lacerations over liver and spleen.
7. laceration over anterior surface of right lung lower lobe of size 5X3x2 cms and on left lung of size 4x1.5X1 cms.

Few metallic pieces recovered from the chest cavity on dissection (Fig.2). Other examination was unremarkable with no features suggesting any toxicity. Considering the above post-mortem findings the cause of death in this case was attributed as shock due to multiple ante-mortem injuries produced by blunt force possible in a blast.

Discussion

Oxygen is the element with atomic number 8 and represented by the symbol O. At standard temperature and pressure two atoms of the element bind to form dioxygen, a colorless, odorless, tasteless diatomic gas with the formula O_2. Oxygen is the third most abundant element in the universe by mass after hydrogen and helium and the most abundant element by mass in the Earth's crust.

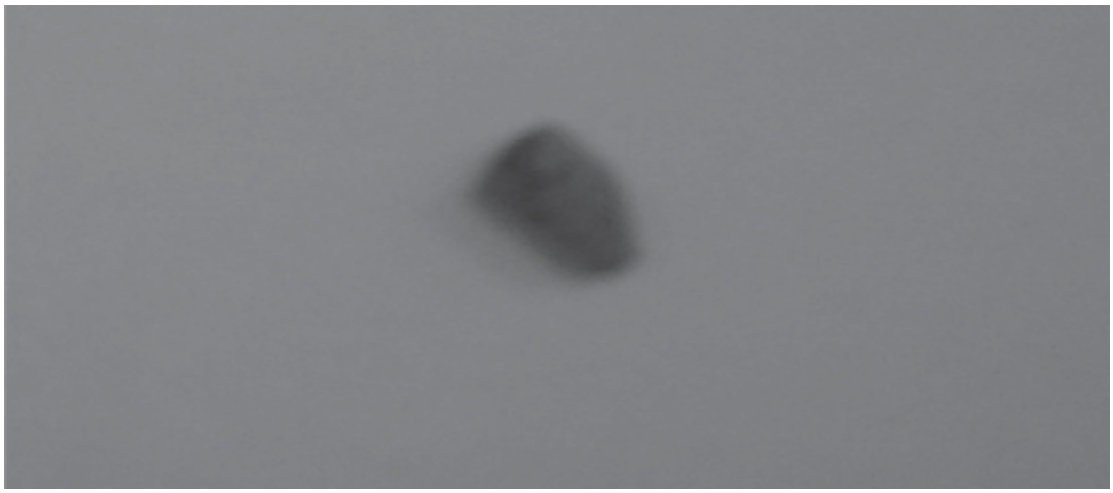

Fig.2: The piece of metal recovered from body

Diatomic oxygen gas constitutes 20.9% of the volume of air (1).
All major classes of structural molecules in living organisms, such as proteins, carbohydrates, and fats, contain oxygen, as do the major inorganic compounds that comprise animal shells, teeth, and bone. Oxygen in the form of O_2 is produced from water by cyanobacteria, algae and plants during photosynthesis and is used in cellular respiration for all complex life. Oxygen is toxic to obligatory anaerobic organisms, which were the dominant form of early life on Earth until O_2 began to accumulate in the atmosphere 2.5 billion years ago. Uses of oxygen include the production of steel, plastics and textiles; rocket propellant; oxygen therapy; and life support in aircraft, submarines, spaceflight and diving(2).
Highly concentrated sources of oxygen promote rapid combustion. Fire and explosion hazards exist when concentrated oxidants and fuels are brought into close proximity; however, an ignition event, such as heat or a spark, is needed to trigger combustion. Oxygen itself is not the fuel, but the oxidant. Combustion hazards also apply to compounds of oxygen with a high oxidative potential, such as peroxides, chlorates, nitrates, perchlorates, and dichromates because they can donate oxygen to a fire (3).
Pure O_2 at higher than normal pressure and a spark can led to a fire. Concentrated O_2 will allow combustion to proceed rapidly and energetically. Steel pipes and storage vessels used to store and transmit both gaseous and liquid oxygen will act as a fuel; and therefore the design and manufacture of O_2 systems requires special training to ensure that ignition sources are minimized. The fire that killed the Apollo 1 crew on a test launch pad spread so rapidly because the capsule was pressurized with pure O_2 but at slightly more than atmospheric pressure, instead of the ? normal pressure that would be used in a mission (4).
Oxygen gas is colorless, odorless, non-toxic cryogenic liquid or colorless, odorless, oxidizing gas. Liquid releases will quickly vaporize to gas. The chief physical hazard associated with releases of the gas is its oxidizing power which can greatly accelerate the burning rate for both common and exotic combustible materials. Emergency personnel must practice extreme caution when approaching oxygen releases because of the potential for intense fire. The primary health hazard at atmospheric pressure is respiratory system irritation after exposure to high oxygen concentrations. Maintain oxygen levels in air above 19.5% and below 23.5%.While up to 50% oxygen can be breathed for more than 24 hours without adverse effects, high concentrations in open air accelerate combustion and increase the risk of fire and explosion of combustible or flammable materials. Route of entry:

