

ASSESSMENT OF INTENSIVE CARE UNIT NURSES' KNOWLEDGE OF  
ELECTRICAL SAFETY; NURSING IMPLICATIONS

by

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## ABSTRACT

Extended monitoring and treatment modalities for the critically ill patient have contributed significantly to nursing capability, while concurrently imposing increased nursing responsibility. Nurses, as the primary users of health care technology, need a comprehensive understanding of bioinstrumentation to provide safe, high level nursing care.

To date, no empirical demonstration of nurses knowledge of electrical safety is found in the literature. The purpose of this investigation was to document the level of electrical safety knowledge of a representative sample of Salt Lake City Intensive Care Unit nurses.

A researcher designed questionnaire was utilized to define the sample demographics, to test the level of electrical safety knowledge and to elicit the relationship of pertinent background variables with the percentage of correct answers in the electrical safety questionnaire.

Statistically, significant relationships were found between: age with the percentage of correct answers in the electrical safety questionnaire, sex with percentage of correct responses in the electrical safety questionnaire and number of years as a Registered

Nurse with percentage of accurate answers in the electrical safety questionnaire.

Descriptive statistical evaluation revealed that 63% of the sample answered less than 70% of the electrical safety questionnaire accurately. This information led to the conclusion that this sample demonstrated an inadequate nursing knowledge base of electrical safety. It is this lack of electrical safety knowledge that precludes the nurses ability to recognize electrical hazards as actual electrical accidents.

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## CHAPTER I

### RATIONALE FOR THE STUDY

#### Introduction

Technology, developed mainly in the post World War II era, has afforded extended monitoring and treatment modalities for the critically ill patient. This technological advance, manifested in the Intensive Care Unit primarily by bioinstrumentation, has augmented diagnostic and therapeutic nursing care. While bioinstrumentation has contributed to additional nursing capabilities, it has also imposed an increased nursing responsibility (Stanley, 1981).

Nurses are the primary users of health care technology (Schultz, 1980). As equipment users, nurses must have a comprehensive understanding of bioinstrumentation, the environment in which bioinstrumentation is used, and the added patient susceptibility equipment creates (Shepard, 1980; Stanley, 1981). Nursing has not adequately incorporated electrical safety education into basic nursing programs or hospital orientation (Abbey, 1980; Gerhard, Chalfoux & Melvin, 1979; Schultz, 1980).

Education leaders of nursing schools and hospitals have sought to improve nursing-machine interface through didactic and clinical experience geared at sharpening the nurse's understanding of the

patient's physiological representations by way of bioinstrumentation. While nursing knowledge in related areas of bioinstrumentation has improved, nursing understanding of bioinstrumentation basics (i.e., electronics and electrical safety) has seriously lagged the advances of bioinstrumentation.

In the last decade, national standards and codes have been implemented requiring hospitals to provide electrical safety education for hospital nurses (Joint Commission on Accreditation of Hospitals, 1980; National Fire Protection Association, 1978). Nurses, required to attend hospital electrical safety inservices, complain that the material presented is too technical to comprehend (Gerhard et al., 1979).

Hospital nurses knowledge of the principles of bioinstrumentation is inadequate (Foxwell, 1979; Gerhard et al., 1979; Lenihan & Abbey, 1978). To date, no empirical demonstration of the hospital nurses knowledge of electrical safety is found in the literature. This lack of empirical documentation creates a need to define the current electrical safety knowledge of the hospital nurse.

#### Purpose

The purpose of this study is to determine the level of electrical safety knowledge of a representative sample of Salt Lake City Intensive Care Unit nurses.

#### Significance to Nursing

The significance of this research to nursing lies in the

identification of the level of electrical safety knowledge of Intensive Care Unit nurses. The electrical safety questionnaire, a developing measurement tool, can provide a vehicle for nursing evaluation of Intensive Care Unit nurses knowledge of electrical safety. Once the level of electrical safety knowledge is ascertained, the strengths and needs in electrical safety knowledge can be defined and addressed.

Additionally, the electrical safety questionnaire can be used by the hospital to determine the execution of electrical safety codes and standards.

### Conceptual Framework

General Systems Theory provides an appropriate conceptual framework within which the relationship of nursing knowledge and the safe use of bioinstrumentation is readily illustrated.

Von Bertalanffy (1972) defined two types of systems, open and closed. The major difference between the two types of systems is predictability of the system-environment interaction. In an open system, outcome cannot be forecast because of the number and type of variables involved, while in a closed system, outcome is always predictable (Abbey, 1978b).

Kast and Rosenweig (1974) defined the hospital as an open sociotechnical system, a structured integration of human activities around a variety of technologies. The hospital, as most systems, has a foundation of three system components: inputs, throughputs, and outputs. Inputs greatly influence outputs. The environment,



the greatest contributor of inputs to the system, makes accessible information, new materials, new equipment and new employees (Steers, 1977). The input is modified or developed by the system during the throughput process and is returned to the environment as output.

As illustrated in Figure 1, the hospital is greatly influenced by technical and social forces. Individually and cumulatively, technical and social forces affect the type of hospital organizational input, the quality and quantity of transformational processes (throughputs) and outputs from parts as well as the whole of the hospital. In the Intensive Care Unit, the greatest percentage of technical forces is represented by bioinstrumentation. The greatest percentage of social forces is represented by nursing.

Nursing, in the acute care setting, has accepted much of the responsibility for bioinstrumentation operation. It is the social forces of the hospital, most often the nursing staff, who determine the efficiency and effectiveness of the technological services. Technology positively affects the social force.

Nursing assessment is the product of subjective data, and information that is sensed and interpreted by the individual nurse (Lenihan & Abbey, 1978). Bioinstrumentation provides objective data (Lenihan & Abbey, 1978). Ideally, the combination of subjective and objective information, and the cumulation of social and technical data, compliments and maximizes the advantages of each other. The result, optimized inputs, throughputs and outputs,

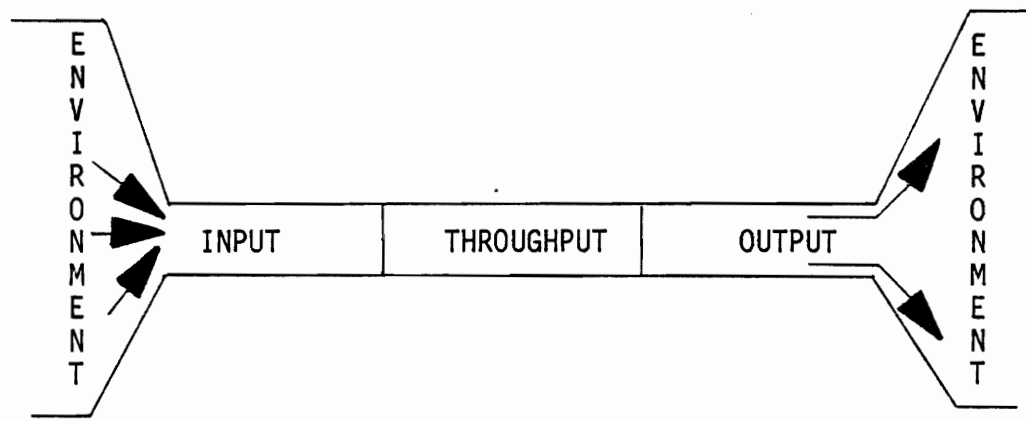


Figure 1  
Open Socio-Technical System

affirm the system goal of optimal patient care. Optimum patient care, as seen in the Intensive Care Unit effectively combines the system subsets of social forces and technology. Figure 2 demonstrates the system benefit of combining technical and social forces. The hospital utilizes a complementary combination of technical and social services. In the Intensive Care Unit, the technical services include bioinstrumentation and computer capabilities while the social forces are the nurses and the health care team. Hemodynamic parameter assessment is obtained through the use of bioinstrumentation. Through automatic data acquisition, the information is made available to the computer. The computer analyzes and reports the data, together with the analysis, to the nurse and the health care team. The nurse then evaluates the data and computer analysis in relation to what she has perceived, and then, determines nursing action. Information from both the technical source and the skill of the nurse contribute to the common goal of the system, the hospital and of the subsystem, the nurse. Bioinstrumentation extends the senses of the nurse (Abbey, 1978a). Additionally, the nurse expands the capabilities of bioinstrumentation through the proper use of the equipment and cooperation in the planning and design of future bioinstrumentation. This continued combination of technical and social resources enables the system to most effectively and efficiently reach the shared goal of optimum patient care.

The intention of this study is to determine if an harmonious

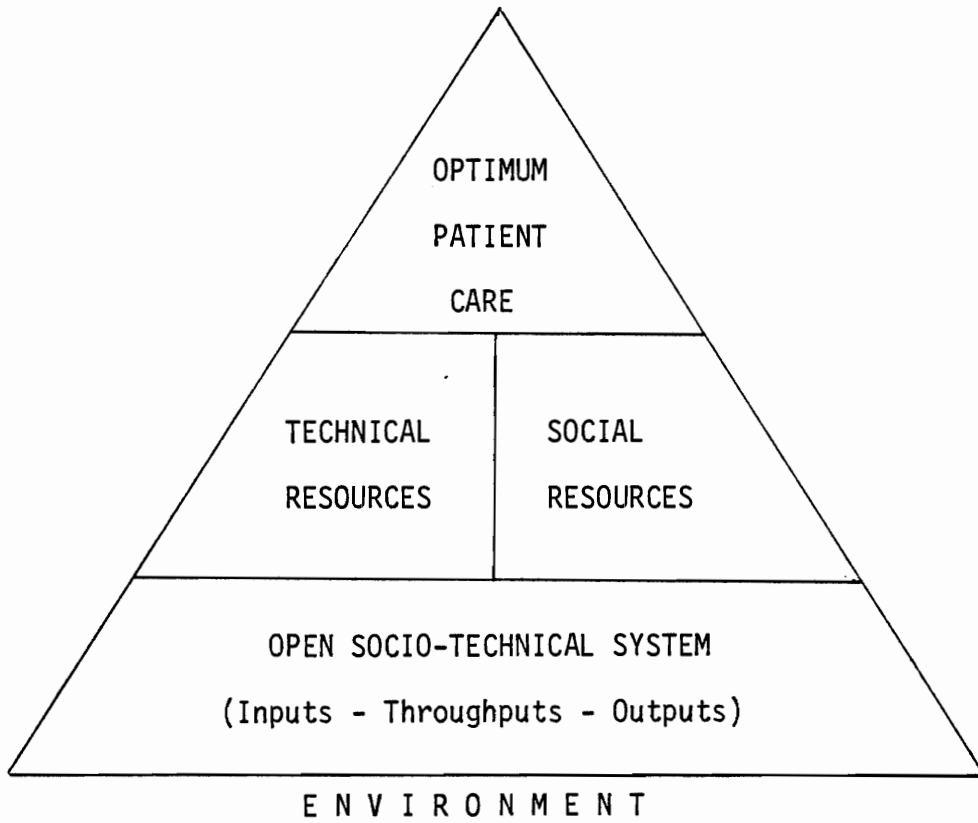


Figure 2  
Hospital System

working relationship exists between Intensive Care nurses and bio-instrumentation. Incorrectly used bioinstrumentation and/or nursing assessment jeopardizes the system goal of optimum patient care. If nurses understand and maximize bioinstrumentation to their goal of optimum patient care, then the social and technical forces of the Intensive Care Unit effectively and efficiently complement each other.

