ASSESSMENT OF ELECTRICAL SAFETY IN THE OPERATING ROOM
AS PRACTISED BY THE ANESTHESIA PRACTITIONERS AT THE
KENYATTA NATIONAL HOSPITAL

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A DISSERTATION SUBMITTED IN PART FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF MEDICINE IN ANESTHESIOLOGY,
UNIVERSITY OF NAIROBI

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DECLARATION

This thesis report is my own original work and, to the best of my knowledge, has not been presented to any other university for the award of a degree. All the statements herein are my own and not those of the hospital, the university or my supervisor.

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<tr>
<th>Abbreviation</th>
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<tr>
<td>CNS</td>
<td>Central Nervous System</td>
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<tr>
<td>ECG</td>
<td>Electrocardiogram</td>
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<tr>
<td>ESU</td>
<td>Electrosurgical Unit</td>
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<tr>
<td>GFCI</td>
<td>Ground Fault Circuit Interrupter</td>
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<tr>
<td>N$_2$O</td>
<td>Nitrous Oxide</td>
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<td>NFPA</td>
<td>National Fire Protection Association</td>
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<td>VF</td>
<td>Ventricular fibrillation</td>
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<td>LIM</td>
<td>Line isolation monitor</td>
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<tr>
<td>OR</td>
<td>Operating room</td>
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<tr>
<td>mA</td>
<td>milli amperes</td>
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<td>μA</td>
<td>microamperes</td>
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<td>MRI</td>
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ABSTRACT

Objective – To assess the practices on electrical safety in the operating room by the anesthesia practitioners at the Kenyatta National Hospital (KNH) during anesthesia and surgery

Setting – Kenyatta National Hospital Operating Rooms

Target population – Anesthesia practitioners working in the KNH operating rooms

Methodology – The anesthesia providers were picked by purposive sampling method and they were provided with questionnaires which most of them filled within a week. Various aspects of electrical safety were assessed including their knowledge on electrical devices and their classification, the harmful effects of electrical current, their experience of power outages and backup, knowledge of combustible agents used within the operating room and their daily practices and difficulties experienced in achieving electrical safety within the operating room.

Results – Most anesthetists (95.8%) had experienced power outages within the operating room. Substances that can be ignited by a spark of electricity were indicated as halothane (29.2%), surgical spirit (87.5%), ether (79.2%), and oxygen (70.8%). There were mixed responses as to the use of line isolation monitors and ground fault circuit interrupters within the operating room. All the anesthesia providers gave the correct responses concerning the harmful effects of electricity in the operating room. The laryngoscope, cardiac pacemaker and nerve stimulator were correctly identified by 91.6%, 29.2% and 54.2% respectively of the respondents as low risk devices using less than 24V of electricity. The electrosurgical unit, defibrillator, x-ray machine and anesthesia machine were correctly classified as earthed by 62.5%, 50%, 75%, and 45.8% respectively of the respondents. Sixty six point seven (66.7%) disagreed that electrical extension cords are not desirable while 33.3% agreed they are not desirable within the operating room. A well gelled grounding pad and the area in contact with the patient were each indicated by 70.8% of the respondents as very important safety practice. Distance of the grounding pad from the operative site and pacemaker wires were indicated as important safety practice by 20.8% and 62.5% of the respondents respectively. Against the distance from the operative site 62.5% indicated it made no difference. The distance from ECG wires was indicated as making no difference by 37.5% of the respondents while only 16.7% indicated it to be an important safety practice, and the rest 45.9% indicated that it made no difference. Concerning patients with implanted pacemakers, 75% of the respondents indicated preoperative evaluation was a very important safety practice and documentation of the type of pacemaker used and availability of
drugs for the treatment of heart block were indicated as important safety practice by 66.7% and 70.8% of the respondents respectively. All the respondents indicated that they would immediately report a potential electrical hazard in a machine. Electrical extension cord was reported as desirable within the operating room. Among the drawbacks lack of safety guidelines was indicated by all the anesthesia practitioners as a drawback. Others were faulty electricity outlets (95.8%), faulty equipment (91.7%), lack of sensitization of operating room personnel (91.7%), not considered part of anesthetist’s job (70.8%) and long response time from biomedical technicians/electricians (66.7%)

Conclusion – All the anesthesia practitioners know the dangers associated with electrical current to the body. The hospital has good power backup plan. Most anesthesia providers are familiar with the combustible substances used in the operating room. Classification of devices as per the electrocution risk is not clear to a number of anesthesia providers. The dangers of using an electrical extension cord are not known to most anesthesia providers. Not all safety measures related to the ESU grounding pad are observed. Most anesthetists know what to do when there is a potential electrical hazard. Routine safety measures are observed by most anesthetists. There is an apparent lack of team work among operating room personnel. Electrical safety guidelines are either lacking or are not displayed.
INTRODUCTION

Electrical safety in the operating room is often regarded as being of historical interest only. The reality is that the operating room environment is becoming more electrically complex as time goes by. More complications arise with networking of electrical equipment which may not conform to the rigid safety standards of conventional medical equipment.

Improved alarm systems and safeguards have accompanied the technologic progress but there has also been an increase in the size and number of electrical devices used per case.¹ The result is the introduction of new ways to create unsafe electrical configurations that can lead to severe injury during surgery and anesthesia. Despite technological advances that have increased the sophistication of an operating room electrical equipment, three types of danger persist from the days of flammable anesthetics; fire, electrical burns, electrical shock (micro shock and electrical macro shock).

Tragic events continue to be reported in the medical literature in some cases in which a moment of injury leads to a lifetime of patient suffering. In most cases the problem is unsafe equipment or its unsafe handling. Disasters can also arise from damaged or misused anesthesia equipment including physiologic monitoring devices. Severe burns have been caused by electrical equipment with inadequate grounding or other faults and by induced currents from radiofrequency fields.

Electrocution is uncommon although it was once a well recognized hazard of surgery and operating room and even of hospitalization in general. Electrical malfunctions in the operating room continue to cause fires and explosions, central and peripheral nerve stimulation and damage, muscle stimulation and contracture, tissue burns, pacemaker interference and sudden loss of power to important equipment. Understanding electrical safety is an important responsibility for the anesthesiologists because perioperative electrical dangers can often be identified before they lead to disruption of patient care or injury.

DEFINITIONS

When electrons move from one atom to another in a consistent direction, current is said to flow. The applied force to do this is described as potential difference and energy is used up by the process. The energy is available to both fulfill its function or to injure our patients or staff. Materials that permit easy transfer of their electrons from one atom to another are termed conductors while insulators don’t. Resistors allow transfer of electrons reluctantly. An excess
of charge may be carried by some materials as a result of friction (static electricity). This may be later discharged by contact with a conductor, or if the potential is high enough by jumping the gap as a spark.

