Electro-Technical
Council of Ireland

Electricity in the medical workplace

An educational guide for users of electrical equipment in medical practice

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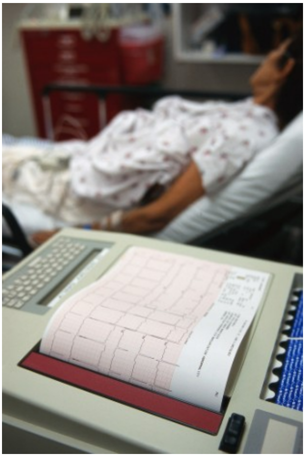

Electricity in the medical workplace

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Introduction

This booklet is intended to raise awareness of electricity in the medical workplace. It gives an overview of electricity and its use in the medical workplace setting.

We know that electricity can be useful for certain medical interventions, particularly when applied in small, controlled amounts. However it can also be hazardous at unsafe levels of exposure.

This booklet discusses electricity as it affects the human body, referring to beneficial aspects as well as not so beneficial aspects. We explore electricity and its usage in the medical workplace, and look at important aspects of electrical equipment in medical practice. Some tips and guidelines for users of electrical equipment in medical practice are offered.

Who should read this booklet

If you are a nurse, allied health professional, doctor, or a consultant, you should find this booklet useful and informative. Remember, the aim of this booklet is to highlight important messages about electricity in the medical workplace, and in particular

- the need to be careful in general when using electrical equipment in medical practice, and when connecting equipment to the electrical supply;
- in patient areas, and in particular in cardiac protected areas, additional measures need to be observed. Users of electrical equipment in medical practice need to be more aware of the effects of electricity when treating patients in these areas.

Electricity and the human body

The human body contains low level electrochemical processes which produce small amounts of electricity, necessary for the normal functioning of nerves and muscle fibre. The heart muscle is an example of an electrical system controlled by these electrochemical processes. The pumping action of the heart is controlled by a regular cycle of electrical activity within the heart structure and this can be disturbed by an external source of electricity. A relatively small amount of electricity, imposed directly on the heart muscle at a critical point in the cardiac cycle, can cause ventricular fibrillation. This is known as a ***micro shock***. A relatively large amount of electricity applied externally to the body would constitute a ***macro shock***. Both of these are examples of electric shock.

> The human skin provides a protective barrier to the flow of electricity into the body. In electrical terms this is called ***resistance*** (measured in Ohms). Normal skin resistance (surface resistivity) is approximately 1000 Ohms per square centimetre. If the skin barrier is bypassed then the resistance can be as low as 10 Ohms, and the flow of electricity into the body can increase by a factor of 100. For this reason electrical safety in surgical environments is of paramount importance. Protection of a patient during cardiac surgery, or where arterial or central lines are inserted into the patient, is critical.

Question: How much electricity is needed to produce a micro shock condition?

Answer: As little as 40-50 micro Amperes, which is about 3400 times smaller than the amount needed to power a 40 Watt light bulb

From physics, we know that the flow of electricity is described as a ***current*** (the flow of electrically charged particles) and is related to ***resistance*** by Ohms Law:

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Voltage (V) = Current (I) x Resistance (R)

In this description, *voltage* is a driving force, and is measured as an electrical *potential difference*. Electricity always flows in a closed circuit, and requires a source and a return path.

The human body offers resistance to the flow of electricity, and our skin provides a barrier and protection against the flow of electricity into the body.

In medical practice, electricity can provide benefits when used for treatment. Some notable examples are:

Electrotherapy: electrical energy in various controlled forms is used to relieve pain for example in injured muscle tissue. Pain relief through nerve stimulation can be achieved using a technique called Transcutaneous Electrical Nerve Stimulation (TENS)

Surgical diathermy: this technology uses high frequency electrical energy to make incisions and seal blood vessels during a surgical procedure.

Resuscitation: the clinical defibrillator generates a controlled electric shock which can be delivered to a patient who has suffered a cardiac arrest.

Pacemaker: electrical energy in small controlled amounts is used to stimulate the heart muscle in patients whose heart muscle pacing system requires artificial assistance.

At unsafe levels of exposure, electricity can cause injury through electric shock, heating effects, burns, and internal damage to tissue and vital organs. These injuries can lead to death. A large body of work has been done by various researchers since the 1950s to investigate the adverse effects of electricity in human beings and animals. The objective of these investigations was to determine the threshold of unsafe levels and to assist with setting limits for levels of exposure and the operation of protective devices. The results of these investigations are reflected in the safety standards which apply to electrical equipment in general, and particularly so for electrical equipment in medical practice.

