Operating Theatre Setup

Maziar Nourian, Rachel Baker, Jason Fader

Editor's Note: *In this article, we have tried to describe the standards for an operating room in a high-resource setting. After each paragraph, we provide a commentary by one of the authors (JF) with compromises, tips and other suggestions for adapting these standards to a low-resource setting.*

Introduction:

Safety in operating room environments is paramount to surgery regardless of setting. The operating theater poses unique risks to patients and staff members, and it is important to understand how to properly set up a functioning operating theater to minimize these. In this chapter, we will discuss basic principles of how to set up an operating theater, including an overview of medical gasses, electrical and fire safety, theater environment control, and anesthesia machine requirements. Additionally, we will outline basic operating theater layout, equipment, technology, and maintenance standards.

We have divided this chapter into five sections:

1. Setup
2. Gasses and Vacuum
3. Electricity
4. Safety
5. Anesthesia Machines

1. Setup

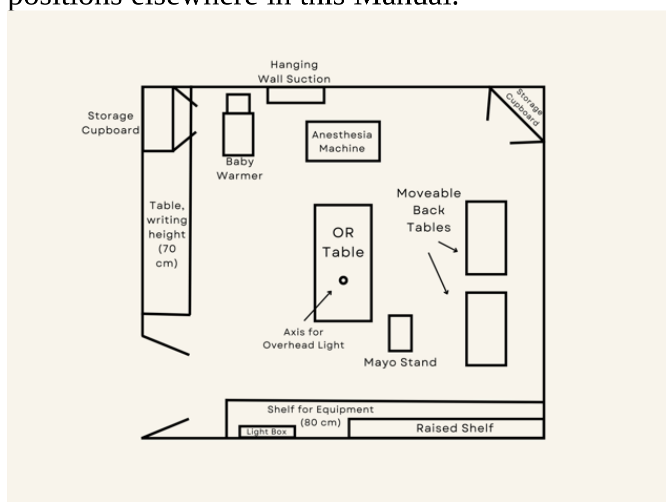
Layout and Physical Requirements

The operating theater should be accommodating to safe surgery and anesthesia and should be at least 7x7m with a ceiling height of 3.5m. This is to allow adequate space for operating theater equipment, intraoperative imaging and patient monitoring.

The typical design and layout of the operating theater involves a patient bed with an anesthesia machine at the head, surgeons and assistants standing to the right and left of the patient and a scrub technician near the feet of the patient or to one side with a sterile table full of surgical equipment.

There should be adequate room for various patient positions for the various sub-specialties and types of surgeries as well as space to adequately allow an anesthesia machine and various instruments to come in and out of the operating theater.

In order to allow for intraoperative patient positioning, a safety strap shall be placed above the patient's knees to prevent movement if the bed is tilted or moved. Safety straps shall also be placed on patients arms to prevent unintended injury from an arm falling off the arm table. In the supine position, the operating table should be able to tilt and rotate into various positions including Trendelenburg and reverse Trendelenburg positions. These positions will place pressure on various parts of the body, therefore it is important to provide padding to pressure points along the patient. We discuss the approach to patient positioning and various surgical positions elsewhere in this Manual.

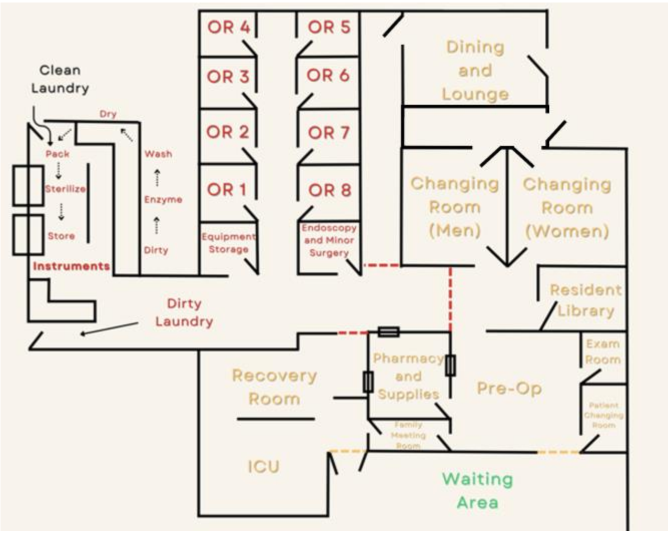


A suggested layout for a single operating room. The baby warmer can be portable and moved to another room, or a neonatal resuscitation area, as needed. There should be outlets on all four walls (220 and 110V).