## CHAPTER II

### DEFINITION OF THE PROBLEM

#### Review of the Literature

##### Introduction

Ralph Nader (1971), consumer advocate, reported in a non-professional journal that negligence associated with electrical equipment increased the risk of death or injury in the hospitalized patient a thousandfold. Nader (1971) claimed that annually 1,200 patients were electrocuted in the hospital. Because the Nader accusations were not statistically supported, physical therapy, medical and engineering writers of the early and mid 1970's balked at the report (Arledge, 1978; Burchell, 1977; Curran, 1971; Feldtman & Derrick, 1976; Friedlander, 1971; Shaffer, Rios & Klingemaier, 1976).

However, as Burchell (1977) pointed out, the Nader report was advantageous in drawing attention to a long ignored problem. Gradually through the last decade, the potentially harmful electrical environment of the hospital has been recognized by nursing, hospital administration, engineering and medicine. Constructively accompanying this recognition are detailed plans for effective safety

programs directed at minimizing electrical hazards of bioinstrumentation (Berger, 1979; Chisholm, Telder & Dolan, 1974; Foxwell, 1972; Health Devices, 1971; Neuberg, Hunt, Budkin & Katchis, 1979; Shepard & Coddington, 1979).

The literature reviewed, as it relates to electrical safety, is categorized into the following topics: hospital electrical hazards; empirical studies of hospital electrical incidents; criteria for electrical safety: codes, standards and litigations governing hospital electrical safety; successful electrical safety programs; and the role of the nurse in electrical safety in the hospital.

#### Hospital Electrical Hazards

The five types of electrical hazards relative to bioinstrumentation identified by Shepard (1980) are: shock, burn, fire, function failure of the equipment and diagnostic or therapeutic error. To this list Weeks (1978) added the hazards of overuse of the equipment for legal protection, and failure to use equipment when standards dictate its use.

The electrical hazard of shock has received major focus in the literature. The cause of electrical shock, vulnerability of the patient to electric shock, pathophysiology resulting from electrical shock, and prevention of electric shock have been defined in nursing, hospital administration, medical and engineering literature (Burchell, 1977; Meth, 1980; Shepard, 1980; Stanley, 1971).

The Intensive Care Unit patient, by virtue of his pathophysiology and electrical environment, is particularly vulnerable to

shock hazard. Current and conductors, in close proximity to the patient and nurse are readily available in the Intensive Care Unit. A source of available current, leakage current due to grounding failure, is a frequent cause of electric shock hazard for the patient and the nurse. Within the environment of the patient and the nurse, electrical apparatus documented to leak current and serve as a current conductor includes: bedside and portable electrocardiographs, electrical beds, television sets, radios, lamps, electrical razors, a variety of patient owned appliances, intravenous therapy controllers and electrocautery devices (Aronow, Bruner, Siegel & Sloss, 1969; Dalgetty & Harbout, 1979; Geddes, Tacker & Cabler, 1975; Hospitals, 1979; Lichstein & Gupta, 1973; Sahn & Vaucher, 1976; Stanley, 1971).

As compared with the electrical hazard of shock, much less documentation exists in the literature defining the electrical hazards of burn, fire, function failure and diagnostic or therapeutic error. The electrical hazard of burn is frequently the result of patient or staff contact with hot surfaces (Shepard, 1980). Another electrical hazard of bioinstrumentation, fire, results when oxygen, a heat source and combustible materials, all available in the hospital, cause ignition and burn.

Function failure of bioinstrumentation, as another type of electrical hazard, is caused by interference or loss of electrical power and/or component failure of the device (Shepard, 1980; Stanley, 1981). It is important that suitable alternatives be



instituted by the nurse if necessary when function failure of equipment occurs.

In the experience of the author, diagnostic or therapeutic error, as an electrical hazard of bioinstrumentation, frequently occurs because the nurse is unfamiliar with the bioinstrumentation or the nurse is unable or unwilling to test the equipment for accuracy.

All electrical hazard types hold the common feature that, if recognized promptly, and specific action is taken, electrical accidents can be avoided.

### Empirical Studies of Hospital

#### Electrical Incidents

After tabulation and study of electrical hazards and electrical safety literature, Pacela (1970) determined that an accurate estimation of the incidence of electrical accidents was not possible. Unfortunately, one decade later, the problem remains. Little documentation exists regarding the number and/or type of hospital electrical accidents. The information available in the literature consists of several studies and individual incident reports.

Bruner, Aronow and Cavicchi (1972) conducted a 42 month study of the electrical accidents in a 1,000 bed hospital. Prior to the study, these investigators educated the hospital staff in electrical incident recognition. Then, after meticulous screening of reported incidents, these investigators defined 55 electrically related incidents including three electrical accidents that

resulted in patient ventricular fibrillation (see Table 1).

In another study, Petty (1976) studied 354 consecutive cases of mechanical ventilation in a hospital respiratory care unit. Within that sample, 103 episodes (29%) of ventilator malfunction were documented (see Table 2).

In a third study, Abramson, Wald, Grenvik, Robinson and Synder (1980) reviewed a five year period of Intensive Care Unit incident reports in a 560 bed hospital. Examination of 145 reports of adverse incidents revealed 92 incidents of human error and 53 incidents of equipment malfunction (see Table 3). Note that several areas under the heading of human error such as medications, communications, shortage of nurses and intravenous fluids might not relate to electrical incidents. Analyzed incident reports involving the respiratory and cardiovascular equipment accounted for 47% of human error incidents documented in the study. Of the 145 analyzed incident reports, at least 66% of the occurrences involved human error in equipment use or equipment malfunction. Thus, a minimum of 66% of the reported occurrences were adverse electrical incidents secondary to bioinstrumentation.

Abramson et al. (1980) found that patient mortality for those patients with a documented adverse incident in the Intensive Care Unit was 41%, considerably higher than the institution's average Intensive Care Unit patient mortality of 21%. However, as the study mentioned, this increased mortality may be explained by the positive relationship of patient acuity and bioinstrumentation.

Table 1  
 Analysis of Reported Incidents in a  
 General Hospital

Incident	Number Reported	Percentage (%)
Ventricular Fibrillation	3	5
Shocks	22	40
Skin Burns	14	25
Electrical Arcs and Fires	10	18
Instrument Failure	6	12
<b>Total</b>	<b>55</b>	<b>100</b>

Note. Adapted from Bruner, Aronow & Cavicchi, 1972, p. 223.

Table 2  
 Analysis of Ventilator Malfunction Incidence  
 in a Respiratory Care Unit

Incident	Number Reported	Percentage (%)
Ventilator Mechanical Failure	6	6
Inspired Air Overheating	7	7
Alarm Failure	13	13
Alarm Turned Off	32	32
Inadequate nebulization	45	45
<b>Total</b>	<b>103</b>	<b>100</b>

Note. Adapted from Petty, 1976, p. 113.

Table 3  
 Analysis of Intensive Care Unit Incident  
 Reports

Incident	Number Reported	Percentage (%)
Human Error		
Respiratory Equipment	23	16
Medications	21	16
Cardiovascular equipment	20	18
Communication	13	9
Shortage of nurses	8	5
Intravenous fluids	7	5
Subtotal	92	64
Equipment Malfunction		
Respiratory	34	23
Cardiovascular	16	11
Miscellaneous	3	2
Subtotal	53	37
Total	145	100

Note. Adapted from Abramson, Wald, Grenvik, Robinson, & Synder, 1980, pp. 1583.

In summary, the studies by Bruner et al. (1972) and Petty (1976) demonstrated that the instrument function failure exceeded human error as the cause of hospital electrical accidents. Abramson et al. (1980) documented the converse, that human error is a greater cause of hospital electrical incidents than instrument function failure.

Many brief accounts of singular electrical incidents are found in the literature. Descriptive reports of electrical equipment that has been involved in electrical incidents include: bedside and portable electrocardiographs, electrical beds, television sets, radios, lamps, electric razors, patient owned equipment, intravenous therapy controllers and electrocautery devices (Aronow et al., 1969; Dalgetty & Harbout, 1979; Geddes et al., 1975; Hospitals, 1979; Lichstein & Gupta, 1973; Sahn & Vaucher, 1976; Stanley, 1971).

Limited documentation of hospital electrical accidents is the result of two factors; difficulties in identification of electrical accidents and the absence of a commonly shared reporting system (Bruner et al., 1972; Kilpatrick, 1971). Several factors obscure identification of electrical accidents. First, minute amounts of leakage current, unable to be humanly sensed, may not be recognized prior to, or after, the electrical accident has occurred. Secondly, the patient most susceptible to leakage current, is frequently most vulnerable to arrhythmias secondary to pathology. Therefore, it is possible to view electrical accidents as a pathological event (Hochberg, 1971). Additionally, unless large amounts of current

are conducted through the body during the electrical accident, identifiable tissue damage does not occur (Kilpatrick & Kilpatrick, 1972).

Finally, incident determination is hindered by the fact that nurses and physicians, who are in the best position to identify and act on electrical hazards, have historically had little education in electronics or electrical safety (Abbey, 1980; Gerhard et al., 1979; Schultz, 1980). Lack of knowledge of electrical safety precludes one's ability to recognize electrical hazards as actual electrical accidents.

Sharing information regarding electrical accidents promotes electrical safety understanding and subsequent prevention of electrical accidents. Until a nationwide reporting system is established for accident reporting, accidents should be published in journals, thereby making them accessible to those involved with electrical safety (Burchell, 1977).

#### Criteria for Electrical Safety

Safe use of bioinstrumentation by the Intensive Care Unit nurse, is summarized in Table 4.

With regard to electrical safety, the nursing responsibility includes: a) identification of the electrically sensitive patient, b) minimization of excessive electrical current, c) identification of equipment hazards, d) purchase and use of appropriate equipment and e) education of equipment users in the areas of electronics and electrical safety.

Table 4  
Criteria for Electrical Safety

- 
1. Identify the electrically susceptible patient
    - 1.1 Reduced skin impedance
    - 1.2 Cardiac catheterization
    - 1.3 Body cavity catheterization
    - 1.4 Metabolic disturbances (hypoxia, acidosis)
  2. Utilize electrically isolated monitor for electrically sensitive patients
  3. Minimize excessive electrical current
    - 3.1 Turn equipment on before connecting to patient
    - 3.2 Turn equipment off before disconnecting from patient.
    - 3.3 Minimize static charge
      - 3.3.1 Touch ground before patient
      - 3.3.2 Use grounding cloth and flooring
      - 3.3.3 Keep room humidity greater than 40%
      - 3.3.4 Wear natural fiber uniforms
    - 3.4 Isolate pacemaker terminals from environment
  4. Monitor for any signs of equipment hazard
    - 4.1 Avoid use of cheater adapters or extension cords
    - 4.2 Avoid use of equipment that was dropped, spilled on, or has smoked or shocked.
    - 4.3 Avoid use and report a disrupted ground wire
      - 4.3.1 frayed, broken, bent plugs or cords
      - 4.3.2 burnt or cut plugs or cords
      - 4.3.3 loose or damaged receptacles
  5. Buy equipment knowledgeably
    - 5.1 Participate in equipment design
    - 5.2 Involve engineering, medicine and nursing
  6. Educate equipment users
    - 6.1 Basic electronics principles
    - 6.2 Simple directions on equipment case
    - 6.3 Mandatory inservicing on new machines
    - 6.4 Routine continuing education in bioinstrumentation
- 

Note. Adapted from Green, Breneman, Goldberg, Harkin, Hieb, Kosowsky, Parker, Rinaldo, Webb & Nobel, 1971, pp. A254-A255; Meth, 1980, pp. 1344-1348; Shepard, 1980, pp. 19-20; Stanley, 1980, pp. 811-813).