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Humans and animals are injured or killed each year following exposure to unsafe levels of electricity. Unfortunately, accidents involving electricity can also occur in medical settings.

To illustrate what could happen if a person was to accidentally come into contact with the electricity supply, consider the following scenario:

Electricity flows from the supply source via the faulty device to the person's left hand. The person has also made contact with EARTH via the feet. The electricity can now flow through the person's body and back to the source via EARTH.

In this case, a protective device (called a RESIDUAL CURRENT DEVICE) will protect the person against a fatal electric shock. *This is because the amount of electricity flowing out to the faulty device is not the same as the amount flowing back to the supply source. The residual current device can detect this difference and protect the person.*

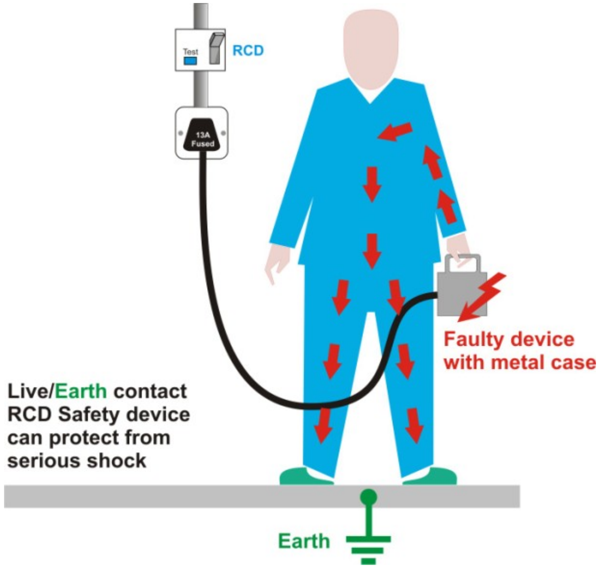

Figure 1: Protection against fatal electric shock by safety device.

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In another scenario, electricity flows from the supply source via the faulty device to the person's left hand, as before.
However, the person has also made contact with the NEUTRAL wire of the supply, via the faulty cable.
The electricity can now flow through the person's body and back to the source. In this case the person would not be protected against a fatal electric shock. *This is because the amount of electricity flowing out to the faulty device is the same as that flowing back to the supply source, and in this case the residual current device will not detect any difference and hence will not protect the person.*

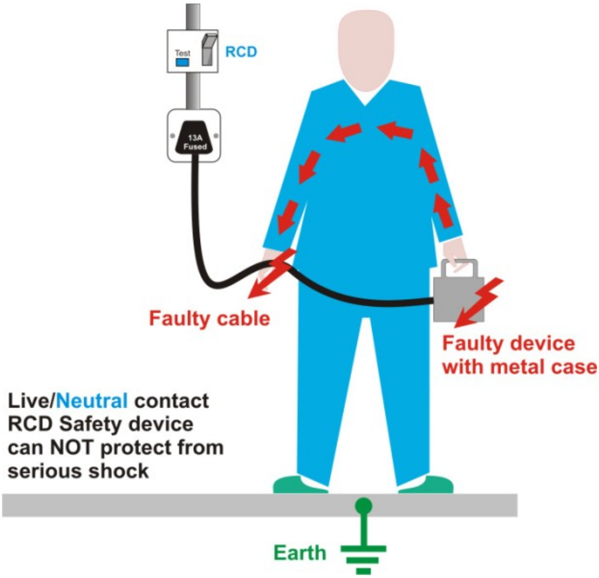

Figure 2: No protection against fatal electric shock.

Electricity and the medical workplace

Sources of electricity

Let us first consider the sources of electricity that are found in the medical workplace. Typically these are:

Mains supply – This is the primary source of electricity in a medical workplace.

Uninterruptible Power Supply (UPS) – When the mains supply is interrupted or fails, the UPS takes over the supply of electricity to a particular appliance or system for a limited period of time. The UPS is very important in high dependency situations.

Backup supply – When the mains supply is interrupted or fails, a back up system can be used until the mains supply has been restored. This facility is usually provided by a diesel powered generator, which is permanently on stand-by.