Inhalation, skin and eye contact. Effects of acute exposure Eye contact: No adverse effects expected. Skin contact: No adverse effects expected. Ref (4)
Liquid oxygen spills, if allowed to soak into organic matter, such as wood, petrochemicals, and asphalt can cause these materials to detonate unpredictably on subsequent mechanical impact. As with other cryogenic liquids, on contact with the human body it can cause burns to the skin and the eyes.
A **gas cylinder** or tank is a pressure vessel used to store gases at high pressure. Gases stored this way are called bottled gases.

Few cases of injury due to oxygen cylinder blast have been reported in the media reports and scientific literature (5-10).

A man and his son were killed in an oxygen cylinder blast at Malsiaha under Shahkot police station in the Janandhar district of Punjab in May 2008.

Both of them used to run a gas welding shop, were killed in the explosion that took place when they were shifting oxygen from a cylinder to a self-made cylinder in order to avoid rent of the original oxygen cylinder. The explosion was so intense that the bodies were reduced to pieces.

In another incident five people were killed and four injured when an oxygen cylinder exploded in a factory in southern Pakistan. The accident took place in a factory in Hyderabad in Pakistan's southern Sindh province, when the oxygen cylinders were being loaded on a truck during which one of the cylinders burst in July 2007.

In Nov.2008, one person was killed and three others injured in a blast at an oxygen cylinder refilling company. The blast was so severe that the roof of the company shed was blown off and the glass from window panes of the neighboring company was shattered.
The transportation of high pressure cylinders is regulated by many governments throughout the world. Various levels of testing are generally required by the governing authority for the country in which it is to be transported. In the United States, this authority is the United States Department of Transportation (DOT) (11). For Canada, this authority is Transport Canada (TC) (12). In India, there are rules called as Gas Cylinders Rules, 2004 published in the gazette of India on 21st September, 2004 that specifies rules related to and concerned with filling, possession, import and transport of cylinders (13). The relevant provisions of the Gas Cylinder Rules in relation to the transport of gas cylinders are reproduced below:

The Gazette of India
EXTRAORDINARY
PART II-Section 3-Sub-section (i)
NEW DELHI, TUESDAY, 21ST SEPTEMBER, 2004
Ministry of Commerce and Industry
(Department of Industrial Policy and Promotion)

NOTIFICATION

New Delhi, the 21st September 2004

G.S.R. 627(E) - Whereas a draft of the Gas Cylinders Rules, 2003 was published as required by section 18 of the Explosives Act, 1884 (4 of 1884) in the Gazette of India, Extraordinary, Part II, Section 3, sub-section (i), dated the 20th October 2003, vide notification of the Government of India in the Ministry of Commerce and Industry, (Department of Industrial Policy and Promotion) number G.S.R. 822(E), dated the 20th October 2003, inviting objections and suggestions from all persons

likely to be affected thereby, before the expiry of a period of forty five days from the date of publication of the said notification in the Official Gazette;
And whereas, the said Gazette was made available to the public on the 20th October, 2003;
And, whereas objections and suggestions received from the public on the said draft Rules have been duly considered by the Central Government;
Now, therefore, in exercise of the powers conferred by sections 5 and 7 of the Explosives Act, 1884 (4 of 1884) and in supersession of the Gas Cylinders Rules, 1981, the Central Government hereby makes the following rules, namely: -

"WARNING"

Gas Cylinders, Rules, 2004

(i) Do not change the colour of this cylinder.
(ii) This cylinder should not be filled with any gas other than the one it now contains.
(iii) No flammable material should be stored in the close vicinity of this cylinder or in the same room in which it is kept.
(iv) No oil or similar lubricant should be used on the valves or other fittings of this cylinder.
(v) Please look for the next date of test, which is marked on a metal ring inserted between the valve and the neck of the cylinder, and if this date is over, do not accept the cylinder for filling.

20. Loading, unloading and transport of cylinders: - Cylinders filled with any compressed gas shall be transported duly complying with the provisions laid down in Schedule VI and also observing the relevant provisions of other statutes as applicable.
It has been observed that majority of the accidents pertaining to oxygen gas cylinders have happened during transportation. The Section 20 of the Gas Cylinders, Rules, 2004 deals with Loading, unloading and transport of cylinders**: -** Cylinders filled with any compressed gas shall be transported duly complying with the provisions laid down in Schedule VI and also observing the relevant provisions of other statutes as applicable and reproduced below:

SCHEDULE VI

TRANSPORT OF CYLINDERS

(1) Transport of cylinders by vehicles: —

(a) Cylinders filled with any compressed gas shall not be transported by a bicycle or any other two wheeled mechanically propelled vehicle.