### Codes, Standards and Litigation

Today, many codes, standards, and legal actions specifically address the area of safe use of bioinstrumentation. Two of the most widely employed guideline organizations are the Joint Commission on Accreditation of Hospitals and the National Fire Prevention Association.

The Joint Commission on Accreditation of Hospitals (1980) outlined the need to educate all nursing personnel in the electrical hazards of shock, burn, fire explosion and power failure. In order for the hospital to gain or renew accreditation, by the Joint Commission on Accreditation of Hospitals, each hospital nurse must have electrical safety instruction and the institution is required to have a productive multidisciplined hospital safety committee (Joint Commission on Accreditation of Hospitals, 1980).

The National Fire Protection Association (1978) issued standards and codes for health care facilities. The National Fire Protection Association outlined the electrical hazards, detailed electrical wiring procedures, specified electrical appliance standards and reported the hospital administrative responsibilities.

Gradually, lawmakers are recognizing the cause and effect relationship of hospital electrical equipment and ensuing injury or death (Swartz, 1969). The physician or hospital has been held legally responsible for the misuses of patient care equipment (Rubin, 1974). As nursing moves toward greater independence and autonomy, the judicial system is requiring accountability of the nurse and the nurse employer for negligent acts or errors of omis-

sion (Walker, 1980).

### Successful Electrical Safety Programs

The engineering literature defines an effective electrical safety program as a blend of education for electrical equipment users, routine maintenance and inspection of that equipment and responsible informed equipment purchase by a multidisciplinary committee (Arledge, 1976; Burchell, 1977; Chisholm, Telder & Dolan, 1974; Foxwell, 1972; Stanley, 1971; Williams, 1973).

An efficacious electrical safety program is tailored to each institution. A comprehensive assessment of hazardous situations, procedures, and equipment is the foundation of risk management (Abramson et al., 1980; Bruner et al., 1972).

Basic to any electrical safety program is the education of the equipment users. Instruction of those using bioinstrumentation must include information in the following areas: type of electrical hazards, basic principles of electricity, recognition of hazards, prevention of accidents and the physiological effect of electrical current (Yoo & Broderick, 1978). Effective methods of electrical safety communication include: simulator teaching, workshops, use of bulletin boards, films, slide presentations, booklets, posters and employee publications (Bertz, diMonda & Sprague, 1976; Pfeiffer, 1975).

### Role of the Nurse in Hospital

#### Electrical Safety

It is the Intensive Care Nurse who consistently monitors the

critically ill patient (Fairchild & Allen, 1971; Shepard, 1980). In order to function as a competent observer and user of bioinstrumentation, the nurse must understand the fundamentals of patient care equipment as well as safe use of that equipment (Jacobs, 1978; Weeks, 1978). Unfortunately, nurses lack the necessary preparation in the area of bioinstrumentation to understand electronics or electrical safety (Abbey, 1978; Gerhard et al., 1979; Schultz, 1980).

Shepard (1980) reported that 75 % of hospital electrical hazards are evident before the electrical accident. Because nurses are in the best vantage point, nursing has an integral role in prevention, detection and management of electrical accidents (Gerhard et al., 1979; Petty, 1976).

### Summary

The nursing, engineering, medical and legal literature reviewed demonstrated that electrical hazards potentially exist in the Intensive Care Unit and that the nurse has an active role in prevention, recognition and management of these hazards. Unfortunately, nurses do not receive adequate electrical safety information. No demonstration of empirical evidence of nursing knowledge was found in the literature.

### Research Questions

1. To what degree do background variables affect the level of electrical safety knowledge of Salt Lake City Intensive

Care nurses?

2. What level of electrical safety knowledge exists in Intensive Care Unit nurses of Salt Lake City?

### Operational Definitions

#### Salt Lake City Intensive Care Nurse

A registered nurse who is currently employed in one of the seven selected Salt Lake City area hospital Intensive Care Units in either a patient care or a nursing management capacity.

#### Intensive Care Unit

A distinct geographical area of the hospital, instituted to enhance nursing care of the Intensive Care patient by the Intensive Care nurse (Disch, Breu & Reynolds, 1980).

#### Intensive Care Patient

A critically ill hospitalized person who meets the following criteria:

1. has actual or possible life threatening compromise;
2. demands constant nursing assessment, diagnosis and care to reinstate health; and,
3. is located in an Intensive Care Unit (Disch et al., 1980).

#### Background Variables

Pertinent background variables are employer, age, sex, length of practice as a registered nurse, length of practice as an Inten-

sive Care nurse, educational preparation and previous electrical safety education, self rating of electrical safety knowledge and self rating of adequacy of that knowledge.

#### Educational Source

A potential origin of the Intensive Care Unit nurse's information of electrical safety related to electrical bioinstrumentation.

#### Electrical Safety Knowledge

Electrical safety knowledge consists of prudent and safe operation knowledge of electrical devices utilized in diagnostic and therapeutic nursing care.

#### Assumptions

The basic assumption of this study is that as electrical bioinstrumentation is an integral part of the nursing care of an Intensive Care patient, safe use of the bioinstrumentation by the nurse, is a nursing responsibility.

Another assumption of the investigation is that all questionnaire respondents will be truthful in the information they provide.

#### Limitations

Several limitations of the study exist. The limitations include: time and financial constraints, subject availability and a non-randomized sample.

The study results may not be statistically generalizable to a larger population because the sample was confined to selected hospitals in one geographical location. However, this investigation

is the first step toward establishing a measurement tool to assess Intensive Care Unit nurses knowledge of electrical safety.

## CHAPTER III

### METHODOLOGY OF THE STUDY

#### Design

The design of this study was a descriptive, correlational investigation of the electrical safety knowledge of seven selected Salt Lake City hospitals Intensive Care Unit nurses. A researcher designed questionnaire was utilized to determine this knowledge and related background data.

#### Sample

One hundred and twenty-five Intensive Care Unit nurses, currently employed by one of the seven selected Salt Lake City hospitals, voluntarily participated in the study as a representative sample of Salt Lake City Intensive Care Unit nurses. Intensive Care Unit nurses were chosen for investigation because of their greater need to use bioinstrumentation in the clinical area.

#### Instrument

A researcher designed questionnaire consisting of 17 background items and 25 multiple choice questions was utilized to test the research questions (see Appendix A). The questionnaire and correct multiple choices were determined to be pertinent, clear and precise

by a panel of experts prior to questionnaire distribution.

The questionnaire addressed the two research questions of:

1. To what degree do background variables affect the level of electrical safety knowledge of Salt Lake City Intensive Care Nurses?
2. What level of electrical safety knowledge exists in Intensive Care Unit nurses of Salt Lake City?

### Procedures

Following approval of the thesis supervisory committee, the thesis proposal was submitted to the University of Utah Review Committee for Research with Human Subjects. Permission to conduct the investigation was granted by the committee and investigation of the preliminary research criteria of each Salt Lake City hospital was accomplished. Subject anonymity was assured.

A pilot study of the questionnaire was conducted in April, 1981. Twenty participants, including graduate nursing students with previous graduate level education in bioinstrumentation, Intensive Care Unit head nurses and staff nurses, completed and critiqued the questionnaire in order to establish questionnaire clarity and reliability.

Computer data analysis of the multiple choice items of the pilot study questionnaire revealed a Hoyt coefficient reliability of 0.50. Thirteen multiple choice items of the pilot study questionnaire were rewritten in an attempt to improve the pilot study questionnaire reliability. Reliability of the rewritten questions



was not restudied because of time and financial constraints of the investigator.

In preparation for questionnaire distribution, the investigator described the study objectives, purpose and method of implementation to each involved Intensive Care Unit head nurse. The investigator also met with staff nurses at unit meetings to describe the purpose of the study and the procedures involved. Opportunity was provided for individual questions from the Intensive Care Unit head nurses and staff nurses.

Over a four day period in May, 1981, 191 questionnaires were distributed to Intensive Care nurses in the seven selected Salt Lake City hospitals. The study purpose, benefits and risks, along with the consent form and questionnaire were briefly explained to each individual nurse by the investigator. Consent forms and questionnaires were distributed to all nurses who agreed to participate in the study. The participating nurse was requested to complete the questionnaire independently, refrain from discussing the questionnaire with others until the data collection was completed and to leave the completed consent and questionnaire forms in a prearranged location.

All nurses participating in the study signed a consent form in order to fulfill the preliminary research criteria of individual hospitals and the University of Utah Review Committee for Research with Human Subjects. The identity of the nurse participating in the study was required only on the consent form. The

consent forms were stored separately from the questionnaires and were available only to the investigator.

Within five days of the onset of questionnaire distribution, 125 (65%) completed questionnaires were collected by the investigator. The information was then coded and computer processed in order to determine the characteristics of the study sample and to insure anonymity of the subjects and hospitals.

#### Data Collection Sites

The following data collection sites served as a representative sample of the Intensive Care Units of Salt Lake City hospitals: Cottonwood Hospital, Holy Cross Hospital, LDS Hospital, Primary Children's Hospital, St. Mark's Hospital, University of Utah Hospital and Veterans Administration Medical Center.

#### Data Analysis

The bulk of the data collected in this investigation was nominal. In order to facilitate data presentation, major data analysis consisted of frequency distributions, percentages, means and ranges.

The relationship of individual background variables and the level of Intensive Care Unit nurse's electrical safety knowledge was defined by an analysis of covariance utilizing the Pearson Product Moment Correlation.

## CHAPTER IV

### DATA ANALYSIS AND FINDINGS

#### Introduction

The purpose of this investigation was to document the level of electrical safety knowledge of a representative sample of Salt Lake City Intensive Care Unit nurses. A researcher designed questionnaire was utilized to define the sample demographics, to test the level of electrical safety knowledge and to elicit the relationship of pertinent background variables with the level of electrical safety knowledge. Descriptive and correlational statistics of the Statistical Package for the Social Sciences were employed to accommodate data analysis and findings within the research questions of:

1. To what degree do background variables affect the level of electrical safety knowledge of Salt Lake City Intensive Care Unit nurses?
2. What level of electrical safety knowledge exists in Intensive Care Unit nurses in Salt Lake City?

The data analysis and findings are divided into three categories. The first section characterizes and describes the study

sample. The second category delineates the level of electrical safety knowledge of study participants. The third section focuses on the relationship of the electrical safety questionnaire score and the independent background variables of the study.

### Descriptive Characteristics of the Sample

The study sample comprised 125 Intensive Care Unit nurses employed by one of seven selected Salt Lake City hospitals. The frequency and distribution of each hospital's study participants is specified in Table 5. Combined, the seven hospitals afforded a total population of 430 Intensive Care Unit Registered Nurses. The sample represented 29% of the population. An analysis of variance (ANOVA) demonstrated no difference between the nurses electrical safety questionnaire scores in the individual hospitals.

### Sample Demographics

The summary of descriptive characteristics of the sample is compiled in Table 6. Ninety-one percent of the study participants were female, and 9% were male. The average age of the study subjects was 28.4 years, with 60% of the sample being 28 years or less (see Figure 3). The majority of the investigated nurses, 43.2%, were employed in a general Intensive Care Unit (refer to Table 7). Of this group, 12% rotate work settings between a general Intensive Care Unit and a Coronary Care Unit.