Batteries – Some equipment is powered from batteries and requires a mains supply to maintain batteries at a fully charged "ready to go" state, e.g. defibrillator, physiologic monitor.

How electricity is used:

A typical hospital is heavily dependant on electricity as a source of energy, for lighting, heating, air conditioning, life safety systems, information and communications technology, catering, medical systems and equipment, administration, etc.

Electricity is normally supplied to a hospital at a "high voltage" and is converted locally to a lower voltage for use within the hospital. The standard mains supply is described as ***230 Volts alternating current, 50 Hertz frequency***. This is the same standard as we have in our homes and offices. The standard mains supply is distributed throughout the hospital via the building electrical installation, and made available via power outlets.

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Protection against electric shock:

Electrical installations are designed and installed so that a person cannot make direct contact with the mains supply. As we have seen earlier, the mains supply contains energy levels that are hazardous to our health and safety. Therefore electrical supply systems must provide protection against direct contact with live parts. In general, mains socket outlets must be protected by a suitable Residual Current Device (RCD). An RCD is a device that protects against a dangerous leakage current from the circuit.
Fixed electrical wiring and connections will normally provide protection using INSULATION or suitable ENCLOSURES. It should not be possible to make contact with any live parts of the electrical system.

For more information please refer to the National Rules for Electrical Installations Section 710: Medical Installations.

Extension leads (connecting equipment to the supply)

Extension leads are commonly used in the home and office environments. However their use can present hazards in the medical setting. **Therefore they must be used with care at all times.**

The following points should be carefully noted:

1. The quality of extension leads can vary. They can have poor contacts at the live terminals. Over time this can cause overheating and possibly fire.

2. Extension leads are often positioned on the floor where they may be subject to liquid ingress such as in an arthroscopy procedure in theatre, or where liquid can drop onto them from fluids hanging on a drip stand.

3. Extension leads are often stored in cupboards and are not routinely inspected as is the case with other “electrical equipment in medical practice”. If the earth connection has been broken at the mains plug or at the socket outlet housing, the fault will not be obvious unless the continuity between the earth pin on the plug and the earth terminal in each socket outlet is thoroughly checked.

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4. The earth contacts can be of poor quality and can fail. In such circumstances, the electricity in a piece of equipment can be returned to the supply source via the patient’s body, by touching the casing of equipment or even worse via connection leads attached to the patient. If the patient’s skin resistance has been broken by arterial lines or similar, even a small amount of energy could be potentially fatal. By breaking or bypassing the protection provided by the skin layer, the chance of an electric shock is greatly increased.

Good practice:

Connect all devices to fixed mains sockets, if possible.

Avoid using mains extension leads and multiple adaptors; instead ensure that enough wall socket outlets are installed in your work area. This is particularly important in operating theatres where staff need to work unencumbered by trailing cables and where there is a risk of saline-based irrigation coming in contact with sockets and electrical connections.

If you need to use an extension lead in a patient treatment area, use only one lead and limit the number of devices connected to it.

Use only good quality mains extension leads. Note illustration below (Figure 3).

If you are using a trailing cable, always use a cable protector to prevent damage or trip hazards.

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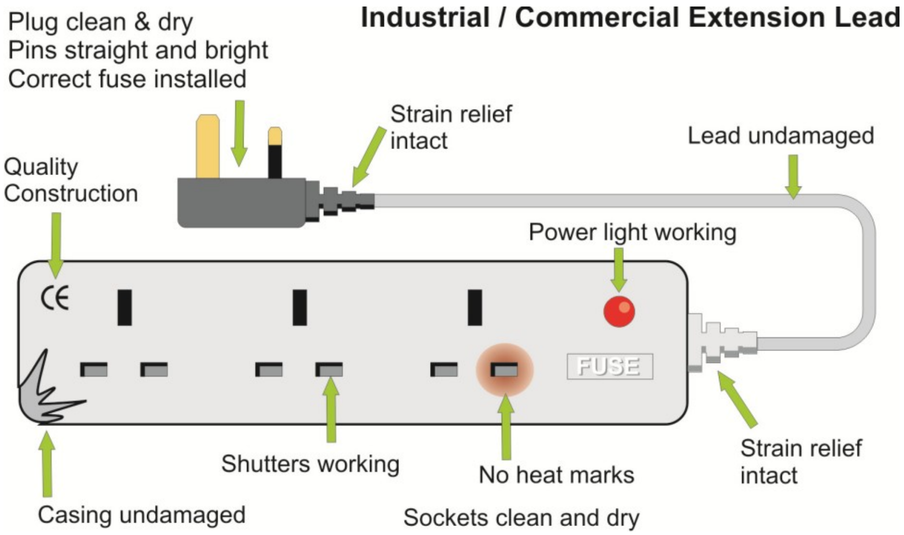

Figure 3: Extension lead with multiple socket outlet.

