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Special Article

Fires in Indian hospitals: root cause analysis and recommendations for their prevention☆,☆☆

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Abstract There is an increase in the incidence of intraoperative fire in Indian hospitals. It is hypothesized that oxygen (O_2) enrichment of air, is primarily responsible for most of the fires, particularly in intensive care units. As the amount of ignition energy needed to initiate fire reduces in the presence of higher O_2 concentration, any heat or spark, may be the source of ignition when the air is O_2-rich. The split air conditioner is the source of many such fires in the ICU, neonatal intensive care unit (NICU), and operating room (OR), though several other types of equipment used in hospitals have similar vulnerability. Indian hospitals need to make several changes in the arrangement of equipment and practice of handling O_2 gas, as well as create awareness among hospital staff, doctors, and administrators. Recommendations for changes in system practice, which are in conformity with the National Fire Protection Association USA, are likely to be applicable in preventing fires at hospitals in all developing countries of the world with warm climates.

1. Introduction

Loss of human life and property by fire is always distressing. Hospital fire happens with alarming frequency and potentially devastating consequences in hospitals around the world. Fire may be initiated in a hospital for the most ordinary reasons, such as electrical short circuit, heating due to electrical overload, cooking oil or gas in the kitchen, stored inflammable liquid, arson, or smoking in bed.

Most hospital fires generally originate from three distinct sources: 1) inflammable liquids, such as alcohol-containing solutions (eg, certain prepping solutions) and other volatile chemicals, such as ether or acetone used in the operating room (OR), which become even more fire-prone in the presence of oxygen (O_2) and nitrous oxide (N_2O); 2) a small spark or heat that originates in equipment operating near the zone of application of O_2 to patients; and 3) in components of O_2 gas lines, liquid O_2 tanks, and cylinders that carry pure O_2 (near 100%). Metals become readily involved in such fires.

As shown in Fig. 1, three elements complete a fire triangle: 1) fuel, 2) oxidizer, and 3) ignition sources. If one of these elements is missing, it is impossible to initiate fire [1,2]. Increasing the intensity of even one of the arms of this triangle increases the probability of fire. The presence of all three arms of the fire triangle is a necessary but not sufficient condition to initiate fire. With the oxidizer, as O_2 concentration, pressure, velocity, and temperature increase, the situation becomes more vulnerable to initiation of fire [3].

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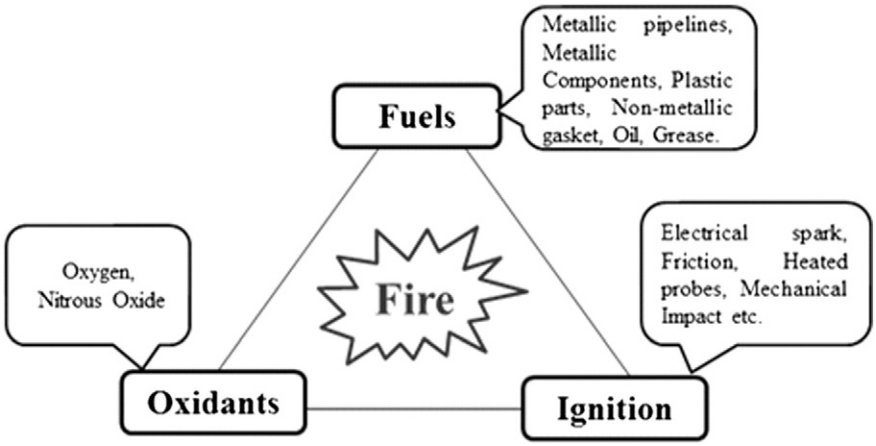

Fig. 1 Diagram of the three arms of the fire triangle: 1) fuel, 2) oxidizer, and 3) ignition sources.

As an effective ignition mechanism, a spark needs to possess the required energy density or the heat generated should be sufficient to reach the ignition temperature of the solid, liquid, or gaseous fuel in the given environment, material, and configuration. As for fuel, the flammability of materials subjected to sparks, or the configuration (for solid) or dispersion (for gas) at the spot of application of energy should be such that the heat gained is higher than the heat lost and the temperature increases to exceed ignition temperature needed for the prevailing environment. Though accentuation of any of these three arms of fire triangle increases the chance of fire, it is never guaranteed. An accident is a probabilistic phenomenon that demands that many variables occur simultaneously. Suppression of the intensity of the arms of the fire triangle reduces the risk of fire.

2. Literature survey and objective

A hospital generally handles solid materials such as oxygen masks, nasal cannulae, endotracheal tubes (ETTs) made of polyvinyl chloride (PVC) or silicone, dressings, ointments, gowns, beds, blankets, suction catheters, flexible endoscopes, fiberoptic cable coverings, gloves, packaging materials, all of which are prone to fire [4]. However, the hospital uses many chemicals in the OR and pathology laboratory that are highly flammable in nature. Even gastrointestinal tract gases, rich in methane, are sometimes highly prone to fire. These chemicals render the "fuel" arm unusually strong. Second, O_2 gas is made available in cylinders or pipelines with near 100% purity and is used in the intensive care unit (ICU), neonatal intensive care unit (NICU), and OR routinely. During administration to patients, a substantial amount of O_2 gas may leak out, increasing the O_2 percentage in the surrounding air. This situation strengthens the "oxidizer" arm, increasing the chance of fire. The "ignition" arm is also present in different forms at all locations within the hospital. For example, electrosurgical or electrocautery devices, lasers, heated probes, and defibrillator pads serve as ignition sources in the OR. As all three arms of the fire triangle are present in the OR environment, it is a challenge to avoid fire at any time in the OR. In the United States alone, approximately 100 surgical fires are reported annually. Of this number, 20 cause severe injury, leading to one to two deaths each year [5].

Apart from the fires involving OR beds, reports in the media over the last several years have named cigarette, kitchen, storage room, incubator, air conditioner, space heater, ventilator, defibrillator, voltage stabilizer, electrical room, switchboard, electrical box, transformer, motor air handling unit, X-ray machines, ultrasound machines, and others as the sources of fire. Regulators and valves in O_2 cylinders, O_2 line, and plastic ETTs carrying near 100% pure O_2 have caused many devastating fires [6,7]. These incidents were analyzed by the author, who also inspected the possible locations of fire. This review was undertaken to examine the possible root causes of such fire incidents that take place in Indian hospitals (particularly in ICUs and NICUs).

3. Methodology

Google searches led to the web links of newspapers and television clips that reported such hospital fire incidents. From these news items, efforts were made to determine the time, location, and source of each fire. As the keywords used for the search were in English, it is very likely that news items from non-English newspapers did not appear in the search results.

4. Inclusion and exclusion criteria

Any one particular incident was reviewed from different newspapers to determine the time, location, and possible source of the fire. If the source of the fire was not found, the