Each operating room fits into a well-designed system that meets the various needs of operative patient care. In addition to easy access to the operating rooms themselves, a theater area should include:

- A waiting room for patients and family with reception
- Patient changing areas
- Examination rooms
- A pharmacy
- Storage areas for surgical and anesthesia equipment

- A central supply store for non-reusable items
- A surgical instrument storage area
- Decontamination and sterilization facilities
- A postoperative recovery area
- Dressing rooms for theater staff
- Lounge for theater staff
- Clinicians' work and documentation area



Suggested layout of an operating room. Consideration is given to sterile areas and the exit of contaminated linens, entry of clean linens, and the entry and exit of theater personnel through the changing rooms. If there is enough space, consider adding extra exam rooms. These can double as patient changing rooms so that several patients can enter at once, or family rooms when needed for private discussions.

Commentary: *6x6m is a very adequate size. If it is much bigger than that, the equipment can have trouble reaching the patient. The one exception might be an orthopedic operating theater where a C-arm (portable x-ray machine) is used routinely. 3.5m for height is just right – much higher and the overhead light will need some sort of extension; much lower and the surgeons will hit their heads on the light. Putting multiple 220v and 110v outlets on each wall helps with flexibility. Windows above 1.8m help with natural light, but prevent people from looking in. Table surfaces on 2 walls which are off the ground ensure that the legs will not rot or rust, since the operating theaters get mopped multiple times per day. These can be finished wood. Side tables should be stainless steel and are easily found from medical suppliers. Tile is usually the most practical flooring and should go up the wall about 20 cm. It is always prudent to plan on expansion so that if it happens, it occurs in a way that maintains a workable environment with good patient flow. Consider placing the ICU near the recovery room as well, since they serve overlapping functions and have similar needs. The lounge should include the possibility of having lunch served to the operating staff as this facilitates shorter lunch breaks and loss of momentum. Clear vinyl (often used for boats) is very useful to cover operating theater tables to prolong the life of the foam mattresses, which are hard to replace.*

Environment

Temperature:

The temperature of the operating theater should be between 18°C and 24°C. Keeping the room above 18ºC is important to prevent intraoperative hypothermia. Hypothermia (patient temperature <35°C) has been associated with greater morbidity and mortality. Complications include metabolic changes, impaired drug metabolism, cardiovascular changes, effects on coagulation, etc. Patients under general anesthesia will typically lose 0.5ºC to 1.5ºC within the first hour as a result of vasodilation and redistribution of body heat. Most of the body's heat loss happens at the skin level in the form of radiation; however, convective, conductive, and evaporative modalities can further lead to heat loss in a patient.

Warming devices can be used to maintain normothermia in a patient if they meet the following standards. A device that forces heated air over a patient shall not exceed 48ºC, and the average contact surface temperature should be below 46ºC. If a fluid warming device is utilized, it shall not be heated past 43ºC with an average surface temperature of 42ºC.

When comparing various warming strategies, forced air warming devices that blow air into a warming blanket in contact with bare skin have been shown to prevent hypothermia better than fluid warmers, warmed blankets, or increasing the temperature in the room. Passive coverings of patients, such as thermal head coverings or warm blankets over exposed parts of the patient's body, are adequate ways to prevent heat loss. Lastly, the anesthesia team can decrease fresh gas flows and use a heat and moisture exchanger in the anesthesia circuit to reduce heat loss. An anesthetized surgical patient is also at risk for burns or cold injuries due to human error, such as a forced air warmer or ice being placed directly on patient skin.

Commentary: Hot water bottles are a very cheap way to provide heat to patients. Latex gloves can also be filled with warm water. Sterilization should have a hot water source that can be used for this. A broken refrigerator is an excellent way to warm blankets and gowns for patients by installing light bulbs inside the refrigerator along with a thermostat (for a terrarium, for example.)

It is important to test any water with your own hand before placing it on a patient's skin, as anesthetized patients will not be able to tell you that they are being burned by something that is intended to warm them. Portable electric "space heaters" have a similar danger if placed too close to an anesthetized patient.

Humidity

The humidity in the operating room is a safety concern. If the operating room is above 60% humidity, condensation may occur on cool surfaces and affect the integrity of barrier devices. If the humidity is less than 20%, static charge may build up and contribute to operating theater fires. Additionally, low humidity facilitates the spread of airborne disease vectors. Therefore, it is advised to keep the operating theater between 20-60% humidity.