An electric circuit is an interconnection of electric components such that electric charge is made to flow along a closed path (a circuit), usually to perform some useful task. Electrosurgical units are devices that use electrical energy to deliberately produce tissue injury for the purpose of cutting the tissue or stopping bleeding during surgery. Capacitance is the ability of a device to store charge and electrical potential energy. Electrical Ground Conducting connection intentional or accidental between an electrical circuit or equipment and earth (or some conducting body that serves in place of the earth) which is an infinite reservoir of electrical charge with a limitless ability to give up or receive electrons. Impedance: Resistance to flow of electricity depending on its frequency. Line isolation monitor (LIM) is a device that alarms when there is undesirable connection of the electric circuit to the ground. Ground fault circuit interrupter (GFCI) Breaks the circuit when patient gets connected directly to the ground.
LITERATURE REVIEW

Historical Background

Before 1846 surgery was performed without any sympathy to the patient as they were operated awake without any analgesia. Hippocrates’ (460 – 377BC) advice to the patient was "to accommodate the operator and maintain the figure and position of the part operated on and avoid sinking down, and shrinking from or turning away." In 1844 a dentist extracted a tooth painlessly using nitrous oxide (N\textsubscript{2}O) establishing its value in surgery. In 1846 AD ether was introduced in clinical practice and this marked the beginning of inhaled anesthesia. It is worth noting that nitrous oxide and oxygen which were used together support combustion. Ether is explosive at certain concentrations with oxygen or nitrous oxide.

From mid 1950s more and less flammable inhalational anesthetics were developed. With this knowledge it was important that sources of ignition like electricity be kept low and therefore, the concept of electrical safety in the operating room (O.R.) developed.

The first undesirable effects of electricity recognized in the operating room were those resulting from the production and discharge of static electricity. This was especially important before 1955, when flammable and explosive anesthetic agents were used. Introduction of antistatic rubber, conductive flooring, safe grounding principles, and ventilation and humidity control saw an increasing awareness among O.R personnel, hospital administrators, architects and even the general public, of the dangers of the electric spark in the operating room.

Until late the 1940s electrosurgical unit (ESU), standard electric lighting, power points and occasional portable X-ray machines were the only pieces of electrical equipment used in O.R.

Beginning of Rapid Change

In 1947 therapeutic use of dynamic electricity to the exposed human fibrillating heart began a new era in the medical use of electricity. In the 1950s improved understanding of physiological processes and development of hypothermia and extracorporeal circulation opened the way for more complex and prolonged surgeries from which arose a need for supporting instrumentation and new electronic devices such as patient monitors, defibrillators, pump oxygenators, heat exchangers and various electrosurgical tools were introduced into the operating room.
Supply of Electricity to the Hospital

Power station supplies electricity at very high voltage to a substation, where the voltage is reduced by a transformer. From the substation current passes along two wires, the live and the neutral, the neutral being connected to the earth at the substation. Mains electric sockets in the hospital provide connections to the live and neutral conductors and also to a third conductor which is connected to the earth at the hospital. If a person touches the live wire in the hospital, an electric circuit can be completed through his body, through the earth and back to the substation. This could be an anesthetisia practitioner or patient or any other OR staff. The mains electricity supply in Kenyatta National Hospital comes from the Kenya Power and Lighting Company. The mains electricity supply in Kenya is at 240V potential with a frequency of 50Hz. In addition the hospital has a standby generator which automatically goes on when the mains supply goes off.

Skin Impedance

Impedances of the contacts with the source of electric current and with the earth are of vital importance when considering the risk of ventricular fibrillation (VF) in equipment users and patients. Skin impedance is high when it is dry, lower if the skin is damp and lowered further if there are needles or cannulae passing through the skin. The area of contact also determines impedance where a large area of contact lowers the impedance.

Antistatic shoes have a strong protective effect by virtue of their high resistance. It is recommended that the impedance of such shoes should be between 75kΩ and 10MΩ when new.

Use of electricity in the operating room

Electricity has various uses in the OR. In anesthesia: Electricity is used to power physiological monitoring equipment, defibrillators, powered beds, anesthesia machines, nerve stimulators, laryngoscopes, cardiac pacemakers. The current used is mostly small and well isolated from the ground. In surgery: It is used to power drills, microscopes, laparoscopy equipment, electrosurgical units, MRI machines, portable X-ray machines. The current used may be high and dangerous. Some of these equipment are discussed in details below and how they can be hazardous to the patient and operating room personnel.
Electricity Risks

Despite the benefits that electricity provides in the operating room, there are risks associated with it if safety measures are not adhered to. Mains alternating current of 50Hz is more dangerous than a high frequency current of 1 kHz or greater. Ventricular fibrillation from an electric shock can occur at a lower current in patients with myocardial disease.

Direct electrical injury

Macro shock refers to disturbances of neural or muscular function or both caused by the application of large voltages or currents. Macro shocks can be fatal when they occur near the heart or cause injury when they occur on the peripheral parts of the body. The pathophysiologic effects of different intensities of current ranges between a mild tingling sensation at 1mA to cardiac arrest at more than 5A.

Of the total current that passes through the body 0.1% passes through the heart. If there is a connection straight to the heart like the intracardiac catheter, small amounts of current like 150μA can have the same effect as that produced by 24mA from the hand or feet and may induce VF. This is called micro shock.

Morbidity of excessive currents passing through the living body may be due to one or more of the following:

- Electrical energy being converted into heat which will cause damage proportional to the product of time and current. Damage may progress to charring.
- Hypoxemic damage due to respiratory muscle spasm, or temporary cardiac arrhythmia; permanent cardiac damage may ensue.
- Chemical burns at contact points due to electrolysis.

Electrosurgical Unit Risks (ESU)

Electrosurgical units use electrical energy to deliberately produce tissue injury for the purpose of cutting the tissue or stopping bleeding during surgery. They are capable of causing shock, burns, explosions, arrhythmias and disturbances in pacemaker functioning.

Current flows from the diathermy probe to return via a neutral electrode (monopolar) or passes between two points of the probe to return directly to the ESU (bipolar). With monopolar it is
important that the return plate has good electrical contact and is of sufficient size to allow a low current density at the skin site and minimize the risks of skin burns.

In patients undergoing surgery blood spilling from the surgical field, saline, urine or other conducting fluid can form electrical contact with the operating table, the ground, or other conductors, including monitoring electrodes and surgical retractors.

**Cardiac Pacemaker Risks**

This is a device used to stimulate the heart to beat due to various pathological situations. There are 2 types: i) For temporary use a special pacemaker catheter is inserted through the subclavian or neck veins into the right ventricle. ii) For longer term use there is a battery powered pacemaker and its pacing lead is embedded in the patient’s tissues. The modern ones called demand mode pacemakers pace the heart when it is outside the acceptable range according to the signals it receives from the heart. Problem with the demand mode pacemakers is that electromagnetic fields from sources outside the patient can cause interference. Sources of signals include electric motors and microwave ovens. In the operating room the sources include electrosurgical units, MRI equipment, nerve stimulators and some monitoring equipment.

**Power Failure Risks**

This is also a risk to the patient especially those on monitoring and life support systems in the operating room or intensive care areas. In Kenyatta National Hospital there is automatic connection of power supply to an emergency generator, should mains power failure occur. Some equipment can be battery operated and some ventilators are powered from gas cylinders or piped supply. Power can also be lost as a result of ground fault circuit interrupters(GFCI) being triggered in which case it might be protective.