The mean tenure as a Registered Nurse was 6.8 years. The

Table 5  
 Frequency and Percentage Distributions of  
 Individual Hospitals

Hospital Code	Total ICU RNs per hospital	# in study sample	% total ICU RNs per hospital	% of study sample
1	90	20	22	16
2	39	10	26	8
3	50	5	10	4
4	71	9	13	7.2
5	21	11	52	8.8
6	109	32	29	25.6
7	50	38	76	30.4
Total	430	125	29	100.0

Table 6  
Summary of Descriptive Characteristics of  
the Study Sample

Variable	N	%	$\bar{X}$	S.D.	Range
<u>Sex</u>	125	100			
Female	114	91.2			
Male	11	8.8			
<u>Age in years</u>	125	100.0	28.4	7.79	22-54
<u>Years as a R.N.</u>	125	100.0	6.8	7.20	.08-36.5
<u>Years as an ICU R.N.</u>	125	100.0	3.7	3.50	.08-23.0
<u>Hours worked per week in ICU</u>	125	100.0	36.4	8.10	8-50
<u>Previous Electrical Safety Education</u>	91	73.0			
<u>Self rating of Electrical Safety Knowledge</u>	125	100.0	2.6	0.90	1-5
<u>Self rating of Adequacy of Electrical Safety Knowledge</u>	125	100.0	2.5	1.25	1-5
<u>Number of Professional Journals regularly read</u>	103	82.0	2.0	0.95	1-5
<u>Electrical Safety Questionnaire Score</u>	125	100.0	15.8	3.25	7-23

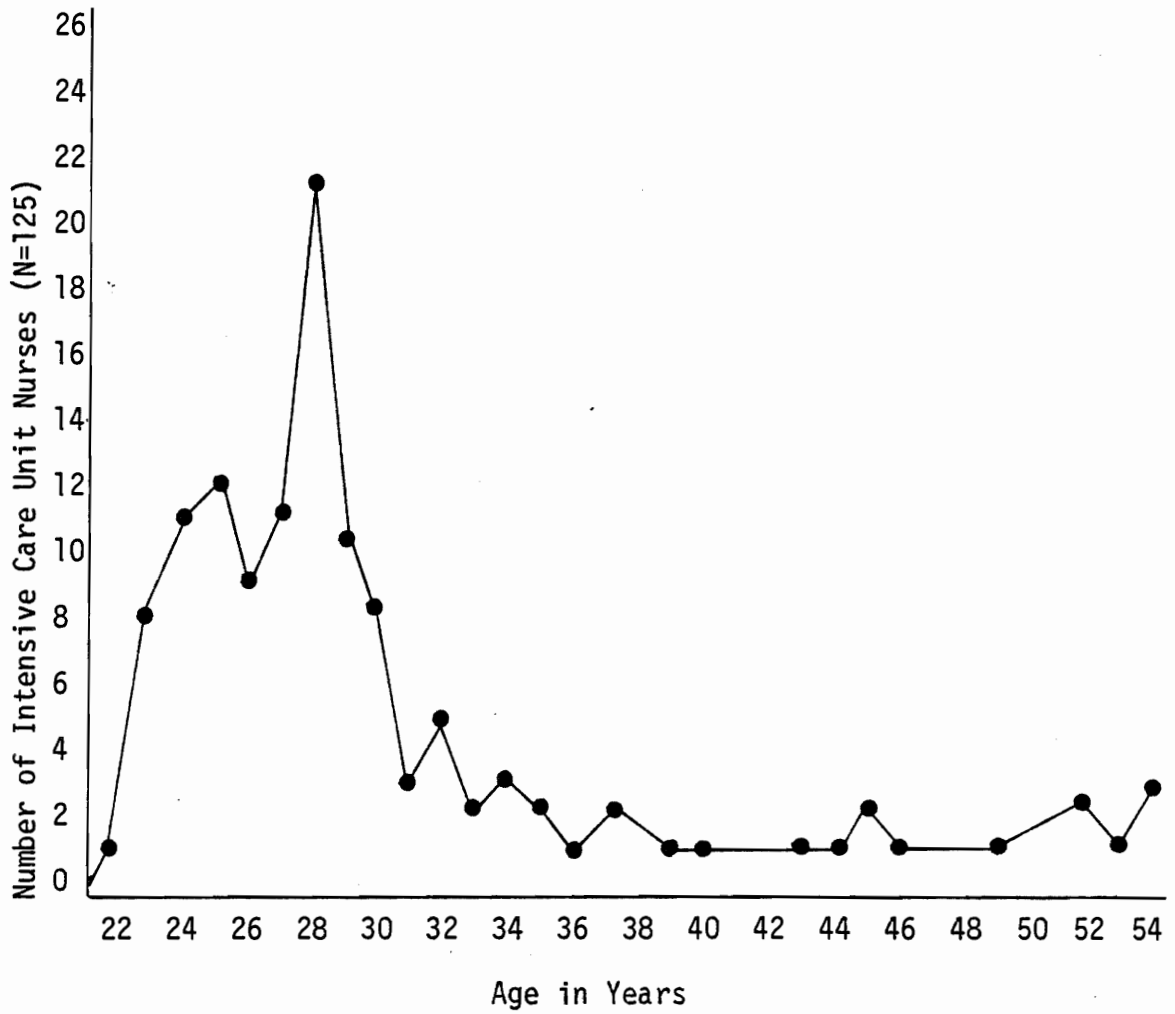


Figure 3  
Age Distribution of Intensive Care  
Unit Nurses

Table 7  
Intensive Care Unit Nurse  
Sample Distribution

	N	%
General	54	43.2
Coronary	13	10.4
Cardiovascular/Thoracic	13	10.4
Pediatric	13	10.4
Surgical	12	9.6
Respiratory	7	5.6
Newborn	7	5.6
Shock and Trauma	5	4.0
Medical	1	0.8
Totals	125	100.0



length of time as an Intensive Care Unit Registered Nurse ranged from 0.8 years to 23 years. One area of conspicuous inconsistency was noted on the questionnaire of a participant who reported her age as 35 years and employment as an Intensive Care Unit nurse for 23 years. This information is incongruous from the standpoint of the nurses age, expected age at graduation, and the availability of Intensive Care Unit employment in 1958.

### Educational Preparation

Sixty-five percent of the participants were prepared as a Registered Nurse with a Bachelor of Science in Nursing (note Table 8). Table 9 details the sources of previous electrical safety education for the 73% of the sample that acknowledged exposure to earlier electrical information. Interestingly, only 53% of the nurses with previous electrical safety education received that information from hospital inservice. All hospitals involved in the study were accredited by the Joint Commission on Accreditation of Hospitals. In order to become accredited by the Joint Commission on Accreditation of Hospitals, the hospital must show evidence of employee electrical safety continuing education and new employee orientation to electrical safety. This instruction includes the following topics: electricity use, electrical hazards of electrical shock, burn, explosion and function failure.

Twenty-two percent of the nurses studied, received electrical safety education in nursing school. Twenty percent of the study participants self-initiated electrical safety education with

Table 8  
Educational Preparation as a  
Registered Nurse

	N	%
Associate degree	28	22
Diploma	16	13
Bachelor of Science in Nursing	81	65
Totals	125	100.

Table 9  
Source of Electrical Safety Education

	N	%
Hospital Inservice	74	53.0
Nursing School	31	22.1
Continuing Education	17	12.1
Own Reading	11	7.9
Military Service	3	2.1
Electrical/Engineering Course	2	1.4
Mining Class	1	0.7
Television	1	0.7
Totals	140	100.0

continuing education and reading. Three study participants, one male and two females, reported previous electrical safety content in engineering, electronics and mining courses. The male participant scored 92% accuracy in answering the electrical safety questionnaire. However, the female nurses with electrical safety education through courses of electronics and mining, both correctly answered 44% of the electrical safety questionnaire. Two male nurses and one female nurse indicated previous electrical safety education while in the military. The male subjects responded correctly to 72% and 76% of the questions on the electrical safety questionnaire. The female nurse correctly answered only 52% of the electrical safety questionnaire. Comparatively, 27% of the male subjects received electrical safety education through military or electrical courses, while only 2.4% of the female participants received electrical safety information in military, mining or an electronics course.

#### Journals Regularly Read

The average number of professional journals read regularly as indicated by the study sample was two. Eighteen percent of the sample did not indicate that they read journals. The study participants identified the following journals as containing electrical safety information: R.N., American Journal of Nursing, Nursing 81, Heart and Lung, and Critical Care Nurse.

### Self Rating

Eighty-six percent of the participants rated themselves with moderate, or less than moderate, electrical safety knowledge (see Figure 4). Most nurses (89%) indicated that their electrical safety knowledge was less than adequate (refer to Figure 5). Eleven percent of the nurses indicated that their electrical safety knowledge was better than adequate while 11% stated they felt their knowledge to be adequate. It is worthy to note that only 14.4% of the sample correctly responded with a score of 76% or more of the electrical safety questionnaire.

### Reported Electrical Accidents

Thirteen percent (18 of 125) of the nurses studied reported personal involvement in an electrical accident. Five nurses, 4% of the sample, stated they had been involved in two or more accidents. A total of 22 electrical accidents were reported, one was determined by the investigator to be an electrical hazard (the electrical cord was worn) not an electrical accident. Therefore, it was deleted from the results. The types of electrical accidents reported by the nurses included electric shock, burn, fire and functional failure of equipment (note Table 10). A description of each incident is found in Table 11.

Electric shock accounted for 29% of reported incidents. Sixty-seven percent of the incidents were caused by nursing error. Thirty-three percent of electrical shock accidents involved lethal cardiac arrhythmias for the patient caused by the nurse. Electric