Electrical equipment in medical practice

Protection against electric shock

For our safety, electrical equipment in medical practice is designed to provide protection against electric shock. This protection is provided for the patient and the user. It will usually employ one of the following two methods:

- Single insulation of live parts, and connecting to earth of accessible conductive parts, providing two levels of protection. ***Equipment employing this method is known as Class I equipment.*** The equipment should be supplied with the following marking, usually located at the equipment earthing terminal.

Symbol for protective earth

- Double insulation, also providing two levels of protection. ***Equipment employing this method is known as Class II equipment.*** The following symbol should be visible on the equipment.

Symbol for Class II

These methods of protection are used when electrical equipment in medical practice is powered from the mains supply.

When electrical equipment in medical practice is connected to a patient, additional protection measures are required. These are known as ***degrees***

of protection, and depend on the nature and purpose of the patient connection. The term "**applied part**" is used to refer to that part of the electrical equipment in medical practice which is in ***direct contact*** with the patient. When the applied part is attached to the patient, the resulting electrical connection is called the ***patient circuit***.

Applied parts are classified according to the degree of protection against electric shock that they provide.

Type B applied part.
The patient circuit may be connected to earth. Protection from macro shock is not provided

Type BF applied part.
The patient circuit is floating and isolated. Protection from macro shock is provided.

Type CF applied part.
The patient circuit is floating and isolated. Direct connection to the heart is allowed.

Defibrillation proof Type B applied part.
Defibrillator may be used while equipment is connected.

Defibrillation proof type BF applied part.
Defibrillator may be used while equipment is connected.

Defibrillation proof Type CF applied part.
Defibrillator may be used while equipment is connected.

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These symbols should be marked on electrical equipment in medical practice and applied parts by the manufacturer.

For example, in the case of a physiologic (vital signs) monitor, the relevant symbol would typically be located on the applied part itself or next to the point of attachment for the patient connections, such as the ECG lead set.

Cardiac protection

When several items of electrical equipment in medical practice are used in close proximity to a patient, it is important that accessible conductive parts of these items such as metal covers and casings etc are at the same electrical potential. If they are allowed to be at different potentials, there is a risk of electric shock to the patient. This is particularly important in an operating theatre. Additional earthing of equipment may be necessary to ensure that all equipment in close proximity to a patient is at the same reference potential and connected to the earth terminal of the building wiring. This is known as equipotential bonding. See Figure 4.

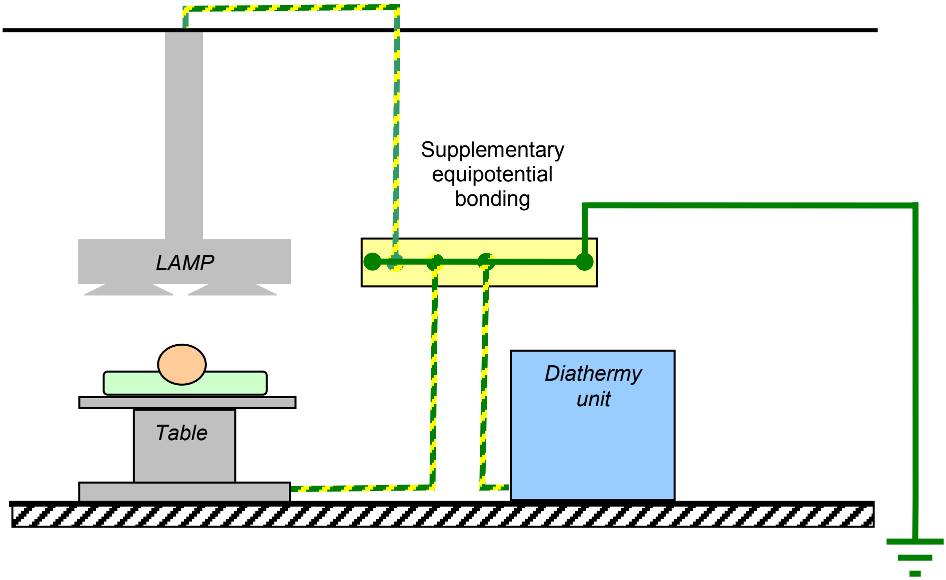

Figure 4. Equipotential bonding

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Example of equipotential bonding connection points provided for equipment when used in close proximity to the patient.