**Equipment with Microprocessors**

Microprocessors are integrated electronic circuits performing data storage, computing and control functions. Example of application is infusion pumps where rates are set by appropriate buttons. Electrical interference may alter stored values posing a risk to the patient.
Risk associated with current leakage

Leakage of power line current can also be a risk to the patient or staff member. In this regard medical equipment are classified according to the maximum currents permissible for particular applications. Whenever new equipment is received into a hospital it should be subjected to an acceptance test which will verify that leakage currents and other characteristics affecting electrical safety are within the allowed specifications.

Although it has always been assumed that the risk caused by leakage of power line electricity current is due to VF, complete hemodynamic collapse has been demonstrated below the VF threshold and this implies that medical devices meeting current standards may pose a previously unanticipated danger.

General electrical safety considerations in the operating room.

All electrical equipment used in the operating room should be grounded. If a power cord of a piece of equipment has a plug with only two prongs which implies no grounding prong, then it should not be in the operating room.

Patients should not be directly connected to the operating room’s electrical ground. When ESU is in use, a grounding pad should be used that connects the patient to the ground connection provided on the ESU machine. The grounding pad should be well gelled and placed in contact with the patient across a large area. The grounding pad should be inspected during long cases and gelled again or replaced if necessary. The electrosurgical ground pad should be placed as near to the operative site as reasonably possible and as far as possible from pacemaker wires and ECG wires. The anesthesia practitioner should beware of errant current paths that include the grounding pad and other electrical contacts for example the ECG electrodes.

If the Line Isolation Monitor (LIM) alarms after someone activates an electrical device, the anesthesiologist should immediately unplug the piece of equipment that caused the LIM to sound and examined for unwanted connection to the ground.

If a patient has an implanted cardiac pacemaker a bipolar ESU should be used. A preoperative consultation with a cardiologist having pacemaker expertise should be obtained and documentation should be provided regarding the type of pacemaker, the equipment that should be available in the operating room for immediate use, plan of action for different scenarios of
pacemaker dysfunction and a plan for pharmacologic treatment of complete heart block should be in place particularly for pacemaker-dependent patients.²

All electrical equipment should be tested periodically by experienced personnel. This usually is a clinical bioengineering group associated with the operating rooms. Anesthesia practitioner should verify that equipment has been maintained properly, that standards of performance have been met, and that the entire electrical environment also meets international standards.², ⁶

When using a pulse oximeter to monitor the oxygen saturation of patients in an MRI magnet, the connection between the oximeter console and the patient must occur through a long fiber-optic cable having no wires or conducting segments.², ⁶

Short circuit can be produced by dripping or spilling saline, blood or other conducting liquid into the receptacle of an electric extension cord that is on the floor near an operating table. In this regard electrical extension cords should not be used in the operating room. If an extension cord has to be used then it must tolerate very high currents and have watertight covers that flip into place over unused outlets.², ⁶

**Medical Equipment Electrical Safety Standards**

The risk posed by medical equipment varies and to aid the operator a series of classifications have been devised. The precise description is detailed in a series of international standards known collectively as IEC 60601.⁴ Risk to the operator comes when a within the device wire breaks and contacts the metal chassis. This may be prevented by either earthing the chassis or by preventing the operator being able to touch the chassis.⁷ All equipment should be maintained to the highest standards and any damage to any electrical device should be investigated by suitably qualified engineers.

In modern equipment it is rare for the patient to be directly connected to earth. Increasing use of floating circuitry has largely isolated the patient from earth-related current sources. Since the operating table may have an earth contact, patients should not be allowed to touch the metal of the table to prevent currents flowing to the earth via this point of contact.²

**Electrical ground**

Discussions of electrical safety often center on whether circuits are grounded. Electrical ground is any object connected to a circuit capable of instantaneously supplying or receiving large amounts of electrical charge.², ³ Any charged object connected to the earth loses its charge and
assumes the same potential as the earth. Relative to the earth and to each other the, voltage between two grounded objects is zero. The clinicians should know whether their patients or equipment are grounded.\textsuperscript{2}

Unintended new contacts with ground can be injurious to the body when they enable very small electric currents to reach the heart or neural tissue. Alarms can be designed to provide danger signals before an injury occurs. Protection against accidental grounding is important in wet environments like the operating room.\textsuperscript{2,11}

**Isolation of electric power from ground**

This can be achieved by installation of GFCI or to have power come from an isolation transformer equipped with a LIM.\textsuperscript{2} All modern patient-monitoring equipment uses an isolation transformer so that the patient is connected only to the secondary circuit of the transformer, which is not earthed. This implies that even if the patient makes contact between the live circuit of the secondary transformer and ground, no current is transmitted to ground.

**Capacitative linkage**

Electrons interact with each other to repel the other. If a material carries an excess of electrons (negative charge), all other nearby electrons will tend to move away.\textsuperscript{2,7} If the potential at that point varies from positive to negative, such as happens with all alternating current sources (mains electricity) then the surrounding electrons will be attracted and repelled alternatively. This implies alternating current can be induced in a material without an electrical source being directly connected to it. This is termed *capacitative linkage*.\textsuperscript{7}

This concept is relevant to the anesthesiologists because it can account for electrical connections being present at high current frequencies. Capacitive coupling can be responsible for severe patient burns from conventional pulse oximetry (with non-fibreoptic cable) in patients anaesthetized for MRI.\textsuperscript{2}

Surgeons should avoid capacitive coupling between unipolar cautery tools and neighboring metal conductors like trocar cannulae during laparoscopy and endoscopy because stray currents can involve and injure organs such as bile duct and bowel. Anesthesiologist should be aware of this risks.\textsuperscript{2,12}
STUDY JUSTIFICATION

The patients under anesthesia in the operating room depend on the anesthetist for their safety. This is particularly so for the ones under general anesthesia because they cannot complain. Technological advances have resulted in an increase of electrical devices in the operating room but this has brought with it new ways of creating unsafe electrical configurations.

Electrical safety being one of the ancillary activities of the anesthesia practitioners there is need for him/her to be familiar with the electrical devices in the operating room. Improved alarm systems and safeguards have accompanied the technological progress and have made electrical accidents rare. This may lead to staff being complacent and likely to be oblivious of the risk that electric current poses.

Patient and personnel safety in the operating room is an ever present concern for the administrators, clinical staff and engineering support personnel. Injury to a staff member may result in him/her staying away from work for several days denying the hospital the much needed workforce.¹²

The anesthesia practitioner being an integral part as far as patient safety is concerned, there is need for him to be updated with current safety concerns in line with the technological advances. Anesthesia practitioners should regularly review guidelines for the practice of electrical safety. The hospital is spared unnecessary law suits by a vigilant and knowledgeable anesthesia practitioner and more importantly the patients and personnel are safe. No similar study has been done in our own hospital setup as well as this region from literature review and consultation.
OBJECTIVES

Research Question
Are the anesthesiologists’ knowledge and practices on electrical safety satisfactory to ensure the safety of patients and personnel in theater during surgery and anesthesia?

Broad Objective
To assess the practices on electrical safety in the operating room by the anesthesia practitioners at Kenyatta National Hospital (KNH) during anesthesia and surgery.