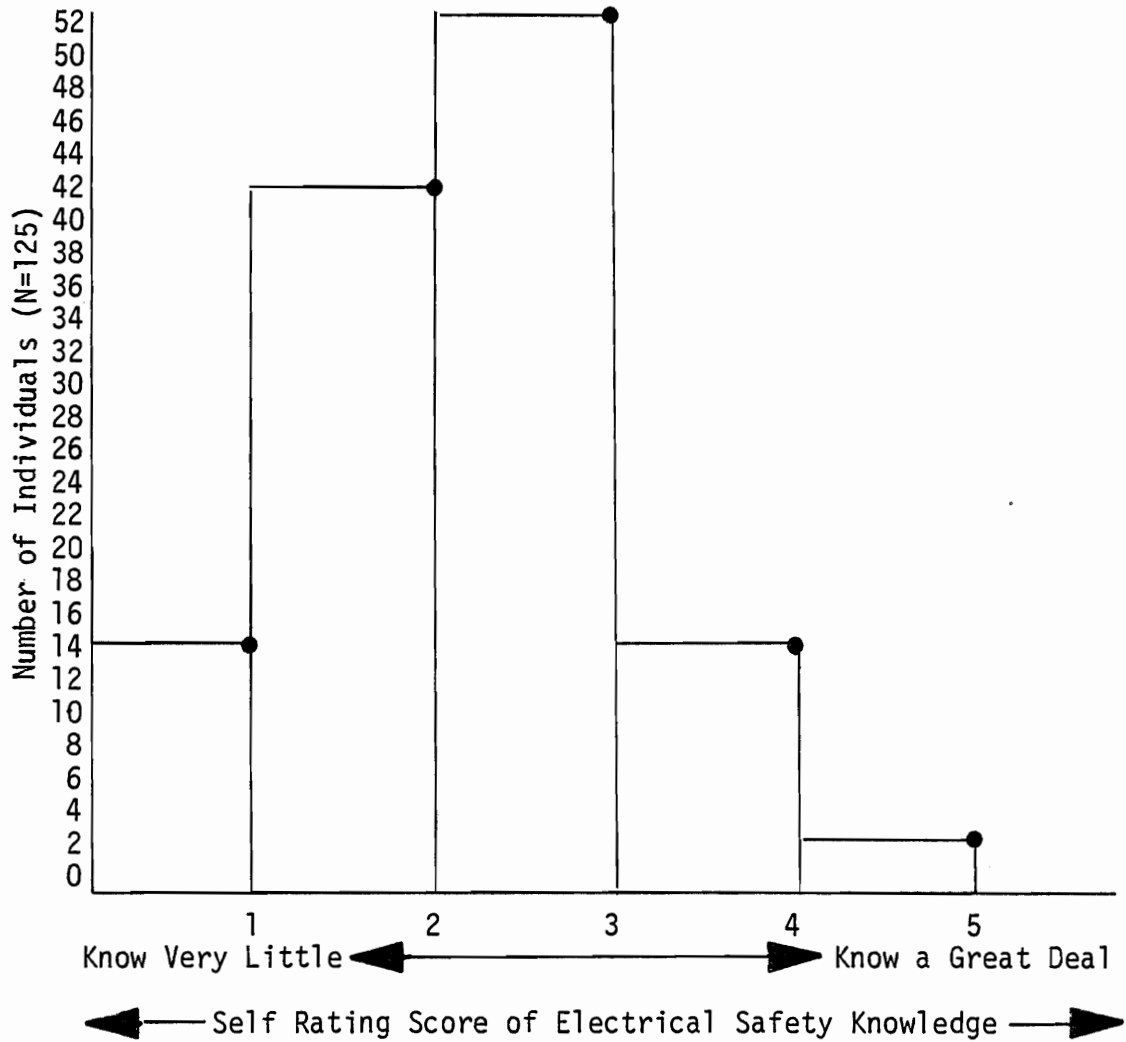


Figure 4  
Individual's Self Rating of Electrical  
Safety Knowledge

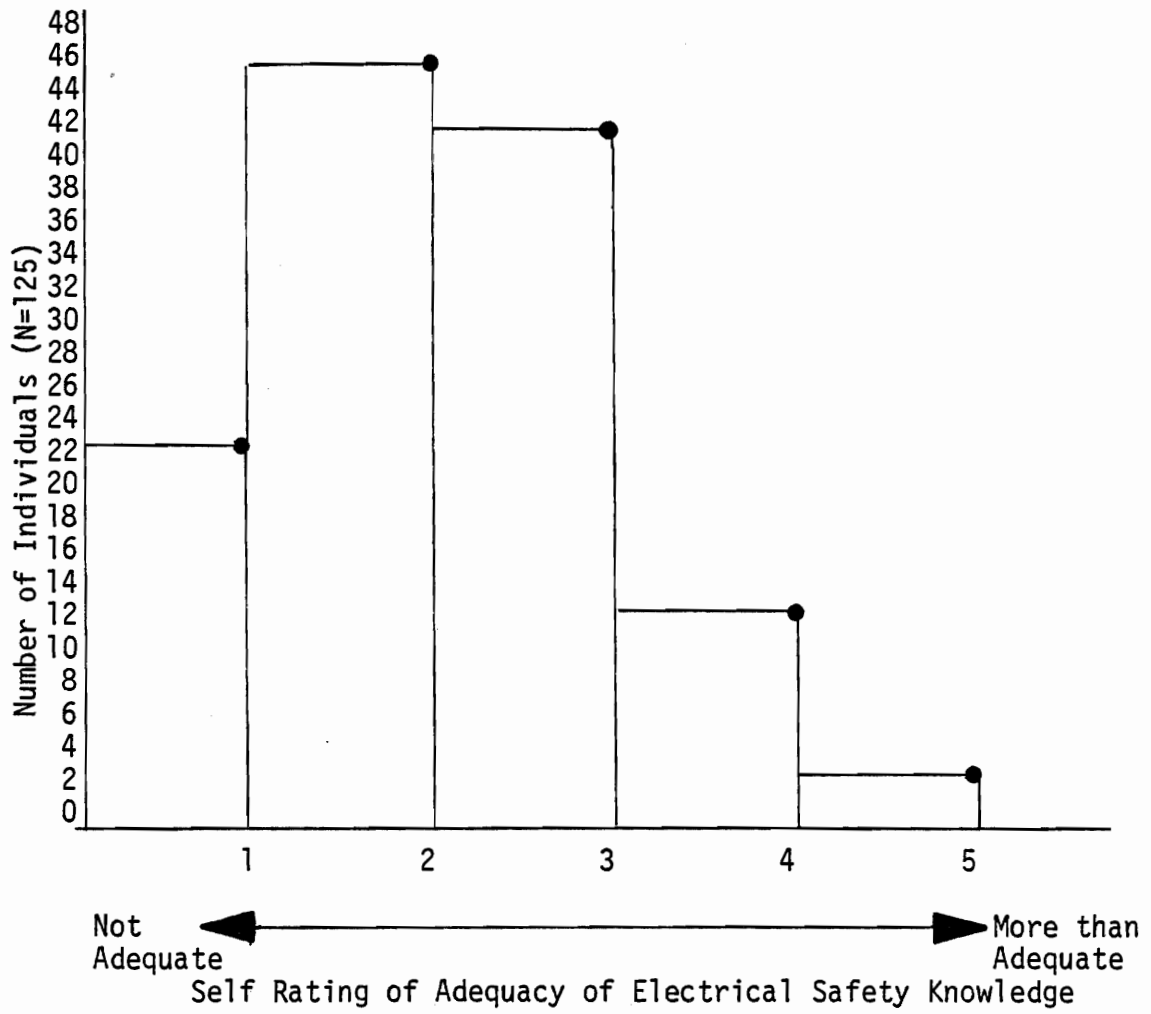


Figure 5  
Individual's Self Rating of Adequacy of Electrical  
Safety Knowledge

Table 10  
Study Participants Reported Involvement in  
Electrical Accidents

Accident Type	N	%	Probable Cause = Nursing Error	% Nursing Error
Electrical Shock	6	29	1	67
Burn	6	29	6	100
Fire	1	4	--	--
Function Failure	8	38	2	25
Totals	21	100.	12	57



Table 11

## Synopsis of Accidents Reported by Study Participants

Type of Electrical Accident	Probable Cause	Outcome	Circumstances
Electric Shock	Nx error <sup>a</sup>	1. Nurse macroshock	Contact with bed when patient defibrillated.
	Nx error	2. Nurse macroshock	Stood in leaking refrigerator coolant.
	Nx error	3. Patient microshock Ventricular tachycardia	Ungrounded bed. Intracardiac pressure lines connected to monitor.
	Nx error	4. Patient microshock Ventricular fibrillation	Ungrounded bed. Left atrial pressure line connected to monitor.
	Eq. failure <sup>b</sup>	5. Nurse macroshock	Contacted bed.
	Eq. failure	6. Nurse macroshock	Contacted bed.
Burn	Nx error	1. Infant burn	Thermal source = heating blanket.

Table 11 Continued

Type of Electrical Accident	Probable Cause	Outcome	Circumstances
Burn (continued)	Nx error	2. Patient burn	Alcohol gauze used for defibrillation. Electrical arc between paddles.
	Nx error	3. Patient burn	Prep solution spilled onto metal grounding plate attached to patient.
	Nx error	4. Patient burn	Electrocautery ground not secure on skin.
	Nx error	5. Patient burn 2nd & 3rd degree	Excessive saline on gauze leaked between gauze pads & down patient's side to bed. Large electrical arch seen with defibrillation.
	Nx Error	6. Patient burn	Solution spilled on electrocautery ground.
Fire	Eq. failure	1. Fire	Wire shorted in ECG monitor.
Function Failure	Nx error	1. Shorted ventilator motor	Water hose kinked-water leaked into motor.

Table 11 Continued

Type of Electrical Accident	Probable Cause	Outcome	Circumstances
Function Failure (cont.)	Nx error	2. Shorted intra-aortic balloon pump motor.	Wrong size fuse used.
	Eq. failure	3. Smoking ECG monitor	-----
	Eq. failure	4. Smoking ECG monitor	-----
	Eq. failure	5. Overloaded circuit blew	Multiple life support equipment, (i.e. Intraaortic Balloon Pump, ventilators, intravenous control pumps) on circuit. Took 48 hrs. to repair.
	-----	6. Electrical black-out	Failure of emergency generator backup.
	Eq. failure	7. Shorted bed	Previous damage to electrical bed.
	Eq. failure	8. Shorted wall receptacle.	Construction ongoing. Leaking roof. Brief flame seen at receptacle.

<sup>a</sup>Nx error = Nursing Error, <sup>b</sup>Eq. failure = Equipment failure

shock of the nurse occurred in 67% of the reported incidents.

Patient thermal burn comprised 29% of the reported electrical accidents. All of these accidents resulted from nursing error in equipment use. Fire was the third type of electrical accident named. This had a 4% occurrence in the reported electrical accidents.

Function failure or equipment failure was the most commonly reported electrical accident. Function failure comprised 38% of all electrical accidents. Nursing error was responsible as the cause of two electrical accidents. Both incidents involved life support equipment, one of the Intraaortic Balloon Pump and the other a ventilator.

#### Identified Resources for Electrical Problems

Ninety-two percent of the sample readily identified resources for reporting electrical accidents (refer to Table 12). The resource varies from institution to institution. Only one participant identified the incident report as a means of appropriately documenting an electrical accident.

Resources for reporting faulty equipment or electrical hazards include the Biomedical engineer (44.6%), maintenance department (29.7%) and supervisory nursing personnel (13.2%). Again, the majority of the study sample (97.4%) was able to readily identify resources for reporting of faulty equipment or electrical hazards (Table 13). Additionally, 61% of the study participants

Table 12  
Identified Resources for Reporting Electrical  
Accidents

	N	%
Head nurse, nursing supervisor or charge nurse	86	39.1
Biomedical engineer	66	30.0
Security	34	15.4
Maintenance	27	12.3
Safety Committee	3	1.4
Hospital telephone operator	3	1.4
Incident Report	1	0.4
Totals	220	100.0

Table 13  
 Identified Resources for Reporting of Faulty  
 Equipment or Electrical Hazards

	N	%
Biomedical Engineer	81	44.6
Maintenance	54	29.7
Head nurse, nursing supervisor or charge nurse	24	13.2
Security	10	5.5
Department responsible for equipment <sup>a</sup>	7	3.8
Safety committee	3	1.6
Unit clerk	3	1.6
<b>Total</b>	<b>182</b>	<b>100.0</b>

<sup>a</sup>e.g. Pharmacy, Central Service

stated that resource attention to electrical accident, faulty equipment and electrical accident was prompt (note Table 14).

#### Level of Electrical Safety Knowledge

The level of electrical safety knowledge of the nurses participating in the study was documented by establishing the percentage of correctly identified items on the electrical safety questionnaire. Unanswered questions were statistically analyzed as incorrect. The Hoyt coefficient of reliability for the electrical safety questionnaire was established at .60.

Sixty-three percent of the study participants answered less than 70% of the electrical safety questionnaire items correctly (see Figure 6). Additionally, the percentage of study participants accurately responding to each item was calculated (refer to Figure 7). Questions 1, 6, 8, 9, 10, 11, 17, 18, and 23 were answered correctly by less than 65% of the study participants. These questions will be discussed in Chapter V.

