

2 Equipment Found in OR, ICU and ER

2.1 Working in the Operating Theatre and ICU

In the developing world, the biomedical engineer will often be called into an active room to do a quick repair or adjustment. You will need to know what procedures to follow. Procedures will vary from hospital to hospital but the core requirements are the same. Most OR suites are set up with 3 distinct areas, clean, dirty and sterile. In the hallways there will be a red line on the floor or wall and a door, which indicates the start of the sterile area. To enter this area you need the proper clothing, head and shoe covers and a mask. In the clean area proper clothing, head and shoe covers are needed. In the dirty area street clothes may be permitted but it is a good idea to be properly clothed, as you may have to cross into other areas.

2.1.1 Clothing

There are jump suits which you can wear over your clothes; however, these are hot and uncomfortable after about 30 minutes. In general, you should change into scrubs. In the developing world, these will be cotton coverings. In the same area will be boxes of masks, head and shoe covers. These will also be reusable cotton items in the developing world. Masks are disposable paper or reusable cotton. If disposable, the nose stay needs to be bent over the bridge of your nose to get a good fit. This is very important if you wear glasses as a bad fit on the mask will cause your glasses to fog over as you breathe. If you are assigned to the operating room you may want to have a special pair of shoes that is only worn in the OR. If you do that no shoe covers are required. If you go out of the OR to another area you must change out of the scrubs back into your street clothes. Generally, in the developing world, it is not reasonable to cover your scrubs and leave the OR for a later return.

2.1.2 Hands and Behavior

You don't have to wear gloves when you enter an operating room but you should touch nothing. A good procedure to follow is to cross your arms across your chest as you move about the room. Someone in the room will direct you to the problem and tell you if it is OK to touch the device or if it has to be removed to be serviced. Never assume that you can touch anything in an active OR room. If the room is not active, after a case there generally is no problem in touching equipment. If the room is being set up for a case you should consider the room active and act accordingly. Be especially careful of anything blue, which is in the sterile field of the active room.

If you have to work on a device during a case you may have to wipe down the tools and test equipment with alcohol before proceeding. However, this precaution is rarely adhered to. Move slowly and watch where you step. Watch out for power cords on the floor and fluid spills. Stay away from the sterile field (blue things) unless specifically directed to it by the staff. Talk softly and directly to the person who asked you into the room. All body fluids and tissues are considered hazardous material.

Radiation exposure is possible from the x-rays that are taken in the OR and from radioactive implants that are put into a patient. Most x-ray devices are well collimated and there is very little scatter but it is still a good idea to be a minimum of 12 feet away from both the generator and the patient.

The greatest danger in the OR is the physician or nurses egos. The staff can be under great stress and become abrasive and obnoxious to the support staff (meaning you). In their minds they can do no wrong and everyone else just contributes to their problems. If this starts it is time to leave the area until they cool down.

2.1.3 Working in ICU

As technology advanced in healthcare, in the 1950's, decisions were made to put the technology into confined areas instead of dispersing it throughout the hospital. This led to the creation of the first intensive care units. In larger hospitals, there may be a number of intensive care areas, cardiac (CCU), surgical (SICU), cardio/thoracic (CTU), medical (MICU), Neuro (NCU), neonatal (NICU), and respiratory (RICU). In some very large hospitals there may be an area just for patients with infectious diseases where they are quarantined from the general hospital population. In smaller hospitals these patients are often put into isolation rooms that are part of an existing ICU.

In the typical ICU setting the nurses and other staff are under considerable stress and may not always be friendly to the biomedical engineer. They need and expect their equipment to work and work the same way every time they use it.

In almost all cases, no special clothing is required and there is no need to avoid touching certain areas (there is no sterile field). However, if you are called in to work on active equipment, you must be extremely cautious. These patients are very ill and cannot typically tolerate any disturbance. If at all possible, remove the equipment from the floor before working on it. Be especially cautious with ventilators, which can cause serious injury when disconnected or connected prematurely.

In developing world ICU's, there may or may not be emergency power outlets. If there are, electrical outlets commonly might be divided into several circuits. Most outlets will be connected to emergency power sources, designated by their color, generally red but sometimes white. All outlets should have the circuit number on them so resetting the breaker is easy. In the developing world power outages are very common. However, it may or may not be common for the backup generator to function properly. In some hospitals, even those with an ICU, the backup power generator may be the only source of power.