Ventilation

The ventilation system of an operating theater should minimize the spread of contaminants and infectious agents. Therefore, the operating theater should maintain negative pressure, thereby preventing airflow out to the hall or other operating theaters. Additionally, the flow of fresh air into the theater should allow for six to ten total air exchanges each hour. This circulation can be achieved by exhausting the operating room air outside or recirculating it through a filtered system.

Commentary: When forced air ventilation is not feasible, keeping some doors and windows open is an easy way to get air exchange. Moving air is less infectious than stagnant air. Installing exhaust vents in strategic locations can help pull air through very cheaply and effectively.

A ventilation duct near the floor of an operating room in a resource-rich setting allows recirculation and maintains a slight negative pressure inside each room, minimizing spread of contamination out of the room.

Noise

The operating theater is full of various noises which can be damaging to patients and operating theater personnel. At the very least, excessive noise makes communication difficult. Sources of noise include suction machines, forced air warmers, alarms, and surgical equipment. The United States Occupational Safety and Health Administration (OSHA) recommends noise to be less than 80 decibels on average (which is louder than conversational level). Certain equipment in the operating theater can get above 125 dB, and hearing protection may be required while those machines are in use.

Lighting

Lighting in the operating theater can help a surgeon visualize the surgical field, allow intraoperative nursing/technicians to perform their functions, and ensure safe anesthesia is provided. While different surgeries require different types/intensities of lighting, it is generally accepted that lighting capabilities of at least 200 foot-candles is required.

As light source technology improves, there are brighter and more affordable lighting systems in the form of LED technologies that can be used in headlamps, overhead lights, and orbit lights. The use of LED technologies also reduces the amount of infrared heat produced with other light sources.

An overhead light in a resource-rich setting with multiple LED bulbs and a sterilizable handle that allows the surgeon to adjust and direct it.

Finally, backup lighting in the form of battery powered flashlights and headlamps should be made available in cases of power insecurity.

As LED technology has improved and become affordable, "camping headlights" such as this one emit 600 lumens and are entirely suitable for surgical use.

<u>Commentary</u>: *When buying lights, be sure and get many extra light handles that can be sterilized. Camping headlights make overhead lights almost unnecessary. The operating room is one of the key areas that should be put on a generator back up, as well as the oxygen system, lab, and Casualty / Emergency Room. An operating theater typically only uses a couple of kW of power, so a big generator is not necessary (depending on the size of the sterilizer, which likely uses the most electricity in the theater.)*

Radiation/Intraoperative Imaging

Radiation exposure may occur due to diagnostic imaging done intraoperatively. This includes fluoroscopy, linear accelerators/beam therapy, computed tomography (CT), and x-rays. Radiation is measured in gray (gy), rads, Sievert (Sv), and Roentgen equivalents in man (REM). The goal in the operating theater is to use radiation "as low as reasonably practical."

Radiation exposure is reduced by using shielding techniques, decreasing the duration of exposure, and increasing the distance from the radioactive source. For example, a person may be exposed to 1000 millirads of radiation at a distance of one centimeter from the source but increasing the distance to 100 centimeters reduces the radiation exposure to 0.1 millirads.

In order to shield organs that are highly sensitive to radiation (such as eyes, thyroid, gonads, and blood), it is recommended to wear lead shields or to stand behind leaded walls or shields. Leaded goggles are also an option for those exposed to radiation on a frequent basis. Leaded aprons and thyroid shields should be at least 0.25mm on the front and back whereas thyroid shields should be at least 0.5mm. This protective equipment should be tested every year to ensure full protection.

<u>Commentary</u>: *When lead aprons and portable lead walls are not readily available, distance from the radiation source is a very effective way to decrease exposure.*

2. Gasses and Vacuum

Oxygen

Oxygen delivered to patients should be 99% oxygen. Oxygen is typically stored as a gas at room temperature or liquid when refrigerated. Oxygen can be stored in high-pressure cylinders (H-cylinders) and connected to a manifold that will reduce the cylinder pressure of 2000 pounds per square inch (psi) down to an appropriate line pressure of 55 psi. Oxygen at 55 psi can be routed to operating theaters and recovery areas to be safely used. Each anesthesia machine should have the capability of hooking up to an emergency cylinder (E-cylinder) in case of hospital gas system failures. E cylinders should have a pressure of about 2000 psi and never be filled above 5000 psi.

In high-resource settings, oxygen can also be stored at -119C in liquid form in a large tank.