#### Relationship of the Level of Electrical Safety Knowledge with Background Variables

Pearson correlations were calculated on the electrical safety questionnaire score and the independent background variables in order to determine presence of significant relationships (Note Table 15). The independent variables compared were age, sex, nursing unit, length of time as a Registered Nurse, previous

Table 14  
Subject Perception of Response to Reported Electrical  
Accidents, Faulty Equipment, or Electrical  
Hazards

	N	%
Prompt	76	60.8
Neutral	32	25.6
Slow/No Attention	5	4.0
Question Not Answered by Subjects	12	9.6
Total	125	100.0



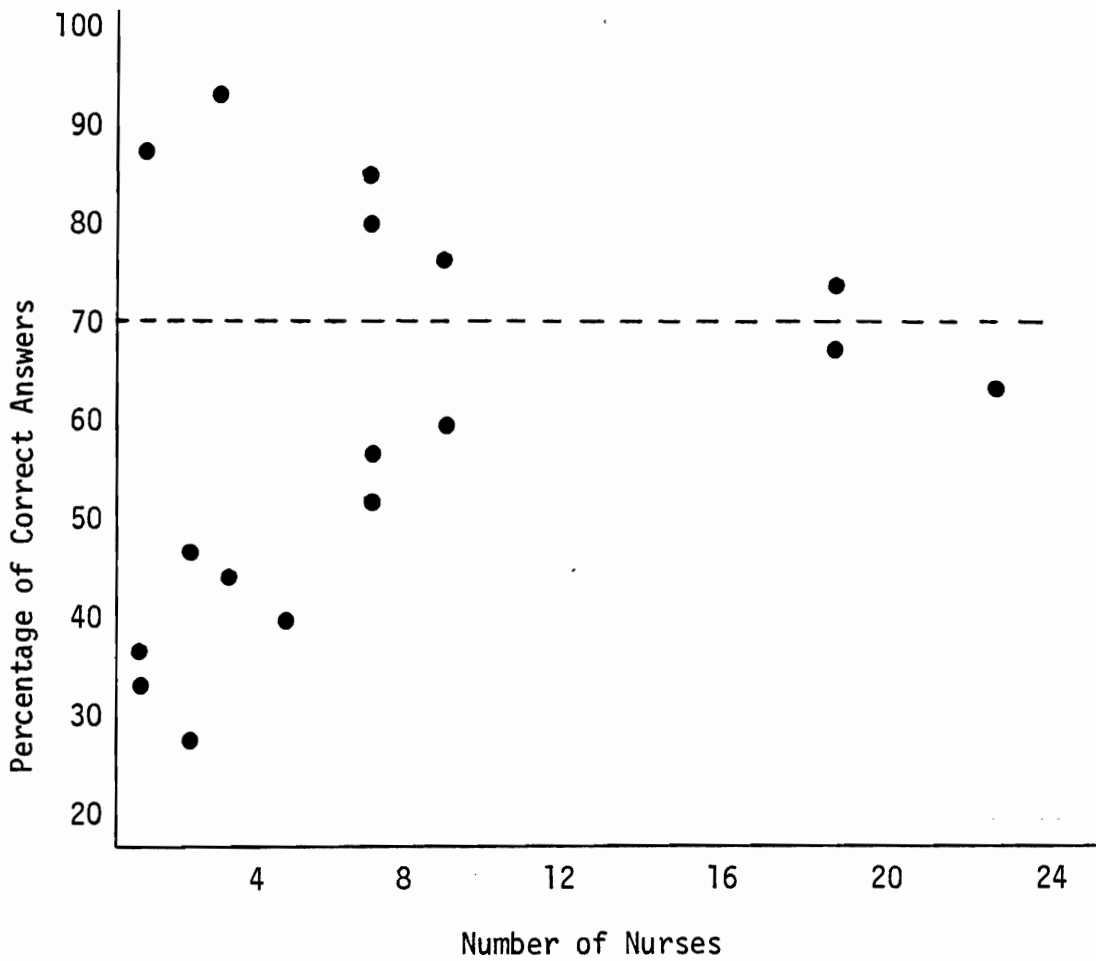


Figure 6  
Frequency of Correct Answers

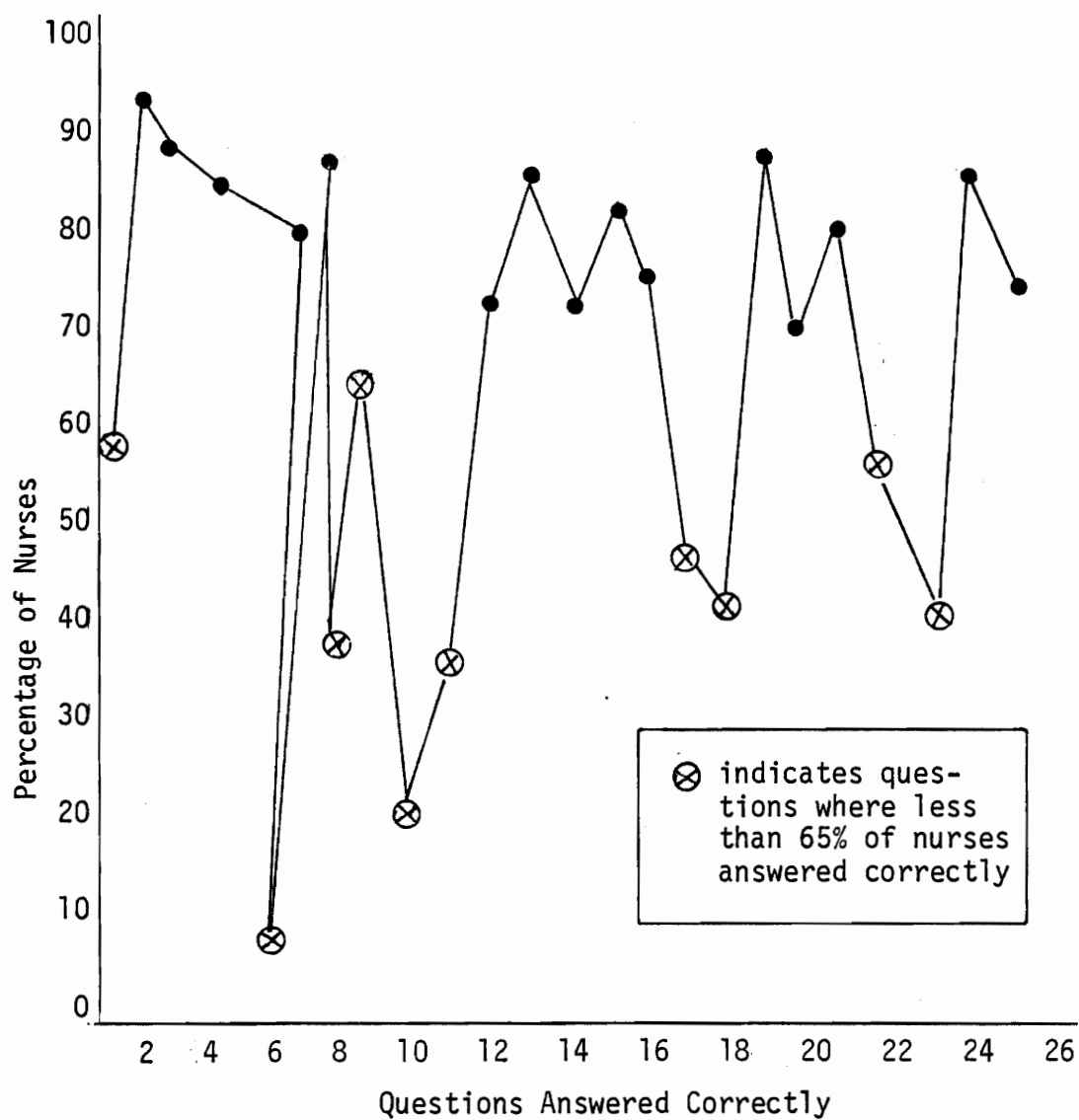


Figure 7  
 Percentage of Nurses Answering Each  
 Question Correctly

Table 15  
Pearson Correlations of Electrical Safety Questionnaire  
Score and Independent Variables

Variable	<u>p</u>	r
Age	0.05*	-.15
Sex	0.00*	.31
Unit	ns	-.06
Years as R.N.	0.01*	-.20
Years as ICU R.N.	ns	.03
Hours worked in ICU	ns	.06
Previous Electrical Safety Education	ns	-.06
Electrical Safety Know- ledge Self Rating	ns	.13
Adequacy of Electrical Safety Knowledge - Self Rating	ns	.12
Number of Journals Read	ns	.10

\*p  $\leq$  0.05

electrical safety education, self rating of electrical safety knowledge, self rating of adequacy of electrical safety knowledge and number of professional journals read regularly.

The three statistically significant relationships found to exist were:

1. a negative relationship ( $p = 0.05$ ) of age with electrical safety questionnaire score;
2. a positive relationship ( $p = 0.00$ ) of sex with electrical safety questionnaire score, and
3. a negative relationship ( $p = 0.01$ ) of the length of time as a Registered Nurse with electrical safety questionnaire score.

### Summary

Descriptive and correlational statistics provided information useful in answering the research questions of:

1. To what degree do background variables affect the level of electrical safety knowledge of Salt Lake City Intensive Care Unit nurses?
2. What level of electrical safety knowledge exists in the Intensive Care Unit nurses of Salt Lake City?

Pearson correlations of the electrical safety questionnaire score and independent variables demonstrated a negative relationship of age with electrical safety questionnaire score, a positive relationship of sex with electrical safety questionnaire score and a negative relationship of the length of time as a Registered

Nurse with the electrical safety questionnaire score.

Descriptive statistics defined the level of electrical safety knowledge of the sample as 63% of the nurses achieved less than 70% of the correct answers on the electrical safety questionnaire.

## CHAPTER V

### DISCUSSION OF DATA ANALYSIS

#### AND FINDINGS

##### Introduction

The discussion of the data analysis and findings is divided into three categories. The first section briefly recapitulates the descriptive characteristics of the sample. The second category examines the level of electrical safety knowledge of study participants. The third section examines the relationship of the electrical safety questionnaire score and the independent background variables of the study.

##### Descriptive Characteristics of the

##### Study

The sample comprised 125 Intensive Care Unit nurses from seven selected Salt Lake City hospitals. A return of 65% of the electrical safety questionnaire was achieved. Factors that contributed to this study return by Intensive Care Unit staff nurses were: patient census, nursing staffing and nursing care levels; support of the unit supervisor and the investigator's familiarity with unit

routine.

Male subjects with military or electrical courses scored considerably higher on the electrical safety questionnaire. This is perhaps due to the fact that male subjects received additional information from classes, jobs, technical training or hobbies.

#### Journals Regularly Read

The sample identified a total of 23 regularly read professional journals. Of this total, all but 7 (33%) are nursing publications, the others being medical periodicals. Eighteen percent of the study population did not indicate use of any professional journals. Because of this information, this route of providing electrical safety education is unreliable. The study participants named the following five journals: R.N., American Journal of Nursing, Nursing 81, Heart and Lung and Critical Care Nurse, as professional journals containing information regarding electrical safety information. However, the author's computerized literature review encompassing 1971 - 1981 revealed only the American Journal of Nursing and Nursing 1976 as containing electrical safety information.

#### Self Rating

It is of interest to note that 89% of the sample rated their electrical safety knowledge as less than adequate. The electrical safety questionnaire corroborates this by indicating that nursing knowledge of electrical safety is inadequate.