Specific Objectives
1. To determine the anesthesia providers’ awareness of the risk electricity poses to the patients and staff.
2. To identify the electrical safety measures taken by anesthesia providers at KNH.
3. To document the anesthesia providers challenges towards achieving electrical safety in the operating room.
STUDY METHODOLOGY

Study design
Descriptive cross-sectional study was done. The participants were recruited from KNH. A self-administered questionnaire was formulated and pretested before being administered to the respondents.

Study Population
The target population was anesthesia practitioners working at KNH including Consultant anesthesiologists, Residents in Part II of MMed (Anesthesia) program and Registered clinical officer anesthetists.

Study site
Kenyatta National Hospital operating rooms

Sampling Procedure

i) Sampling method
Purposive sampling method was used

ii) Sample size determination

Using Fisher’s formula \( n = \frac{z^2 \cdot P \cdot q}{d^2} \)

\( n \) is the desired sample size (if target population is less than 10,000)
\( Z^2 \) is the standard error of the mean corresponding to 95% confidence interval. The z-statistic is 1.96.
\( P \) is the proportion of anesthesiologists practicing electrical safety satisfactorily (0.5)
\( q \) is the proportion of anesthesia practitioners not practicing electrical safety well.
\( d \) is the level of statistical significance which is 5%.

\( n = \frac{1.96^2 \times 0.5^2}{0.05^2} = 384 \)

Since target population was less than 10,000 the following formula was used:

\( n_f = \frac{n}{1-n/N} = \frac{384}{988} \times 62 = 61.33 = 62 \)
Where

\( n_r \) is the desired sample size (when population is less than 10,000)
\( n \) is the desired sample size (when population is more than 10,000)
\( N \) is the estimate of population size

**Data analysis and Presentation**

After collection using a standard questionnaire data was entered into the computer. Analysis was done using Scientific Package for Social Sciences (SPSS), Microsoft Excel and Calculator. Presentation was by tables, pie charts and bar graphs.

**Validity and Reliability**

To ensure accuracy, and errors were minimized, all questionnaires were coded and the investigator went through all of them to ensure that the questions had been answered appropriately.

**Inclusion Criteria**

All anesthesia practitioners including, consultant anesthesiologists, registered clinical officer anesthetists and residents undertaking MMed in Anesthesia in their second and third year of study who consented to participate in the study.

**Exclusion Criteria**

All consultant anesthesiologists, registered clinical officer anesthetists and residents undertaking MMed in Anesthesia in their second and third year of study who refused to give consent to participate in the study. The residents undertaking MMed in anesthesia in their first year of study were excluded. The investigator and the supervisor were also excluded.
ETHICAL CONSIDERATIONS

1. This was a non-invasive study based on questionnaire to the anesthesiologists.
2. It did not involve any costs to either the practitioner or the institution.
3. Informed consents were obtained from the practitioners.
4. Confidentiality was maintained for all the respondents.
5. Consent was obtained from the Kenyatta National Hospital Ethics and Research Committee before the study was conducted.
6. Feedback shall be provided to the institution and the practitioners on the safety outcomes of the study.
RESULTS

A total of 55 anesthesia practitioners were interviewed. The age distribution is as shown in Fig. below. Majority of the practitioners were aged between 30 to 40 years accounting for 54%. Few were over fifty years accounting for 8%.

Figure 1: Age distribution of anesthetists

![Age distribution of anesthetists](image)

The male anesthesia practitioners were 44 accounting for 79% of those interviewed while the females were 11 accounting for 21%.

Figure 2: Gender distribution.

![Gender distribution](image)
Registered clinical officer anesthetists constituted the majority of those interviewed (45.8%) followed by consultant anesthesiologists (29.2%) and then the resident anesthesiologists (25%).

**Figure 3: Qualification of the anesthesia providers**

The practitioners were asked whether they experienced power outages and a majority of them (95.8%) answered yes. Two of them (4.2%) said they did not. The response as to how soon back-up power took over is as shown in Fig. 5.

**Figure 4: Experience of power outages**
The practitioners were asked to indicate the substances in the operating room that could be ignited by a spark of electricity. Eighty seven point five percent (87.5%) indicated halothane, 79.2% ether, 70.8% oxygen, 37.5% nitrous oxide. Halothane had 29.2% indicating that it can be ignited, 16.7% isoflurane, 20.8% enfurane and 4.2% iodine solution.

Figure 6: Substances that can be ignited by a spark of electricity
Thirty practitioners accounting for 54.2% responded that the GFCI should be fitted in all the operating rooms, while 20.8% responded that it may be useful in some operating rooms while 25% responded that they were not useful. Concerning the line isolation monitor (LIM) 25 practitioners (45.8%) responded that it must be fitted in all operating rooms, 16 practitioners (29.2%) did not find it useful while 14 practitioners (25%) said it may be useful in some operating rooms.

**Figure 7.1: Ground fault circuit interrupter**

![Graph showing the responses to the GFCI](image1)

**Figure 7.2 - Line isolation monitors**

![Graph showing the responses to the LIM](image2)
Concerning the harmful effects of electric current all the practitioners responded ‘yes’ to the effects that were listed in the questionnaire.

**Table 1: Harmful effects of electric current**

<table>
<thead>
<tr>
<th>Effects (Yes)</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrocution</td>
<td>55</td>
<td>100</td>
</tr>
<tr>
<td>Fire</td>
<td>55</td>
<td>100</td>
</tr>
<tr>
<td>Electric shock</td>
<td>55</td>
<td>100</td>
</tr>
<tr>
<td>Tissue damage</td>
<td>55</td>
<td>100</td>
</tr>
</tbody>
</table>

Devices were classified as per their electrocution risks by the anesthesia providers. Figures 8.1 to 8.8 summarize their responses.

**Figure 8.1: Laryngoscope**
The majority of anesthesia practitioners classified the physiological monitoring machine as double insulated and this was 41.7% while 29.2% classified it as earthed and the remainder 29.2% classified it as low risk device using less than 24V of electric current.
The electrosurgical unit was classified by 62.5% of the respondents as earthed, 33.3% said it was double insulated while 4.2 percent classified it as low risk.

**Figure 8.4 - Electrosurgical (Diathermy) unit**

![Bar chart showing the classification of electrosurgical units](image)

- Earthed: 62.5%
- Double insulation: 33.3%
- Less than 24V of electricity: 4.2%

**Figure 8.5 - Defibrillator**

![Bar chart showing the classification of defibrillators](image)

- Earthed: 50%
- Double insulation: 33.3%
- Less than 24V of electricity: 16.7%
The majority of the practitioners (75%) classified the X-ray machine as earthed, 12.5% double insulation, and 12.5% as low risk.
The majority of the practitioners (75%) classified the X-ray machine as earthed, 12.5% double insulation, and 12.5% as low risk.
The anesthesia machine was classified as earthed by 45.8%, 37.5% classified it as double insulated and 16.7% as low risk using less than 24V of electricity.

**Figure 8.8 - Anesthesia machine**

Concerning the use of electrical extension cords within the operating room, a question was posed that the devices are not desirable in the operating room. Sixty six point seven (66.7%) disagreed they were not desirable while 33.3% agreed they were not desirable.

**Figure 9.1: Electrical extension cords**
Eighty seven point five percent agreed that the microwave ovens were not desirable in the operating room while 12.5% disagreed.