Oxygen concentrators are an alternative to liquid storage or tank oxygen. Concentrators can deliver a concentration of 90-96% by absorbing nitrogen and other trace gasses through a pressure swing adsorber. Oxygen concentrators are governed by the international standards (ISO 8359 and ISO 10083.) The benefit of such devices is that they are compact and can be easily transported from the operating theater to ICU and other locations. These can also be utilized in case of pressure malfunctions of a pipeline system. Of note, it is key that air filtration systems be changed or cleaned regularly and humidity be controlled in the operating theater; a concentrator's performance may decrease if used in very high humidity. (Recall that at maximum performance a concentrator can deliver only 96% oxygen.)

A portable, wall-powered oxygen concentrator

A hospital's oxygen concentrator. Note that this size machine is not sufficient for the hospital's needs- the tanks on the right side are connected in-line to the system and changed as needed, to add to the system's capacity.

<u>Commentary</u>: Obtaining a high-quality oxygen concentrator should be a priority. This oxygen is piped to the key services through copper tubing. If that is not an option, portable concentrators should be fixed in one place (as they break easily) and the

patients moved to the beds which are served by the concentrator.

Medical Air

Medical air is utilized mostly in operating theater settings and consists of blending oxygen and nitrogen to provide a dehumidified (unsterile) air mixture. This allows the anesthesiologist to decrease the amount of oxygen given while a patient is on a ventilator.

<u>*Commentary*</u>*: Centralized Oxygen Concentrators require compressed air, so this air can be used as the "driving gas" for ventilators thereby decreasing the consumption of oxygen.*

Vacuum Systems

Suction is essential to both safe surgery and anesthesia. Suction is usually created by creating negative pressure using a vacuum system. This can help the movement of liquids, solids, and other gasses through the vacuum system. Suction exists in many forms, such as pipeline suction with terminal inlets and portable devices.

The International Standards Organization produces a guideline for pipelines for compressed medical gasses and vacuum (ISO 7396.) This guideline states that a vacuum must be able to maintain suction of 40.6 kPa (12 inches of mercury.) The basic setup for a piped vacuum system is a pump, receiver, piping and vacuum inlets. The pumps should have the capability to connect to emergency electrical supply, and there should be backup pumps in case of pump malfunction. The receiver should help maintain the pressure within the system and drain exhaust and byproducts. The pipeline system is described below, and is comprised of shut off valves, pressure gauges, and alarms. Lastly, vacuum inlets will allow users to access the system via Y connectors that cannot be interchanged with anesthetic gasses.

Portable suction can be used where there is no pipeline vacuum and can either be electrically powered or manually powered. Portable suction devices shall have a vacuum regulator to control the amount of negative pressure and not cause harm to the patient. Suctioned contents can be collected into a container to be either disposed of or measured. It should be ensured that the canister is upright and unlikely to be tipped over. Usually, the canister is placed below the patient to allow for drainage. If suction canisters and tubing are to be reused, proper sanitization must be followed to prevent cross contamination between patients.

Most suction canisters that originate in high-resource settings are intended for single use. When such canisters are reused several times, leakage of suction is the usual result. This leads to decreased effectiveness of the suction.

A wall-powered portable suction machine. Note that this machine runs on 110 volts and needs a separate outlet, as it is being used in a country where 220 volts (Blue outlet) is more commonly used.

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A glass suction canister such as the one on the left is intended to be cleaned and reused. The rubber seal in the cap can be replaced as needed. The plastic suction canister on the right was originally intended for single use in a high-resource setting. As it has been reused multiple times, "patchwork" is needed to repair it and maintain suction. Such canisters are probably more trouble than they are worth in a low-resource setting.

<u>Commentary</u>: Whereas centralized oxygen is very helpful, centralized vacuum is rare and not necessarily advisable. A much better system is to buy multiple portable suction units of the same kind and build a cart which supports the canisters as well. Each operating theater should have a portable suction unit fixed to the wall (ideally in a noise-reducing box.)

We discuss elsewhere in this Manual how to convert an aquarium pump motor into a suction device and how to integrate it into patient care, such as for a wound vac, NG tube suction or chest tube suction.