### Reported Electrical Hazards

In the cited literature, Abramson et al. (1980) and Petty (1976) both reported that adverse electrical accidents occur in the Intensive Care Unit. Abramson et al. (1980) reported that approximately 29 incidents of human error occurred annually. Petty's (1976) study documented a 29% incidence of mechanical ventilator malfunction or misuse. In light of these studies, one suspects the study sample of nurses, who report only 13% involvement in electrical accident, may not be uniformly recognizing electrical accidents as they occur in the ICU. The sample's mean length of years as an Intensive Care Unit Registered Nurse was 3.7 years. Therefore, it is highly plausible that the nurse witnessed, but failed to recognize, electrical accidents.

### Electrical Problem Resources

The study participants identified appropriate resources to be notified in the event of electrical accidents, faulty equipment and/or equipment hazards. The resource individual remained consistent within each hospital but varied from facility to facility.

### Level of Electrical Safety Knowledge

Sixty-three percent of the study participants answered less than 70% of the electrical safety questionnaire items correctly. Electrical safety questionnaire items 1, 6, 8, 9, 10, 11, 17, 18 and 23 were answered correctly by less than 65% of the study participants. In order to facilitate ease of discussion, the



questions were categorized as follows: basic electricity (questions 6, 9, 10, 18) and nursing procedure (1, 8, 17, 23). The category of basic electricity questions included: definitions of voltage and current; reduction of skin resistance; and minimization of static charge. The category of nursing procedure included: assessment of defibrillator function; and recognition of microshock hazard and nursing assessment; and patient susceptibility to electrical injury. The content of both categories contains fundamental electronics and electrical safety information. Without a comprehensive understanding of these basics, the nurse is unable to interact effectively with bioinstrumentation.

Relationship of the Level of  
Electrical Safety Knowledge  
with Background Variables

The three significant relationships found to exist using Pearson Product Moment correlations were:

1. negative relationship of age with electrical safety questionnaire score;
2. positive relationship of sex with electrical safety questionnaire score, and
3. negative relationship of the length of time as a Registered Nurse with electrical safety questionnaire score.

Correlational statistics demonstrated that the independent background variables of age and length of time as a Registered

Nurse adversely affected the subjects score on the electrical safety questionnaire. The positive significant relationship of sex with electrical safety questionnaire score suggested that the male subjects obtained a higher percentage of correct items on the electrical safety questionnaire than did the female participants.

The negative relationship of age with electrical safety questionnaire score indicated that the older the nurse, the lower the score. The oldest ten percent of the sample had a range of 15 years (39-54). This range is attributable to a limited number of older subjects.

As previously reported, 60% of the study sample was 28 or less years of age. Within the last decade, the importance of electrical safety and nurse-machine interface has been recognized. Therefore, the younger study subjects had opportunity for exposure to electrical safety information in nursing school or hospital orientation. Conversely, the older nurse group could have graduated from nursing school prior to the initiation of electrical safety education.

The statistically significant relationship of sex with electrical safety questionnaire score is in a positive direction. This relationship indicates that the male nurse identified a greater percentage of correct answers in the electrical safety questionnaire. It is of interest to note the previously reported finding that 27% of the male subjects received electrical safety education through military or electrical courses, while only 2.4% of the

female participants obtained electrical safety information in military, mining or electronics courses.

Finally, the third significant relationship defines a negative relationship between length of time as a Registered Nurse and the score on the electrical safety questionnaire. This relationship suggests that the longer time the nurse has worked, the lower the score of correct answers on the electrical safety questionnaire. Again, it is necessary to point out that the older age range of subjects had fewer individuals than did the younger age range; therefore, this relationship may not be linear as the curve may be influenced by the disproportionate number of younger nurses.

### Limitations

#### Design

The limitations of the study due to study design were created primarily by the hospital setting. Due to the large number of nursing staff, the investigator began contact with Intensive Care Unit nurses three weeks prior to the onset of data collection. This possibly served as a warning to potential study participants and made them more alert to electrical safety information prior to the data collection. This was not, however, reflected in the scores.

A major limitation to the study design was the pressure of patient care. The electrical safety questionnaire had the potential of becoming "the last order of the day", therefore, possibly not

receiving the study participant's undivided attention.

Another limitation of the study design was the inability of the investigator to predict prior to data collection, patient census and nursing staffing patterns.

#### Instrument Weakness

Inapplicability of the electrical safety questionnaire items to all specialized, Intensive Care Units limited the investigation. The focus of the bulk of the clinical problem questions was adult cardiovascular, rather than being broader in scope.

Additionally, two of the items on the electrical safety questionnaire involved nursing care of the patient with a pulmonary thermodilution catheter: These questions were difficult for Neonatal Intensive Care Unit nurses who do not use pulmonary artery catheters.

#### Sampling Deficiencies

The study sample was not randomized. At data collection, the investigator entered the nursing unit and individually requested each Registered Nurse for their participation in the study. Voluntary participation could have attracted people with similar traits thereby skewing the results. The overall number of responses (N=125) was, however, sufficient for statistical analysis and no statistical difference was found in the scores of the various hospitals.

## CHAPTER VI

### SUMMARY, CONCLUSIONS, NURSING

#### IMPLICATIONS AND

#### RECOMMENDATIONS

##### Summary

This study occurred because of the investigator's interest in nurse-bioinstrumentation interface. One hundred and twenty-five Intensive Care Unit nurses employed by one of seven selected Salt Lake City hospitals comprised a convenience sample for a descriptive study.

The findings, reported as correlational and descriptive analyses, demonstrated that the independent background variables of age, sex, and length of time as a Registered Nurse had significant relationships with the percentage of correct answers on the electrical safety questionnaire. The descriptive analyses revealed that 63% of the study participants correctly answered less than 70% of the electrical safety questionnaire items.

##### Conclusions

It is the conclusion of this study that an inadequate nursing

knowledge base existed in this sample of Intensive Care Unit nurses.

All hospitals involved in the study were accredited by the Joint Commission on Accreditation of Hospitals. Joint Commission on Accreditation of Hospitals standards require the hospital seeking accreditation to demonstrate ongoing education in electrical safety for new and current employees. Of the 73% of the sample that had previous electrical safety education, only 53% had received electrical safety education from hospital inservicing. It is the legal and ethical responsibility of all accredited hospitals to abide by the standards set forth by the accrediting body. The accredited hospital is accountable to provide nurses with comprehensive electrical safety instruction.

Inadequate electrical safety knowledge precludes the nurses ability to operate bioinstrumentation safely, to recognize electrical hazards and to protect herself, the patient and the visitors from harm. Improperly used bioinstrumentation jeopardizes nursing and the goals of optimal patient care.

#### Implications

As previously stated, nurses are deficient in their level of electrical safety knowledge. This need has been empirically documented with this study. The inadequacies of nursing knowledge of electrical safety must be addressed in the practical and educational arenas of nursing.

In the area of hospital nursing practice the electrical safety knowledge need must be immediately addressed because of the

potential dangers posed to the patients, staff and visitors. A reevaluation of the Functional Safety and Sanitation Standards, utilized for hospital accreditation by the Joint Commission on Accreditation of Hospitals, is a valuable starting point for the determination of nursing practice electrical safety needs.

Finally, within the hospital setting an electrical safety questionnaire should be utilized as an evaluation vehicle of nursing knowledge of electrical safety. Such an electrical safety questionnaire can assist in ongoing determination of adherence to electrical safety codes and standards.

The major implication for nursing education is to become actively involved in presentation of electrical safety information to student nurses and Registered Nurses. As the experts in teaching and learning the educators must become involved in upgrading existing electrical safety programs. Presentation of electrical safety information should include: basic principles of electricity; definition of the types of electrical hazards; recognition of the types of electrical hazards; recognition of electrical hazards and accidents; prevention of accidents and communication of electrical accidents.

#### Recommendations

Based on this study, the following recommendations are proposed for further investigation:

1. Institution of educational programs by hospitals and nursing schools addressing the areas of electronics and

electrical safety.

2. Continued assessment of nursing knowledge of electrical safety through use and evaluation following electrical safety education.
3. Establishment of electrical safety questionnaire validity.
4. Documentation of hospitals efforts to fulfill electrical safety standards of the Joint Commission on Accreditation of Hospitals.
5. Development of larger, more-encompassing electrical safety questionnaires with special emphasis on problems of diagnostic or therapeutic error.
6. Initiation of worldwide accident reporting systems (with standardized classification and language).
7. Repetition of the study in a larger population with more diverse geographic location, such as a national critical care conference.

### Conclusion

The electrical safety knowledge of a representative sample of Salt Lake City Intensive Care Unit nurses has been demonstrated to be inadequate. It is the recommendation of the investigator that hospitals and nursing schools immediately institute effective education programs addressing the areas of electronics and electrical safety.



APPENDIX A  
ELECTRICAL SAFETY QUESTIONNAIRE

Have you ever been involved in a hospital electrical accident? YES \_\_\_\_\_ NO \_\_\_\_\_

If yes, please describe:



SUBJECT NO. \_\_\_\_\_

3

14. In your hospital, who would you report an electrical accident to?

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15. In your hospital, who do you report faulty equipment or electrical hazards to?

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16. If you report electrical accidents, faulty equipment or electrical hazards, what type of response do you get from that person?

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\*\*\*\*\* ON THE FOLLOWING QUESTIONS, \*\*\*\*\*  
 PLEASE CIRCLE THE CORRECT  
 ANSWER -- THERE IS ONE CORRECT  
 \*\*\*\*\* ANSWER PER QUESTION. \*\*\*\*\*

1. Checking the operation of a defibrillator is most safely accomplished by discharging the machine with paddles:
  - a. placed lightly together
  - b. held in the air in front of the operator
  - c. placed against a defibrillator tester
  - d. placed on the metal outer case of the defibrillator
  
2. The three wire plug on hospital electrical equipment is designed to:
  - a. enhance electrical current flow
  - b. reroute stray electrical current
  - c. fit the ICU wall receptacle
  - d. augment electrical resistance
  
3. While working one day, there is a power failure. The emergency generator also fails. Rank order your action with most important action first, least important action last.
  1. unplug all equipment to avoid instrument destruction when power resumes
  2. switch equipment to battery power
  3. notify supervisor of situation
  4. substitute for necessary life support equipment
  - a. 1,4,2,3
  - b. 2,4,3,1
  - c. 3,2,4,1
  - d. 4,2,1,3

SUBJECT NO. \_\_\_\_\_

4. In order to prevent a transient electrical surge to a patient attached to an electrocardiogram monitor:
- a. turn ON the monitor before attaching it to the patient
  - b. turn OFF the monitor before attaching it to the patient
  - c. unplug the electrical bed
5. In cardioversion or defibrillation, either electrolyte gel or saline pads are used to:
- a. increase the defibrillator electrical current output.
  - b. increase skin resistance to deliver maximal electrical current to the heart.
  - c. decrease skin resistance to deliver maximal electrical current to the heart.
  - d. decrease skin temperature to reduce skin burns.
6. Voltage is best defined as:
- a. stored electricity
  - b. rate of electron flow
  - c. measurement unit of electrical capacity
  - d. force that causes electrons to flow
7. In an ICU, 2 components readily available that can possibly cause fire when combined with linens are:
- a. oxygen and a heat source
  - b. nitrogen and oxygen
  - c. nitrogen and a heat source
  - d. electricity and nitrogen
8. A critically ill man has the following equipment in use: a peripheral IV line hooked up to an infusion controller pump; a Swan Ganz (thermodilution) catheter; a six inch femoral arterial line; an electrocardiogram monitor; he is lying in an electric bed. Which apparatus represents his greatest electrical hazard?
- a. the peripheral IV line hooked up to the infusion controller pump.
  - b. the Swan Ganz (thermodilution) catheter.
  - c. the electrocardiogram monitor.
  - d. the electric bed.
9. What decreases skin resistance to electrical current?
- a. hair or scar tissue presence
  - b. low humidity conditions
  - c. skin integrity interruption
10. Accumulation of static charge can be minimized by:
- a. room humidity below 40%
  - b. natural fiber linens and nursing uniforms
  - c. adequate air circulation
  - d. all of the above