Figure 9.2 - Microwave ovens

Concerning area of grounding pad in contact with the patient 70.8% said it is an important safety practice, 12.5% said it is not a must for safety while 16.7% said it makes no difference.

Figure 10.1: Area of grounding pad in contact with patient
Sixty two point percent of the practitioners said the distance of the grounding pad from the operative site is not a must for safety, 20.8% said it is an important safety practice while 16.7% said it makes no difference.

**Figure 10.2 - Distance of grounding pad from operative site**

Concerning distance of grounding pad from pacemaker wires, 62.5% indicated that it is an important safety practice, 16.7% indicated it is not a must while 20.8% said it makes no differences

**Figure 10.3 - Distance of grounding pad from pacemaker wires**
Distance of grounding pad from ECG wires was indicated as important for safety by 16.7% practitioners, 45.8% indicated it is not a must for safety and 37.5% indicated it made no difference.

Figure 10.4 - Distance of grounding pad from ECG wires

[Diagram showing bar chart with categories: Makes no difference, Not a must for safety, Very important safety practice, a must. The percentages are: Makes no difference: 37.5%, Not a must for safety: 45.8%, Very important safety practice, a must: 16.7%]

Use of a well gelled diathermy grounding pad was indicated as an important safety practice by 70.8% of the anesthesia practitioners, while 12.5% indicated it is not a must for safety and 16.7% indicated that it made no difference.

Figure 10.5 - Well gelled ESU (Diathermy) grounding pad

[Diagram showing bar chart with categories: Makes no difference, Not a must for safety, Very important safety practice, a must. The percentages are: Makes no difference: 16.7%, Not a must for safety: 12.5%, Very important safety practice, a must: 70.8%]
For the patients with implanted 75% of the respondents indicated that preoperative evaluation by a cardiologist is very important and 25% said it makes no difference.

**Figure 11.1: Preoperative evaluation by cardiologist**

![Graph showing preoperative evaluation by cardiologist]

Documentation of the type of pacemaker implanted was indicated as very important by 66.7% of the people who responded, 12.5% indicated it is not a must and 20.8 % indicated that it makes no difference.

**Figure 11.2 - Documenting on type of pacemaker implanted**

![Graph showing documentation on type of pacemaker implanted]

Availability of drugs for the treatment of heart block was indicated as very important safety practice by 70.8%, 12.5% said it is not a must and 16.7% said it made no difference.
On encountering a faulty machine 100% of the respondents (55 anesthesia providers) indicated they would report immediately, 37 respondents representing 66.7% would solve the problem if they can and 91.7% said they would get an alternative machine.

**Figure 12: Action in the event of encountering a potential electrical hazard**
Of the respondents 66.7% said they had experienced or witnessed an electrical mishap. The remainder 33.3% had no experience of an electric mishap.

**Figure 13: Experience of electrical mishap**

![Pie chart showing 66.7% experience and 33.3% no experience of electrical mishap.]

The anesthesia practitioners were presented with a number of electrical safety practices and they were to indicate whether they practice them or not. A majority observed most the safety practices. Most reported faulty devices (95.7%), ensuring naked electricity wires are covered (95.7%), avoiding spilling fluids on the floor (87%), using devices inspected by the biomedical and electrical engineering teams. On the other hand most of the anesthesia practitioners interviewed used electrical extension cords (over 80%). See Fig. 14 below.

**Figure 14: Routine electrical safety practices**

![Bar chart showing percentages of safety practices observed by anesthesia practitioners.]

- Wearing antistatic shoes: 82.6%
- Ensuring naked...: 95.7%
- Reporting all faulty...: 95.7%
- Not using electrical...: 17.4%
- Encouraging change of...: 56.5%
- Not spilling fluids on...: 87%
- Ensuring that the...: 87%
Among the drawbacks lack of safety guidelines was indicated by all the anesthesia practitioners as a drawback. Others were faulty electricity outlets (95.8%), faulty equipment (91.7%), lack of sensitization of operating room personnel (91.7%), not considered part of anesthetist’s job (70.8%) and long response time from biomedical technicians/electricians (66.7%)

**Figure 15: Drawbacks to electrical safety**
DISCUSSION

This study was carried out among anesthesia practitioners working at the Kenyatta National Hospital which is a busy referral hospital and can have over 18 operating rooms functioning simultaneously on any working day. A total of 55 anesthesia practitioners were interviewed.

Majority of the practitioners were aged between 30 to 40 years accounting for 54%. There were more males (79%) than females (21%). Qualification of the practitioners was varied and included registered clinical officer anesthetists (45%), resident anesthesiologists in their second part of training and consultant anesthesiologists. It is important to note that risks of electricity affect everyone regardless of qualification and gender. The anesthesia practitioner is at an integral part as far as safety is concerned but the other staff in the operating room including surgeons, nurses, cleaners and any other visitor should be involved for safety to be complete.

Most of the anesthesia practitioners (95%) interviewed agreed they had experienced power outages while working in the operating. Answers were varied regarding the time it took for the back-up power generator to be activated. Uninterrupted power supply is taken for granted by most anesthesia professionals. Leading reference books of anesthesia are also silent on this important topic. The only time it gets real attention is when it is not there. Power failure can affect a number of devices in the operating room including: the anesthesia machine, electric powered vaporizer like the desflurane vaporizer, physiologic monitoring machines, infusion machines, syringe drivers, powered beds, cardiopulmonary bypass machines, transesophageal echocardiogram, electric suction machine, surgical field lights and many other devices. This can disrupt care and more importantly, endanger the life of patients. A working flash light should be there at all times just in case the room is not well lit. A decision should be made by the operating room team on whether or not to continue with the operation depending on the nature of the surgery and the patient. A line power failure event after which the emergency generator electrical power to the red outlets (the outlets supplied by the power back-up) also fails is a potential life-threatening emergency in the OR. This is when anticipation and planning (including verification of correct placement of functioning backup battery-powered lighting and monitors) as well as prior training are critical.
The response of the anesthesia practitioner is important because it can be life saving and may include changing to manual ventilation. Some machines have backup battery and the anesthetist should know how long the battery can run and should also adopt energy saving measures such as manual ventilation when there is no power. An uninterrupted power supply is a mission-critical resource for hospitals and operating rooms. Planning for power failure is imperative given that it is a rare event. If a health care facility has a power failure, the post-event assessment of the organization’s response can be of immeasurable value toward improving preparedness for similar events in the future.