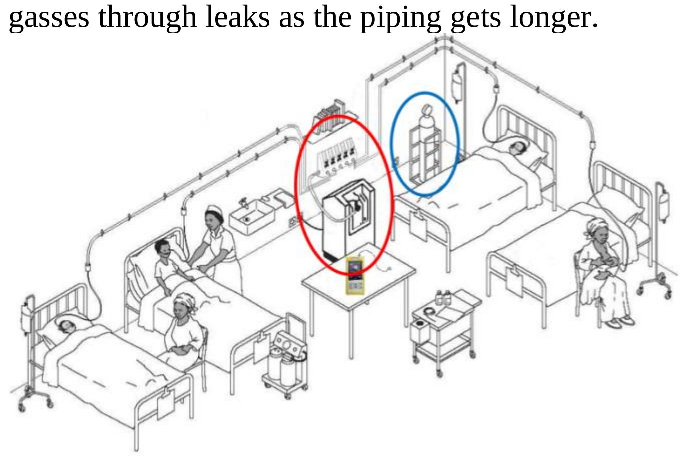
Scavenging

Scavenging of anesthetic gasses can help prevent unintended exposure to health care personnel in the operating theater. Removal of gasses exhaled by the patient and reduction of exposure of administered gasses is the purpose of the scavenging system. Gas should be collected at the site of emission (anesthetic circuit,) transferred to a gas-collecting assembly, and interact with a scavenger interface (open and/or closed interface systems,) and finally exhausted into either the vacuum system or atmosphere. The International Standards for Anesthetic gas scavenging systems (ISO 8835-3) should be followed.

Here, the scavenging system of this anesthesia machine sends the gas through a hole in the wall (Red circle,) to the open air outside the operating room.

Piping Systems

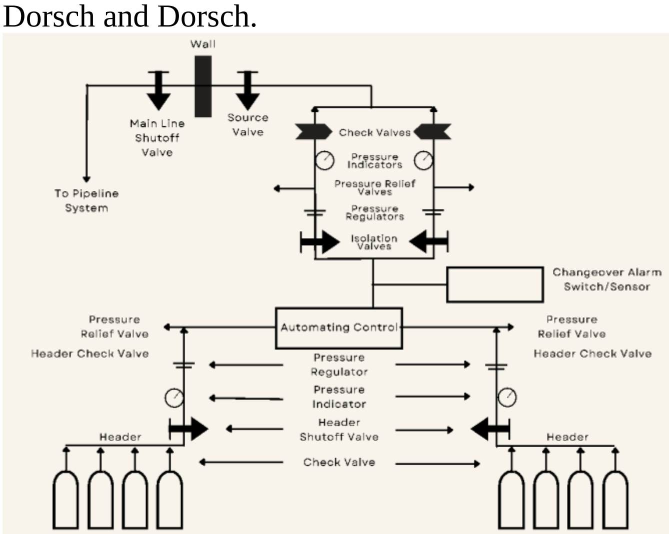
Having contained piping that leads to individual patient beds is much more convenient than having an individual suction machine or oxygen tank at every bed. However, this approach increases the complexity of the system and the potential to lose gasses through leaks as the piping gets longer.



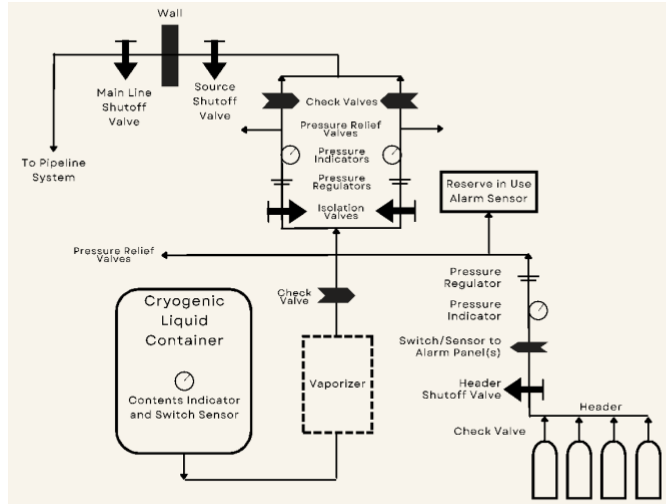
A simple but effective ward setup of an oxygen system. Note that the oxygen concentrator is connected to a flowmeter (both inside the red circle) with five outlets, which send oxygen to each patient through tubing mounted on the wall. Also note the spare oxygen tank (blue circle) in case of oxygen concentrator *failure. Source: Oxygen System Installation Guide Version 2.1 April 2020* [*https://www.ghspjournal.org/content/ghsp/suppl/2020/09/29/GHSP-D-20-00224.DCSupplemental/20-00224-Graham-Supplement4.pdf*](https://www.ghspjournal.org/content/ghsp/suppl/2020/09/29/GHSP-D-20-00224.DCSupplemental/20-00224-Graham-Supplement4.pdf)

There are certain set standards for piping systems to allow for medical gas delivery for multiple operating rooms. Several regulatory agencies have published standards: National Fire Prevention Association (NFPA,) Compressed Gas Association (CGA,) Canadian Standards Association (CSA,) and International Standards Organization (ISO.)