Some outlets in the ICU are "dedicated lines" in that no other equipment can be plugged into that circuit, these are generally for monitors and computers. Unfortunately it is not unusual for other outlets to be connected to the circuit making it non-dedicated in the developed world. In the developing world, dedicated lines are rarely respected.

In developed ICU's there will be a number of compressed gas outlets on the headwall in each ICU bed area. There will be one or more air outlets, one or more oxygen outlets, and possible a vacuum outlet. The pressure at these outlets should be 50 psi. The fittings to connect the hoses from the gases to the devices are specific to the gas so cross connections are not possible, exterior to the wall. However, far more common in the developing world are bottled gases. Most typically the only gas available is oxygen. In some hospitals, even this cannot be obtained, in which case an oxygen concentrator will be used.

If the ventilator being used requires compressed air and it is not present on the wall a compressor has to be used. Some ventilators have a built in compressor but most do not. The external compressor needs to be plugged into AC and may have a large enough current draw to limit what else can be on that circuit, a common source of an open circuit breaker.

The number of suction (vacuum) outlets on the headwall varies with the type of intensive care unit. In a surgical or cardio-thoracic unit suction is needed for airway, gastric and possibly wound and chest tube suction. In a coronary care unit possibly an airway or gastric suction would be used. The vacuum and flow requirements are the same as in the operating room. Suction regulators are generally installed on each active outlet. The regulators may have a selector for constant or intermittent suction and an off position. The constant setting is used for airway, gastric and chest tube applications. The intermittent selection is used for wound suction. However, far more common in the developing world are stand alone suction machines, often called "Gomco's" whether manufactured by Gomco or not. There is a chapter on these machines later in this book.

Most intensive care areas are positive pressure environments. That is, the air pressure inside the unit is higher than the pressure outside of the unit, which helps prevent microorganisms from entering the ICU area. This is accomplished with the air handling system of the hospital that also filters the incoming air. The air handling system can either use outside air or re-circulate some or all of the air through a set of filters called hepa filters. Some intensive care units may have isolation rooms. In this room the air pressure is negative to the adjacent area, which prevents anything from the inside of the room getting outside of the room. There is a second set of doors that separate the rooms with the outside room being positive pressure. It is fairly common in the developing world to see ICU's designed with these types of air handling in mind, even though the doors are left open or no air handling was ever installed.

Isolation rooms are used when patients are infectious to others. If you have to enter such a room you must follow the posted signs for gowns, gloves and masks for your own protection. The sign may say "reverse precautions" which means you can become infected by the patient. "Precautions" means you can infect the patient. Generally, you will not be able to enter, leave or work in one of these areas without help. The clothing and handling restrictions vary from patient to patient and hospital to hospital.

2.1.4 Sections of Every Chapter

The following chapters describe all of the equipment that you are most likely to find in an ICU. About 44% (according to a recent report by EWH) of the errors that you will encounter are user errors. As the manual is often missing in developing world hospitals, you must deduce the operation of the machine from an understanding what the piece of equipment is supposed to do and how it is supposed to do it. Therefore, the first section of each chapter describes the clinical use of the piece of equipment and its principles of operation.

About 27% (according to recent report by EWH) of the problems encountered in developing world equipment relate to power supply. This includes broken fuses, cords which don't match the outlets (donations are coming from all over the world), devices rated for 110 V in a 220 V environment, and occasionally more sophisticated problems. However, the power supply is the focus of the laboratory manual which accompanies this book. Therefore, these issues are not treated here.

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After eliminating user error and power supply problems, there remain a certain number of problems which are commonly seen in a given piece of equipment. These are treated in the second section of each chapter.

According to the annual performance reports of Engineering World Health, about 54% of the equipment currently unused in the developing world can be placed back in service. While most of that success comes from user error and power supply related problems, 26% of the equipment that exhibits other problems (not user error or power supply) is also fixed by engineers who have studied this text. Therefore, the information contained in this manual and the accompanying lab manual is sufficient more than half the time.

Finally, when you have completed your repair, you need to test the equipment before returning it to the floor for use. As each piece of equipment is used by many different staff members, it is the sole responsibility of the engineer working on the equipment to insure that it is in good working order. Unfortunately, you will frequently not have the testing equipment required to properly test a piece of equipment. Therefore, the third section of each chapter gives guidelines on how to conduct the most critical testing in the desolate technical environment of the developing world hospital. Enough testing can and should be completed after every repair to confidently release a piece of equipment for use.