The initial anesthetics to be introduced into clinical practice were explosive but from mid 1950s more and less flammable inhalational anesthetics were developed. However there are still some substances that are in clinical practice that risk causing a fire or explosion in the presence of a spark of electricity. Furthermore in the operating room there are papers and drapes and other plastics which can spread the fire. The anesthesia practitioners were given a list of substances that were used in the operating room and they were to indicate whether they could be ignited by a spark of electricity. Surgical spirit was selected by 87.5% and ether by 79.2%. In a fire or explosion a combustible agent or fuel combines with oxygen or another oxidizing agent to give reaction products and release energy. Before the reaction starts, a small amount of energy known as activation energy must be supplied. The energy appears as heat energy, which increases the temperature of the mixture. Once the reaction exceeds a certain level the reaction becomes self sustaining, as the energy produced is then sufficient to supply the activation energy to propagate the reaction. Surgical spirit can be ignited by a spark of electricity (activation energy) and this was correctly picked by 87.5%. Halothane was picked by 29.2% of the respondents and it is considered non-flammable. However it will burn if mixed in the correct proportions with oxygen or nitrous oxide and if sufficiently high temperatures occur to ignite the mixture. The lower limits of flammability for halothane are higher than those used in normal anesthesia practice, and also any sparks present are unlikely to be of sufficient energy to start the mixture burning. Many anesthetists now use only non-flammable anesthetics, but this should not give rise to complacency because some flammable substances may still be brought in the operating room. Surgical spirit which was picked by 87.5% of the respondents is the commonest. The risk of it being ignited is increased if oxygen or nitrous oxide is present. Accidents have
occurred when liquid spirit on the patient's skin was ignited. It burns in pale blue flames which are not readily visible and severe burns can occur before the accident is noticed. Methane and hydrogen may be present in the patient's gut and may be ignited by diathermy when the gut is opened. Ether may still be present in the operating room for the purposes of degreasing the skin of the patient. Ethyl chloride, which was not provided in the questionnaire, may be used as a local anesthetic spray and it is flammable. With the above knowledge it is important that sources of activation energy like electric sparks be kept as much as possible away from any combustible material, fuel or substance that supports combustion.

The anesthesia providers were presented with a question on ground fault circuit interrupters (GFCI) and line isolation monitor (LIM) and they were to indicate their importance in the operating room. Thirty practitioners accounting for 54.2% of those interviewed responded that the GFCI should be fitted in all the operating rooms while 25 practitioners representing 45.8% responded that LIM must be fitted in all operating rooms. The debate on whether or not an operating room requires GFCI or LIM has never been straightforward. In 1975, the NFPA added National Electrical Cord (NEC) article 517-52(b) that stated “receptacles supplying locations which are commonly subject to wet conditions, shall be provided with GFCIs if power interruption under faulty conditions can be tolerated, or Isolated Power Systems if interruption of power cannot be tolerated.” Operating room electrical standards have also been subject to organizational, state, national, and country-specific regulations. The Department of Defense in the United States of America defined wet areas as those used for cystoscopy, arthroscopy, and birthing rooms in labor and delivery until May 2007, when the Department of Defense stated that “operating rooms, delivery rooms, cystoscopy rooms, oral surgery, cardiac catheterization rooms, and other such rooms were not wet areas.” The designation of ORs as dry locations and thus not requiring IPSs or GFCIs seems illogical to the minds of many anesthesiologists. Blood spillage onto the floor occurs in many major surgeries, including trauma surgeries and cesarean deliveries. Irrigation fluid spillage onto the OR floor during arthroscopies and cystoscopies frequently occurs. The NFPA standards were reviewed in January 2008, and it was proposed that all ORs be designated as “wet locations” but this was opposed by the American Society of Healthcare Engineers. However it is clear that the presence of GFCIs and LIMs can prevent injury or death from electricity.
The question on the harmful effects of electricity that were listed was indicated as “yes” by all the anesthetists (100%). This was the correct response for all of them. Direct electrical current can cause death by electrocution. On a milder form it will result in hypoxaemia due to respiratory muscle spasm or temporary cardiac arrhythmias. Chemical burns at contacts due to electrolysis can also occur. Small amounts of electricity that would ordinarily not have a serious effect when applied directly to the body can result in fatal arrhythmias when there is a direct connection to the heart like the central venous catheter or pacemaker wires.

Medical equipment can be classified by the electrocution risk from contact with chassis. The practitioners were given a list of devices that they were to classify and the results were varied. The laryngoscope, cardiac pacemaker and nerve stimulator were correctly identified by 91.6%, 29.2% and 54.2% respectively of the respondents as low risk devices using less than 24V of electricity. Serious burns have occurred from direct current generated by 9V battery in small neuromuscular stimulator. Although the risks of electrical shock may still be there the particular risks associated with the use of mains electricity are avoided. The physiologic monitor used in the operating room is double-insulated and does not require to be earthed. The electrosurgical unit, defibrillator, x-ray machine and anesthesia machine were correctly classified as earthed by 62.5%, 50%, 75%, and 45.8% respectively of the respondents. These are also called class I equipment and any conducting parts that are accessible to the user such as the metal case of an instrument are connected to an earth wire which becomes the third wire connected to the mains supply socket. When there is a fault and live wire (which has a fuse) is connected to the chassis there is high current flow that melts the fuse disconnecting the circuit and thus removes the live potential from the equipment case. For the system to work the earth wire must be connected correctly and fuses must be present in the live and neutral wires. The ESU although grounded has a different protective mechanism. The connection to the grounding pad is fitted with the isolating capacitor that can allow only high frequency current to pass and not the dangerous and low frequency mains electricity. The ESU may also use the isolated circuits although the chassis is earthed.

Concerning the use of electrical extension cords within the operating room, a question was posed that the devices are not desirable in the operating room. 66.7% disagreed while 33.3% agreed.
Short circuit can be produced by a conducting fluid dripping into the receptacle of an electric extension cord thus the NFPA had forbidden the use of it.\textsuperscript{2} If it has to be used in the operating it must tolerate very high currents and have watertight covers that flip into place over unused outlets. The cords should also be above the ground. Microwave ovens were indicated to be undesirable by 87.5\% of the respondents. Microwave ovens can cause electromagnetic interference of pacemakers and thus they are a danger to the patient.

There are risks associated with the ESU. The grounding pad is usually put in contact with the patient to complete the circuit. A well gelled grounding pad and the area in contact with the patient were each indicated by 70.8\% of the respondents as very important safety practices. Distance of the grounding pad from the operative site and pacemaker wires were indicated as important safety practices by 20.8\% and 62.5\% of the respondents respectively. Against the distance from the operative site 62.5\% indicated it made no difference. The distance from ECG wires was indicated as making no difference by 37.5\% of the respondents while only 16.7\% indicated it to be an important safety practice, and the rest 45.9\% indicated that it made no difference. As per the general safety measures in the operating room the grounding pad should be well gelled and placed in contact with the patient across a large area.\textsuperscript{2} It should be inspected during long cases and gelled again or replaced. The pad should be placed as near to the operative site as reasonably possible and as far as possible from pacemaker and ECG wires.

Concerning patients with implanted pacemakers, 75\% of the respondents indicated preoperative evaluation was a very important safety practice and documentation of the type of pacemaker used and availability of drugs for the treatment of heart block were indicated as important safety practices by 66.7\% and 70.8\% of the respondents respectively. Patients with an automated implanted cardioverter-defibrillator (AICD) need to have the AICD turned off before surgery.\textsuperscript{2, 6} Turning off the AICD feature is commonly done by magnet placement but can also be done by reprogramming. Magnets do not change the pacing program that is in an AICD and therefore preoperative cardiac electrophysiology consultation is essential for establishing appropriate pacing. Bipolar electrocautery units should be used instead of unipolar electrocautery.\textsuperscript{7} All programmable pacemakers should be interrogated preoperatively to ensure proper function. Pacemaker-dependent patients need to have asynchronous pacing programmed along with all
rate-sensing features disabled. A conventional defibrillator should be available. A plan for pharmacologic treatment of complete heart block should be in place, particularly for pacemaker-dependent patients, and isoproterenol should be readily available on the anesthesia drug cart. If electrophysiologic monitoring is being done, the anesthesiologist should review the locations of grounding pads that will be placed by the electrophysiologist.