SUBJECT NO. \_\_\_\_\_

11. It is necessary to wear insulating rubber gloves when:
- a. changing the battery of a pulsegenerator when pacemaker electrodes are not attached.
  - b. handling implanted pacemaker electrodes.
  - c. touching the patient with a temporary pacemaker
  - d. a and b
12. Before touching a patient, it is a good idea to touch the metal part of a grounded bed because:
- a. it eliminates static charge buildup.
  - b. it improves your electrical resistance.
  - c. it reduces available electrical amplitude.
  - d. it alerts you to any electrical leakage current.
13. Electrical resistance is:
- a. exchange of electrical voltage
  - b. lack of electrical flow
  - c. hindrance to electrical flow
  - d. competition of electrical signals
14. Sixty cycle interference on an electrocardiogram monitor is corrected by:
- a. changing skin contact electrodes.
  - b. minimizing chest muscle movement.
  - c. altering grounding conditions.
  - d. decreasing the monitor gain.
15. An improperly calibrated arterial line, with the atmospheric zero below the display zero, will show a blood pressure reading:
- a. falsely high
  - b. falsely low
  - c. unchanged
  - d. dependent upon atmospheric pressure conditions
16. An example of a good electrical conductor is:
- a. urine
  - b. dry skin
  - c. air
  - d. rubber
17. You notice that the display of a patient's arterial line rapidly drops from 100/60 mmHg to 70/30 mmHg. Your first action should be:
- a. flush the arterial line
  - b. recalibrate the arterial line
  - c. tighten all arterial line connections
  - d. palpate for a central pulse

SUBJECT NO. \_\_\_\_\_

18. Current is best defined as:

- a. rate of electron flow  
 b. direction of electrical signal  
 c. force that causes electrons to flow  
 d. electrical charge measurement

19. Adapter plugs (or wires), which change a three wire plug into a two wire plug:

- a. promote electrical equipment longevity  
 b. reduce electrical shock hazard  
 c. negate the ground connection

20. Three hours ago, a demand temporary ventricular pacemaker was inserted in a patient for complete heart block. Suddenly, without previous ventricular arrhythmias, the patient develops ventricular fibrillation. After successful defibrillation, which initial nursing action would be most appropriate?

- a. pull the pacemaker catheter back one centimeter.  
 b. check that the pacemaker electrodes are inserted into the pulsegenerator.  
 c. turn the pulsegenerator to asynchronous mode

21. In cardiac monitoring, skin preparation and chest electrode position:

- a. increase motion resolution  
 b. reduce electrical hazard  
 c. increase skin electrical resistance  
 d. reduce skin electrical resistance

22. In the patient with a Swan Ganz (thermodilution) catheter, when is it advisable to use the intravenous controller pump on battery mode.

- a. if the intravenous controller pump would become dislodged from the wall.  
 b. only in an emergency.  
 c. in case of electrical leakage current.

23. Which critically ill patient has an increased susceptibility to electrical injury?

- a. decreased mental status  
 b. respiratory alkalosis  
 c. brain wave irregularities  
 d. hypothyroidism

24. You should refuse to use patient care electrical equipment if:

- a. the top of the machine is warm  
 b. the manufacturer's warranty has expired  
 c. the machine is connected to a line isolation monitor  
 d. solution has been spilled into the machine

SUBJECT NO. \_\_\_\_\_

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25. Mrs. J. returns from the operating room after a mitral valve replacement. Per usual, electrosurgery equipment was used for cutting and coagulation (cautery). What type of injuries related to electrosurgical equipment use do you check for in the initial nursing assessment?

- a. abnormalities in blood clotting factors.
- b. burned areas in location of the grounding plate.
- c. electrolyte disturbances
- d. decreased perfusion areas due to constriction

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## REFERENCES

- Abbey, J.C. Bioinstrumentation: Twentieth century slave. Nursing Clinics of North America, 1978, 13, 631-640. (a)
- Abbey, J.C. General systems theory: A framework for nursing. Chap. 4. In A. Putt, General systems theory applied to nursing. Boston: Little, Brown and Company, 1978.(b)
- Abbey, J.C. Safety: Accident or responsibility? Paper presented at meeting of the Association for the Advancement of Medical Instrumentation, San Francisco, April, 1980.
- Abramson, N.S., Wald, K.S., Grenvik, A.N., Robinson, D., & Snyder, J.V. Adverse occurrences in intensive care units. Journal of the American Medical Association, 1980, 244, 1582-1584.
- Arledge, R.L. Prevention of electrical shock hazards in physical therapy. Physical Therapy, 1978, 58, 1215-1217.
- Aronow, S., Bruner, J.M., Siegel, E.F. & Sloss, L.J. Ventricular fibrillation associated with an electrically operated bed. New England Journal of Medicine, 1969, 281, 31-32.
- Berger, J. Guidelines for developing an effective electrical safety program. Journal of Clinical Engineering, 1979, 4, 321-327.
- Bertz, E.J., di Monda, R., & Sprague, J.G. Viewing the hospital as a working environment. Hospitals, 1976, 50, 107-112.
- Bruner, J.M., Aronow, S., & Cavicchi, R.V. Electrical incidents in a large hospital: A 42 month register. Journal of the Association for the Advancement of Medical Instrumentation, 1972, 6, 222-230.
- Burchell, H.B. Electrocution, an ever-present hazard. Postgraduate Medicine, 1977, 61, 127-133.
- Controlling patient-owned appliances. Hospitals, 1979, 53, 57, 61, 64.
- Chisholm, L.A., Telder, R., & Dolan, A.M. A patient safety program

- for small hospitals. ISA BM, 1974, 10, 125-128.
- Curran, W.J. Ralph Nader, the consumer and the hospitals. New England Journal of Medicine, 1971, 284, 1017.
- Dalgetty, R.G., & Harbort, R.A. ECG monitor interference from patient call systems. Medical Instrumentation, 1979, 13, 51.
- Disch, J., Brey, C., & Reynolds, M. Scope of practice defined. Focus on AACN, 1980, 7, 18-19.
- Fairchild, R.A., & Allen, H.N. Monitoring systems for intensive care. Medical Clinics of North America, 1971, 55, 1107-1126.
- Feldtman, R.W., & Derrick, J.R. Hospital electrical safety. American Family Practitioner, 1976, 13, 127-137.
- Foxwell, L.G. Equipment and personnel controls can improve safety and reduce insurance costs. Modern Hospital, 1972, 118.
- Friedlander, G.D. Electricity in hospitals: Elimination of lethal hazards. IEEE Spectrum, 1971, 8, 40-51.
- Geddes, L.A., Tacker, W.A., & Cabler, P. A new electrical hazard associated with electrocautery. Medical Instrumentation, 1975, 9, 112-113.
- Gerhard, G.C., Chalifoux, H.D., & Melvin, D.W. A shocking experience, Ohm's law and the nurse. Journal of Clinical Engineering, 1979, 4, 231-235.
- Green, H.L., Breneman, G.M., Goldberg, S.J., Harken, D.E., Hieb, G.E., Kosowsky, B., Parker, B., Rinaldo, J.A., & Webb, G.N. Electronic equipment in critical care areas. Part III: Selection and maintenance program. Circulation, 1971, 44, A247-A261.
- Hochberg, H.M. Effects of electrical current on heart rhythm. American Journal of Nursing, 1971, 71, 1390-1394.
- Interference with external pacemakers. Health Devices, 1974, 4, 233-235.
- Jacobs, M.K. Sources of measurement error in noninvasive electronic instrumentation. Nursing Clinics of North America, 1978, 13, 573-587.
- Joint Commission on Accreditation of Hospitals. Accreditation Manual for Hospitals. Chicago: 1980.

- Kast, F.E., & Rosenzweig, J.E. Organization and management - a systems approach. New York: McGraw-Hill Book Company, 1974.
- Kilpatrick, D.G. The electrical environment. Medical Clinics of North America, 1971, 55, 1095-1105.
- Kilpatrick, D.G., & Kilpatrick, L.B. Electrical safety standards in the health care delivery system. CRC Critical Reviews in Bioengineering, 1972, 289-332.
- Lenihan, J.M., & Abbey, J.C. Symbiosis: Nursing and the bioengineer. Nursing Clinics of North America, 1978, 13, 589-595.
- Lichstein, E., & Gupta, P.K. Television set distortion of electrocardiogram. Journal of the American Medical Association, 1973, 223, 1285.
- Meth, I.M. Electrical safety in the hospital. American Journal of Nursing, 1980, 80, 1344-1348.
- Nader, R. Ralph Nader's most shocking exposé. Ladies Home Journal, 1971, 88, 98.
- National Fire Protection Association. Essential Electrical Systems for Health Care Facilities. Boston: 1978.
- Neuberg, J., Hunt, D., Budkin, A., & Katchis, L.J. An automated electrical safety and preventive maintenance program. Journal of Clinical Engineering, 1979, 4, 71-75.
- Pacela, A.F. Bibliography on electrical hazards, safety and standards. Report CRR-21. Fullerton, California: Beckman Industries, 1970.
- Petty, T.L. Complications occurring during mechanical ventilation. Heart and Lung, 1976, 5, 112-118.
- Pfeiffer, E.A. A simulator for teaching electrical safety procedures in the hospital. Medical Instrumentation, 1975, 9, 103-105.
- Rubin, R. Manufacturers and professional users liability for defective medical equipment. Akron Law Review, 1975, 9, 103-105.
- Sahn, D.J., & Vaucher, Y.E. Electrical current leakage transmitted to an infant via an IV controller: An unusual ECG artifact. Journal of Pediatrics, 1976, 89, 301-302.
- Schultz, J.K. Nursing and technology. Medical Instrumentation,

1980, 14, 211-214.

Shaffer, M.J., Rios, J.C. & Klengenmaier, C.H. Instrument performance testing: A prerequisite for hospital safety. American Heart Journal, 1976, 91, 819-820.

Shepard, M.D. The fundamentals of equipment hazards in critical care areas. University of California, San Francisco, Office of Environmental Health and Safety, 1980.

Shepard, M.D., & Coddinton, B. A method for establishing safety equivalencies. Paper presented at meeting of the American Society of Hospital Engineers, San Francisco, June, 1979.

Stanley, P.E. Monitors that save lives can also kill. Modern Hospital, 1971, 108, 119; 121; 123.

Stanley, P.E. Instrument Safety. Chap. 45. Mosby's Comprehensive Review of Critical Care (2nd ed.). St. Louis: C.V. Mosby Company, 1981.

Steers, R.M. Organizational effectiveness: A behavioral view. Santa Monica: Goodyear Publishing Company, 1977.

Swartz, E.M. Products liability: Manufacturer's responsibility for defective or negligently designed medical and surgical instruments. DePaul Law Review, 1969, 58, 348-407.

von Bertalanffy, L. The history and status of general systems theory. Academy of Management Journal, 1972, 150, 407-426.

Walker, D.J. Nursing 1980: New responsibility, new liability. Trial, 1980, 16, 43-47.

Weeks, H. Bioinstrumentation in the care of the neonate. Nursing Clinics of North America, 1978, 13, 597-609.

Yoo, J.H., & Broderick, W.A. Development of instruction in hospital electrical safety for medical education. Journal of Clinical Engineering, 1978, 3, 263-270.