Central supply of gasses can come in various forms, however it is either through cylinder supply or cryogenic supply systems. The cylinder supply unit commonly has two banks. Each bank will have the daily supply, a check valve, pressure relief valves, regulators, and shut off valves. These serve to deliver continuous gas supply, prevent over-pressurized gas delivery to a patient, and prevent system failure. A detailed schematic of a cylinder supply system and a cryogenic oxygen supply system are displayed below which is adopted and recreated from Understanding Anesthesia Equipment by Dorsch and Dorsch.



Example of a cylinder supply system.



Example of a cryogenic oxygen supply system.

Commentary: Cryogenic oxygen is likely unrealistic for most of the developing world. Creating an oxygen manifold which is then piped to key places is a much simpler method of delivering oxygen in a limited space (i.e. labor and delivery.)

3. Electricity

Electrical Safety

Medical equipment that requires electricity can help improve surgical care and is becoming more common in operating theaters around the world. While electric medical equipment has made many advances in the medical field, it also comes with risks to the patient and user. It is important for all personnel in the operating theater to understand the basic principles of electrical safety.

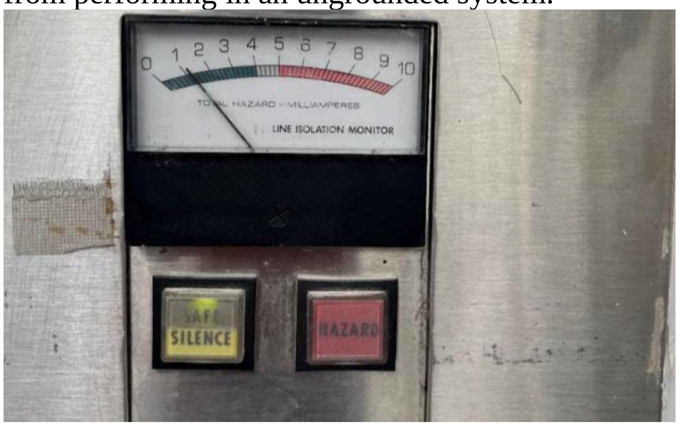
Electricity can pose a threat to operating room personnel and patients through electrical shocks. These can occur when a body part comes into contact with conductive materials at different voltage potentials, thereby closing the circuit. Electricity is produced by flow of electrons in either the same direction (DC) or in alternating directions (AC.) Both AC and DC types of electricity can cause harm to a patient, though AC is more dangerous.

Electrical shock is broken down into two categories: Macroshock and microshock. Macroshock refers to a high current flowing through a person in which harm and death may occur. Microshock is a small amount of current which can become dangerous if in direct contact with the heart (i.e. pacing wire.)

Typical medical equipment in most of the world will use 220V electricity. Hospitals that rely on donated or refurbished equipment from the United States, which uses 110V electricity, should have additional 110V outlets in areas where this equipment will be used.

Power provided to operating theaters is usually ungrounded power and will require an isolation transformer. The isolation transformer adds another layer of safety – a person who comes into contact with a live current does not complete a loop and will not receive a shock. The high current (from the power plant) will instead flow into the ground.

To protect the Isolation Transformer, it is important that operating theaters have a Line Isolation Monitor which monitors the integrity of the Isolation Transformer and prevents faulty equipment from performing in an ungrounded system.



A Line Isolation Monitor in a resource-rich hospital.

Another form of safety comes from a Ground Fault Circuit Interrupter (GFCI), which prevents electrical shock by interrupting current if unequal flow is occurring.

<u>Commentary</u>: Electricity in many developing countries often fluctuates, so a stabilizer for key areas of the hospital with sensitive equipment (i.e. theater, lab, administration wing) is a good idea to have as well.

Diathermy

Diathermy units are becoming widely used around the world due to the ability to maintain hemostasis through cautery and cutting modes. Details about the different modes and uses will be discussed in another chapter. Diathermy comes with many risks as it is the most common ignition source in operating theater fires. The basic (monopolar) design is to have an active electrode which is connected to the generating electrosurgical unit: This is commonly called the "pencil." The circuit is completed by a dispersive electrode pad which collects current from the patient and returns it to the generator: this is commonly called the "grounding pad."

A large surface area of contact between the dispersive electrode and the patient provides the lowest impedance and therefore less potential damage to a patient. If the dispersive electrode is not in proper contact with the patient, risk for burn is present. Situations where this may happen include when the patient's skin is wet, tape/clothing is present between the skin and the pad, or the conductive "sticky" substance on the pad is malfunctioning.