As far as practice is concerned, all the respondents indicated they would immediately report a potential electrical hazard in a machine, 91.7% said they would get an alternative machine, and on solving the problem 66.7% said they would. Among the anesthesia providers 66.7% said they experienced or witnessed an electrical mishap. The anesthesiologist should always be vigilant and ensure that all the devices are in good working condition. Should a device make the LIM alarm to go off the anesthesia provider can try various combinations of unplugging one piece of equipment and plugging in another. However, if it is found that one piece of equipment causes the LIM to sound an alarm under several combinations, that piece of equipment should be removed from the operating room and examined for an unwanted connection to the ground contact. A majority observed most of the safety practices. Most of them reported faulty devices (95.7%), ensuring naked electricity wires are covered (95.7%), avoiding spilling fluids on the floor (87%), using devices inspected by the biomedical and electrical engineering teams. On the other hand most of the anesthesia practitioners interviewed used electrical extension cords (over 80%) and did not encourage the surgeons on the changing of wet drapes. All electrical equipment should be tested periodically by experienced personnel, usually a clinical bioengineering group associated with the operating rooms. Anesthesia practitioners should verify that equipment has been maintained properly and that standards of performance have been met.

Among the drawbacks lack of safety guidelines was indicated by all the anesthesia practitioners as a drawback. Others were faulty electricity outlets (95.8%), faulty equipment (91.7%), lack of sensitization of operating room personnel (91.7%), not considered part of anesthetist’s job (70.8%) and long response time from biomedical technicians/electricians (66.7%)
CONCLUSIONS

1. All the anesthesia practitioners know the dangers that electrical current has to the body.
2. Most anesthesia providers are familiar with the combustible substances used in the operating room.
3. Classification of devices according to their electrocution risk is not clear to a number of the anesthesia providers.
4. A number of anesthetists do not know the dangers of an electrical extension cord within the operating room.
5. Not all safety measures related to the electrosurgical unit grounding pad are observed because of lack of knowledge.
6. Most of the anesthesia providers know what to do when there a potential electrical hazard.
7. Routine safety measures are observed by most of the anesthesia providers.
8. There is an apparent lack of team work among the operating room personnel.
9. The safety guidelines are either not there or they have not been displayed.
RECOMMENDATIONS
1. The safety guidelines should be formulated or if they are already formulated they should be well displayed in the operating rooms.
2. Teamwork and good communication among the operating room personnel should be encouraged.
3. Any electrical mishap should be well investigated and form a basis for future learning
4. Regular seminars should be organized for updates on the current guidelines on electrical safety

STUDY LIMITATION
The study concentrated on the knowledge and practice of the anesthesia provider’s only yet electrical safety within the operating involves everyone including the most junior staff member.
REFERENCES


APPENDICES

APPENDIX I: CONSENT EXPLANATION

Introduction
You are invited to participate in a study conducted by Dr. Edwin Oduor, a third year resident in anesthesia at the University of Nairobi. Any queries arising before or during the study will be addressed.

Purpose of the Study
To assess the practices on electrical safety in the operating room by the anesthesia practitioners at Kenyatta National Hospital during anesthesia and surgery.

Type of Research Intervention
The study will be conducted among anesthesia practitioners at the Kenyatta National Hospital and it is questionnaire based. Selection of participants is by purposive sampling.

Voluntary Participation
Your participation in the study is purely voluntary. You will not be penalized for refusing to participate or withdrawing consent.

Duration: The study is intended to last one month.

Risks and Benefits
You will not be exposed to any risks and does not involve any costs to both the practitioner and the patient. There are no monetary benefits associated with your participation in the study. The outcome of the study will be communicated to the participants and may change or improve their understanding of electrical safety in the operating room.

Confidentiality
This is assured as no name will be used and the questionnaires will be coded.

Contact
If you have any questions about the study, please feel free to ask anytime throughout the study period by contacting:
Dr. Edwin Oduor (Researcher)- 0724462820, email nyahula@yahoo.com
Dr. P.O.R. Olang (Supervisor) – 0722523116, email polang@wananchi.com
CONSENT EXPLANATION IN SWAHILI
UFAFANZI WA KIBALI

Kibwagizo
Unaalikwa kushiriki utafiti unaotekelezwa na Dkt. Edwin Oduor Ojoo ambaye ni mwafunzi katika kitivo cha utabibu, Chuo Kikuu cha Nairobi.

Madhumuni
Ningependa kukagua usalama dhidi ya nguvu za umeme na vyombo vitumia nguvu za umeme katika chumba cha upusuaji unavyoeleweka na kutokelezwa na madaktari wa nusukaputi.

Nawahakikishia ya kwamba ujumbe huu utatumika kwa utafiti peke yake. Majina ya wanaoshiriki hayatatajwa. Iwapo una tashwishwi yoyote tafadhali wasiliana nasi kutumia simu ya rununu au barua pepe kwa namba na anwani zifuatazo.

Dr. Edwin Oduor (Researcher)- 0724462820, email nyahula@yahoo.com
Dr. P.O.R. Olang (Supervisor) – 0722523116, email polang@wananchi.com
APPENDIX II: CONSENT FORM

I have read the above information. All my concerns about the study have been addressed. I have not been given any incentive, monetary or otherwise to participate in the study.

I hereby give consent to participate in the study.

Participant’s name

Signature

Date

Investigator’s name

Signature

Date

FOMU YA KUKUBALI KUSHIRIKI KWA UTAFITI

Nimesoma na kuyaelewa maagizo yote yanayohusu vile utafiti utakavyotekelezwa.

Ninahakikisha sijapewa kiinua mgongo au hongo kushiriki utafiti huu.

Napeana kibali kushiriki utafiti.

Jina la mshiriki

Sahihi

Tarehe

Jina la mtafiti

Sahihi

Tarehe
APPENDIX III: QUESTIONNAIRE

Code Number.......................... Date of data collection..............................