(b) Cylinders shall be so transported as not to project in the horizontal plane beyond the sides or ends of the vehicle by which they are transported.

(c) There shall be no sharp projections on the inside of the vehicle.

(d) Cylinders shall be adequately secured to prevent their falling off the vehicle and being subjected to rough handling, excessive shocks or local stresses.

(e) Cylinders transported in vehicles shall be blocked or braced and be so secured to prevent movement, striking each other or falling down.
(f) Cylinders filled with any compressed gas shall not be transported along with any other article of a highly flammable or corrosive nature.

2. Restriction on transport: —

(a) Cylinders containing flammable gases shall not be transported along with the cylinders containing any other type of compressed gas:

(b) Cylinders containing toxic or corrosive gas shall not be transported along with food- stuffs. Notwithstanding anything contained in clause (a) above, DA cylinders not exceeding 25 in numbers may be transported along with non-toxic non-flammable gases taking due precautions.

3. Loading and unloading for transport: —

(a) No lifting magnet shall be used in loading or unloading of cylinders filled with any compressed gas.

(b) Where any such operation is carried on by means of a crane or a fork-lift truck, a proper cradle with chains or wire rope slings shall be used.

4. Protection of valves during transport: —

(a) Every cylinder containing compressed gas shall, when transported, have its valve protected against damage in the manner provided in sub-rules (b) and (c) unless it is securely packed in a box or crate.

(b) Where the design of the cylinder does not provide for the valve lying wholly below the level of the body of the cylinder, a stout metal cap, metal cover or a protective metal ring or grill of a design approved by the Chief Controller shall be provided, the design being such that the cap or cover or ring or grill is nowhere in close proximity to any part of the valve or valve body.

(c) Where metal caps or metal covers are provided, to protect valves fitted to cylinder other than those containing highly toxic gases like Hydrogen cyanide, Phosgene, Cyanogen, Cyanogen chloride, it shall be provided with a vent of such size so as to prevent any gas pressure inside the cap or covers.

(d) Cylinders containing highly toxic gases like Hydrogen cyanide, Phosgene, Cyanogen, Cyanogen chloride gases, shall have their valves protected with gas-tight metal caps or covers.

(e) Nothing in sub-rules (a), (b) and (c) shall apply to cylinders containing oxygen or nitrous oxide for medical purpose having water capacity not exceeding 5 litres.

5. Leaky cylinders: —

(a) No person shall tender or transport any leaky cylinder.

(b) Any cylinder containing a flammable or toxic gas, which develops a leak during transport shall promptly be removed to an isolated open place away from any source of ignition and the person responsible for transportation shall immediately contact the filler or the consignor as the case may be, for necessary advice. It has been observed that such accidents involving gas cylinders are usually results from non-adherence

to the guidelines/ rules and regulations issued by governments as evident in the present case also described by Rani (14). It is high time that awareness program for strict adherence to the gas cylinder rules be done frequently to all stakeholders and more so for the workforce involved in day to day transport of the cylinders. Making the rules is the first steps, but there implementation and following is different and that is what commonly found lacking in our country. Penalties should be imposed for not violating the legal provisions so that the incident like the one described are minimized.

REFERENCES

1. http://periodic.lanl.gov/elements/8.html. Retrieved on Dec 16, 2009.
2. Cook & Lauer 1968, p.500
3. Werley 1991
4. Report of Apollo 204 Review Board NASA Historical Reference Collection, NASA History Office, NASA HQ, Washington, DC
5. www.webindia123.com retrieved on June 6, 2009.
6. www.nolgroup.com/GASOXYGEN_MSDS.pdf
7. The Hindu, August14, 2000
8. The Times of India August 2, 2003
9. Chandulal R. Accidental death due to explosion of gas cylinder. Med Sci Law 1974; 14: 51-52.
10. Mishra D. Oxygen gas cylinder explosion. J Ind Med Assoc 1995; 93; 114-5.
11. www.phmsa.dot.gov/hazmat/regs/sp-a/approvals/cylinders. Assessed on July 7, 2009.
12. www.bookrags.com/wiki/**Gas**_cylinder. Assessed July 7, 2009
13. http://peso.gov.in/Gas_cyl_Rules.aspx. Assessed July 7, 2009.
14. Rani M, Gupta A, Dikshit PC, Aggarwal A, Setia P, Dhanker V. Accidental death resulting from Acetylene Cylinder Impact. Am J Forensic Med Pathol 2005; 26: 170-173.