The signage shown above indicates that the area in question is a “CARDIAC PROTECTED ELECTRICAL AREA” in which additional safety measures are taken to protect the patient from micro shock.

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Equipment powered by batteries

Many medical devices are battery powered. Some devices employ batteries as their main power source, while others employ batteries as a back-up source. It is likely that you will encounter some of the following cases in your work setting:

Battery powered device, using disposable or rechargeable batteries.
Examples: Tympanic thermometer, ambulatory syringe driver, telemetry transmitter.

Battery powered device (in normal operation), using built-in rechargeable batteries.
Examples: Defibrillator, physiologic monitor, infusion pump, patient hoist.

Mains powered device (in normal operation), containing built-in rechargeable batteries for back-up.
Examples: Ventilator, critical care physiologic monitor.

As we can see from the above cases and examples, batteries can provide a *primary* source of power, which is the case when the device is intended to run on battery power in normal operation. A mains supply is required to recharge the battery. These devices require careful management in order to ensure their availability. Built-in rechargeable batteries should be monitored regularly and recharged when devices are not in use.

Batteries can also provide a secondary source of power. Devices using batteries as a *secondary or back-up* power source are intended to run on mains power in normal operation. However when the mains supply fails, and when other back up facilities (UPS, back-up generator) are exhausted, the internal batteries will provide the ultimate back-up supply. It is critical that these devices and their batteries are maintained in a ready-to-go state; the batteries must be ready to perform at their full capacity.

Contact your local clinical engineering department for assistance.

Important things to remember, and good practice guidelines

- ☑ Always use electrical equipment for medical purposes in accordance with the manufacturer's instructions.
- ☑ Ensure that electrical equipment for medical purposes has been accepted for use by your local clinical engineering department.
- ☑ Electrical equipment, including power leads should be inspected regularly and replaced where necessary.
- ☑ Never swap plug-in mains leads between devices as leads correctly supplied with non-earthed equipment (Class II) may have no earth connection.
- ☑ Never use a damaged power lead. If in doubt, ask for help from the clinical engineering department.
- ☑ Report equipment faults or damage to your local clinical engineering department.
- ☑ Report mains power problems to your local maintenance department.
- ☑ Avoid using mains extension leads and multiple adaptors; instead ensure that enough wall socket outlets are installed in your work area. This is particularly important in operating theatres where staff need to work unencumbered by trailing cables and where there is a risk of saline-based irrigation coming in contact with sockets and electrical connections.
- ☑ If you are using a trailing cable, always use a cable protector to prevent damage or trip hazards.

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☑ When unplugging equipment always pull the mains plug out of the socket. Never pull by the cord.

☑ Always turn off electrical equipment before unplugging or the mains plug and socket may become damaged.

☑ Never place liquids or infusion bags on top of electrical equipment.

☑ **If in doubt, ask for help or advice.**

Further reading

1. Electro-Technical Council of Ireland ET 101:2008 National Rules for Electrical Installations Section 710: Medical Installations.

2. NSAI I.S. EN 60601-1:2006 COR 2010 Medical electrical equipment - Part 1: General requirements for basic safety and essential performance.

3. NSAI I.S. EN 60601-1-1:2001 Medical electrical equipment - Part 1-1: General requirements for safety - Collateral standard: Safety requirements for medical electrical systems.

4. Irish Medicines Board Safety Notices.

5. Health Services Executive Document Reference No. OQR030, Medical Devices/Equipment Management Policy (incorporating the Medical Devices Management Standard).

6. Medicines and Healthcare Products Regulatory Agency (UK), Poster “Shocking Trips”.

7. Electro-Technical Council of Ireland ET 206:2009, Good Practice Guide on the Management of Electrical Safety at Work.

8. Electro-Technical Council of Ireland ET 213:2007, Guide to the Basic Principles of Electrical Safety.

9. Electro-Technical Council of Ireland ET 214:2005, Guide to the Selection and Use of Residual Current Devices.