A diathermy burn injury at the dispersive electrode ("grounding pad,") likely due to reuse of an electrode which is intended for single use.

More modern diathermy units will have an active electrode monitoring system that is triggered when currents are not balanced and can deactivate the unit if an electrical leakage is detected. It is important to understand the diathermy device in your operating theater and its safety implications and potential contribution to fires or patient injury.

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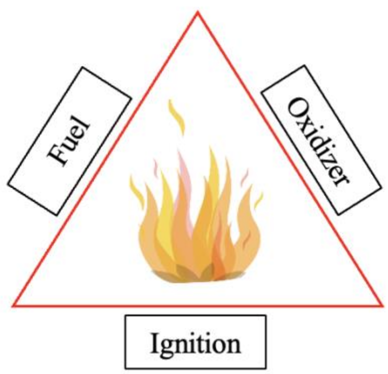
<u>Commentary</u>: Applying petroleum jelly (Vaseline) to the grounding pad ensures a reliable connection with the patient and prevents burns, as does drying the pooling betadine/chlorhexidine on the bed after prepping the patient. A 15x15cm stainless steel plate serves as an excellent reusable grounding pad.

4. Safety

Fire Safety

With the increased use of diathermy and alcohol-based sterile preparing solutions, the risk of operating theater fires becomes a significant concern. All fires have three common elements shown in the "fire triangle," which includes: a fuel source, an oxidizing agent, and an ignition. Fuel sources in the operating theater include alcohol-based solutions, drapes and gowns, blankets, dressings, gauze, airway equipment, etc. Oxidizers found in the operating theater include oxygen and nitrous oxide. Lastly, ignition sources include diathermy, lasers, drills, fiber optic light sources (e.g. for laparoscopic surgery,) or malfunctioning electrical equipment.



The "Fire Triangle" shows the three elements needed for combustion: Fuel, an Oxidizer, and Ignition. All three elements are readily available in an operating room.

High risk operations include tracheostomy with electrocautery, electrocautery in mouth surgery, medical-grade laser ENT surgery, neurosurgery (in which the patient's hair is soaked in ethanol-based cleaning solution,) and laparoscopic surgery (due to fiber optic light sources.)

Fire Prevention & Management

Fire prevention in the operating theater starts with reducing all aspects of the fire triangle. This involves minimizing an oxidizing source, safely managing fuel sources, and ensuring that ignition sources are well controlled. Risky surgeries should be identified ahead of time and a fire management plan should be discussed with the entire theater team. A multidisciplinary fire prevention team with an established protocol is crucial to not only prevent but also manage intraoperative fires. If a fire does occur, personnel involved should debrief and revisit hospital established protocols. An example of a protocol can be found at the end of this chapter.

Airway fires during ear, nose & throat (ENT) operations can be mitigated by decreasing FiO2 to less than 30%, using appropriate endotracheal tubes if electrocautery or lasers are being used, and an appropriate airway fire safety plan.

If ethanol-based disinfecting substances are being used to prepare a patient's skin, it is imperative to wait at least three minutes before the solution has dried on the patient's skin before an ignition source (diathermy) is used. At least 30 minutes is required if the patient's hair is prepped into the surgical field.

Access to a CO_2 fire extinguisher is necessary for all operating theaters. Fire extinguishers must be checked yearly for adequate pressure.

Radiation Safety

Radiation damage is a cumulative process. Operating theater personnel in many hospitals may be considered separate from the radiology department and not be subject to this department's safety measures. This is especially true for fluoroscopy used in orthopedic procedures, where theater technicians will activate the machine and take static and dynamic images during surgery on a daily basis. Ideally these personnel should be given the following:

- Training in radiation safety
- Devices for tracking cumulative radiation exposure
- Radiation safety equipment that is checked at least annually
- Leaded glasses to prevent irreversible cornea damage and loss of vision

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Housekeeping including Personal Protective Equipment

Operating theater personnel should have access to personal protective equipment (PPE), which includes protective hair coverings, fluid resistant masks, eyewear, gloves, waterproof aprons, and non skid shoes (which are ideally waterproof and easily cleanable).

The Association for PeriOperative Registered Nurses (AORN) and the Association for Healthcare Environment (AHE) set out guidelines for setting up facility procedures and practices to ensure proper cleaning and disinfecting of the operating theater.