1. Age (YEARS)
   20 – 30 ☐  30 – 40 ☐  40 – 50 ☐  over 50 ☐

2. Sex Male ☐ Female ☐

3. Qualification:
   RCO Anesthetist ☐
   Resident Anesthesiologist ☐
   Consultant Anesthesiologist ☐

4. Do you experience power outages Y/N............................................................

5. If yes how fast does the generator take over?
   Immediately ☐  Less than 10 s ☐
   After 5 min ☐

6. The following substances used in the operating room can be ignited by a spark of electricity

<table>
<thead>
<tr>
<th>Substance</th>
<th>Yes</th>
<th>No</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halothane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgical spirit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ether</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isoflurane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enflurane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iodine solution</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7. Use the key below to grade the need for the following devices in the operating room. Tick in the box

1 - not useful, should be omitted
2 - may be useful in some operating rooms
3 – must be fitted in all operating rooms

<table>
<thead>
<tr>
<th>Device</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground fault circuit interrupter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Line isolation monitors</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. Harmful effects of electric current in the operating room include

<table>
<thead>
<tr>
<th>Effect</th>
<th>Yes</th>
<th>no</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrocution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric shock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tissue damage</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. Use the table below to classify electrocution risk of the following devices found in the operating room

<table>
<thead>
<tr>
<th>Class</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Earthed, by connecting to protective earthing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Device</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laryngoscope</td>
<td></td>
</tr>
<tr>
<td>Nerve stimulator</td>
<td></td>
</tr>
<tr>
<td>Physiologic monitor</td>
<td></td>
</tr>
<tr>
<td>Electrosurgical(Diathermy) Unit</td>
<td></td>
</tr>
<tr>
<td>Defibrillator</td>
<td></td>
</tr>
<tr>
<td>Cardiac pacemakers</td>
<td></td>
</tr>
<tr>
<td>X-ray machine</td>
<td></td>
</tr>
<tr>
<td>Anesthesia machine</td>
<td></td>
</tr>
</tbody>
</table>
10. The following devices are not desirable in the operating room

<table>
<thead>
<tr>
<th>Device</th>
<th>YES</th>
<th>NO</th>
<th>DK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical extension cords</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microwave ovens</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Use the scale below to answer questions 11 and 12. Tick appropriately within the box

3 – Very important safety practice, a must
2 – Not a must for safety
1 – Makes no difference

11. Concerning the grounding pad of the electrosurgical (diathermy) unit

<table>
<thead>
<tr>
<th>Precaution</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well gelled ESU(Diathermy) grounding pad</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of grounding pad in contact with patient</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance of grounding pad from operative site</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance of grounding pad from pacemaker wires</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance of grounding pad from ECG wires</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12. For the patients with implanted pacemakers grade the following precautions

<table>
<thead>
<tr>
<th>Precaution</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative evaluation by cardiologist</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Documenting of type of pacemaker implanted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of drugs for treatment of heart block</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

13. What would you do if you encountered a machine with a potential electrical hazard?

<table>
<thead>
<tr>
<th>Action</th>
<th>yes</th>
<th>no</th>
</tr>
</thead>
<tbody>
<tr>
<td>Report immediately</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solve the problem if I can</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Take no action</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Get an alternative machine</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
14. In the last 12 months have you experienced/witnessed an electrical mishap
Y/N...........................

15. What are your routine practices to ensure electrical safety in the operating room?

<table>
<thead>
<tr>
<th>Practice</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wearing antistatic shoes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ensuring naked electricity wires are covered</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reporting all faulty devices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not using electrical extension cords</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encouraging change of wet drapes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not spilling fluids on the flow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ensuring that the devices I use have been inspected by the biomedical team</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

16. What would you consider as drawbacks towards electrical safety in the operating room

<table>
<thead>
<tr>
<th>Drawbacks</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faulty electricity outlets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of safety guidelines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faulty equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of interest on electrical safety on part of anesthetist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not considered part of anesthetists job</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of sensitization of operating room personnel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long response time from biomedical technicians/electricians</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX IV: MEDICAL EQUIPMENT ELECTRICAL SAFETY STANDARDS (IEC 60601)

Classification of medical equipment by maximum tolerated leakage currents

<table>
<thead>
<tr>
<th>Class</th>
<th>Normal condition (µA)</th>
<th>Single fault condition (µA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B(BF)</td>
<td>100</td>
<td>500</td>
</tr>
<tr>
<td>C(CF)</td>
<td>10</td>
<td>50</td>
</tr>
</tbody>
</table>

Classification of Medical Equipment by electrocution Risk from Contact with Chassis

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Earthed metal casing. 3 pin plug required. If a broken cable directs current to the chassis, it passes safely to the earth. The high current resulting will usually blow a protective fuse, shutting off power supply to the device</td>
</tr>
<tr>
<td>2</td>
<td>Outer casing is double insulated. No possibility of contact with chassis. No earth wire needed.</td>
</tr>
<tr>
<td>3</td>
<td>Electricity supplied at &lt;24V. Usually battery powered, low risk to the operator</td>
</tr>
<tr>
<td>---------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Literature Review</td>
<td>X</td>
</tr>
<tr>
<td>Protocol Development</td>
<td></td>
</tr>
<tr>
<td>Presentation of proposal</td>
<td></td>
</tr>
<tr>
<td>Ethical Approval</td>
<td></td>
</tr>
<tr>
<td>Data Collection</td>
<td></td>
</tr>
<tr>
<td>Data Analysis</td>
<td></td>
</tr>
<tr>
<td>Writing of thesis</td>
<td></td>
</tr>
<tr>
<td>Presentation of thesis</td>
<td></td>
</tr>
</tbody>
</table>
# APPENDIX VI: RESEARCH BUDGET

<table>
<thead>
<tr>
<th>ITEM</th>
<th>NUMBER/AMOUNT</th>
<th>PRICE PER ITEM</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Printer</td>
<td>1</td>
<td>5000/=</td>
<td>5,000/=</td>
</tr>
<tr>
<td>Internet services(Zuku)</td>
<td>For 10 months unlimited.</td>
<td>4500 per month</td>
<td>45,000/=</td>
</tr>
<tr>
<td>Printing cartridges</td>
<td>Six (6)</td>
<td>1200/=</td>
<td>7,200/=</td>
</tr>
<tr>
<td>Printing papers</td>
<td>2 rims</td>
<td>300/=</td>
<td>600/=</td>
</tr>
<tr>
<td>Binding charges</td>
<td>6 copies</td>
<td>200/=</td>
<td>1,200/=</td>
</tr>
<tr>
<td>Other stationery</td>
<td></td>
<td></td>
<td>1,000/=</td>
</tr>
<tr>
<td>Meals during data collection</td>
<td>20 days</td>
<td>400</td>
<td>8,000/=</td>
</tr>
<tr>
<td>Contingency cash</td>
<td></td>
<td></td>
<td>10,000/=</td>
</tr>
<tr>
<td><strong>GRAND TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>78,000/=</strong></td>
</tr>
</tbody>
</table>
Dear Dr. Ojoo,


This is to inform you that the KNH/UON-Ethics & Research Committee has reviewed and approved your above revised research proposal for the period 24th June 2010 to 23rd June 2011.

You will be required to request for a renewal of the approval if you intend to continue with the study beyond the deadline given. Clearance for export of biological specimens must also be obtained from KNH/UON-Ethics & Research Committee for each batch.

On behalf of the Committee, I wish you a fruitful research and look forward to receiving a summary of the research findings upon completion of the study.

This information will form part of the data base that will be consulted in future when processing related research study so as to minimize chances of study duplication.

Yours sincerely,

PROF A'N GUANTAI
SECRETARY, KNH/UON-ERC

c.c. Prof. K. M. Bhatt, Chairperson, KNH/UON-ERC
The Deputy Director CS, KNH
The Dean, School of Medicine, UON
The Chairman, Dept. of Surgery, UON
The HOD, Records, KNH
Supervisor: Dr. P. O. R. Olang’, Dept. of Surgery, UON