Areas that need to be cleaned on a regular schedule include walls, ceilings, waiting rooms, lounges, storage areas, and locker rooms. Dedicated cleaning equipment and tools should be set aside just for the operating theater. Types of cleaning supplies suitable for the operating theater include liquid detergents in a pour-top or squeeze-top bottle. Aerosolized cleaning agents are not suitable for the operating theater due to potential risk to cleaning personnel. Mopping of surfaces should be done with microfiber mops or disposable wipes. Dipping repeatedly into cleaning solutions should not occur as it degrades the chemicals and reduces the ability to properly clean.

Cleaning of operating theaters should be done in between cases and at the end of the day with periodic deep cleans. Operating room cleaning staff should wear appropriate personal protective equipment and follow standard precautions while using cleaning chemicals. Chemicals shall never be mixed.

Theater turn-overs shall be completed in between cases. This involves removal of prior instruments, trash bags, and linens that have come in contact with the previous patient. All materials in the room from the prior patient should be considered soiled or contaminated and should be disposed of or processed accordingly. Cleaning and disinfection of the room cannot begin until after the patient has vacated. It is important to wipe down the operating theater table, control box, joints, frames, rails, etc. Proceed with routine mopping of surfaces in the operating theater. Spot-clean any areas that appear to have blood or biohazardous waste.

After the last case of the day, the routine cleaning should be followed by a scan for any electrical cord damage. Remove any unnecessary equipment and wipe all surfaces including patient monitors and the anesthesia machine.

For a "terminal clean" at the end of the day, don appropriate PPE and clean areas which are not regularly cleaned such as scrub rooms, utility rooms, sinks, instrument processing rooms, and operating theater lights. Lastly, ensure vents are free of dust or blockages.

5. Anesthesia Machines

The function of anesthesia machines will be discussed in depth in a separate chapter. In this section we introduce the basics of an anesthesia workstation and criteria that deem an anesthesia machine obsolete.

Every anesthesia machine should be checked daily with a "leak test" and system check. The proper function of the following should be evaluated:

- A master on/off switch which activates electrical portions and alarms.
- An alarm that is activated in the event of a power failure.
- The capability to run on reserve power in case of power disruption.
- The ability to provide a safe and constant pressure suitable for a patient, using high pressured gas from a cylinder or wall outlet – this is usually achieved through a yoke check valve and pressure regulators.
- An oxygen pressure safety device to assure no delivery of hypoxic mixtures to patients. Gasses delivered to patients are usually controlled with flow control valves arranged to deliver normoxic mixtures in the setting of a leak or failure. Safety features are designed to permit for minimum oxygen flows before other gasses.

The American Society of Anesthesiologists has developed the Equipment and Facilities Committee Guidelines for Obsolescence. In brief, this is a useful guide to help determine if an anesthesia machine is obsolete. Below we have listed absolute safety features an anesthesia machine must contain. If any of the absolute criteria are not met, this anesthesia machine should not be used.

Absolute Criteria:

- Diameter Index Safety System (DISS) for gas pipeline inlets
- Pin Index Safety System
- Vaporizer interlocking device (to allow for only one vaporizer to be used at once)
- Oxygen supply pressure failure alarm
- Oxygen failsafe device
- Oxygen ratio device for machines that use N_2O

Below is a list of unacceptable features of an anesthesia machine.

Unacceptable Features:

- Copper kettle and verni-trol vaporizers
- More than one flow knob to a single gas
- Vaporizers that increase concentrations turned clockwise (counterclockwise is the convention)
- Scavenging system hookups with the same diameter as the breathing system
- An anesthetic machine which can no longer be serviced by the manufacturer or certified personnel

Lastly, these are relative criteria which should urge a hospital system to replace an anesthesia machine.

Relative Criteria:

- No means to isolate the Adjustable Pressure Limiting (APL) valve during mechanical ventilation
- An oxygen flow control knob that is larger than other knobs
- An oxygen flush control that can be activated accidentally
- Lack of anti-disconnection device at the fresh gas outlet
- Lack of airway pressure alarm

A maintenance record and log should be kept for all anesthesia machines and should be reviewed regularly.

Commentary: *Periodic maintenance of anesthesia machines is very difficult to put into practice. There are often limited biomedical technicians who are competent to do this task in many developing countries. One thing that frequently breaks on machines that have not had periodic maintenance done are the hoses. When that happens, the oxygen or air is depleted very quickly in a given system. It is imperative that operating theater staff know how to disconnect the oxygen hose from the wall if they hear a loud leak from within the machine.*

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Supplemental Internet Resources:

Anesthesia Patient Safety Foundation *"Surgical Fire Prevention: A Review"*
https://www.apsf.org/article/surgical-fire-prevention-a-review/

Review Article: *"Cleaning the Operating Theatre"*
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8528056/