"STUDY OF PATTERN OF ELECTRICAL INJURY CASES AT A TERTIARY HEALTH CARE CENTRE -A CROSS SECTIONAL STUDY"

By

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Dissertation

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ENDORSEMENT BY THE HEAD OF DEPARTMENT, PRINCIPAL OF THE INSTITUTION

This is to certify that the dissertation entitled **"STUDY OF PATTERN OF ELECTRICAL INJURY CASES AT A TERTIARY HEALTH CARE CENTRE -A CROSS SECTIONAL STUDY"** is a bonafide research work done by **REG NO-BF0112001.**

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LIST OF ABBREVATIONS USED:

WHO: World Health Organisation

AC: Alternating Current

DC: Direct Current

A: Ampere

mA: Milli ampere

cps: Cycles per Second

e.g.: Example

RBC: Red Blood Cell

V: Volt

B.C: Before Christ

A.D: After Death

IEA: International Energy Agency

US/USA: United States/ United States of America

UN: United Nations

TBSA: Total Body Surface Area

CK-MB: Creatine Kinase-MB

RR: Relative Ratio

Ref: Referred

Mech: Mechanical

CI: Confidence Interval

HVEI: High Voltage Electrical Injury

R.O.C.: Republic of China

LV: Low Voltage

HV: High Voltage

MLC: Medico Legal Case

OPD: Out Patient Department

IP: In Patient

Incr: Increased

Decr: Decreased

WNL: Within Normal Limit

Recov: Recovered

Expir: Expired

Rt: Right

Lt: Left

UL: Upper Limb

LL: Lower limb

HESCOM: Hubli Electricity Supply Company

MCB: Miniature Circuit Breakers

RCCB: Residential Current Circuit Breaker

ABSTRACT

BACK GROUND AND OBJECTIVES:

WHO has defined injury as 'body lesion at the organic level resulting from acute exposure to energy (mechanical, thermal, electrical, chemical or radiant) interacting with the body in amounts or rates that exceed the threshold of physiological tolerance.

Electrical burns are the fifth leading cause of death among workers. Electrical accidents are at rise although suicidal and homicidal cases have been reported even in rural India with advancement of technology indicating that appropriate preventive and safety measures are not being practiced religiously. Nearly all cases of electrical injury eventually involve litigation for negligence, product liability, or workman's compensation.

Electrical injuries represent a special type of thermal injury, with a pathophysiology depending on the voltage, current flow and resistance of the skin and also on several other factors including environment.

The present cross-sectional study is undertaken with the objective of "Understanding the injuries caused by electricity with a socio-forensic perspective". Thus, helpful in planning the safety measures and legal solutions.

MATERIALS AND METHODS:

Data was collected from patients of electrical injuries visiting casualty/OPD/wards, their medical records and autopsy reports in fatal cases from Oct 2012 to Dec 2013 at KLESs Dr. Prabhakar Kore Hospital and MRC, Belgaum, by

universal sampling method. Informed expressed consent is taken and a pre-tested proforma specially designed for this purpose used for collecting the information.

RESULTS:

In the study adults constituted the bulk. Male victims formed the majority, and maximum were in the age group of 11-20 (30.23%) years followed by 21-30 (18.61%) years. Among the total cases, adults and children constituted, 67.44% and 32.56% respectively. 46.51% cases were seen in rainy season. 74.42% of victims sustained injuries during day time. 62.80% of victims belonged to occupation other than electrician/labour while 20.93% victims were electricians and 16.27% were labours. High voltage contact formed the bulk of the current source contributing to 76.74%. Victims from urban area constituted 32.66% and from rural area 67.44%. Work place victims constituted 41.86% followed by 39.54% at public place and 18.60% at home. 44.19% victims had both entry and exit wounds and 25.58% had only entry wound, while 30.23% of the cases showed no entry/exit wounds. Entry wound was present in 30 (69.77%) out of 43 cases. Out of them, 86.66% showed entry wound in upper extremities. Exit wound was seen in 19 (44.19%) out of 43 victims, out of them 78.95% showed exit wound on lower extremities. Total of 37.21% victims sustained mechanical injuries. Most common current source involved in causing mechanical injury being (87.5%) high voltage. Out of total victims, 40 (93.02%) had associated burn injuries, out of them 29 (72.50%) with less than 25% TBSA burn, 10 (25%) with 25 to 49% TBSA burn and only one (2.50%) with 50 to 74% TBSA burn. 4.65% of the victims were treated on OPD basis while 95.35% victims needed hospitalization. In relation to hospital stay, 34.88% for 1 - 10 days, 32.56% for 11 - 20 days, 9.30% for 21-30 days and 18.61% for more than 30 days.,

whereas surgical intervention was done in 55.81% of cases. Mortality rate is 6.98% (03 cases) with septicaemia as cause of death. The renal parameters (blood urea & serum creatinine) in 41 cases revealed a unique result as, increased blood urea in 03 (7.32%), decreased in 06 (14.63%), WNL(within normal limit) in 32 (78.05%); while decreased serum creatinine in 27 (65.85%), WNL in 14 (34.15%).

INTERPRETATION AND CONCLUSION:

In the present study, electrical injury cases constituted to 0.91% of the total medico-legal cases and were of unintentional; majority consisting of adult males, mortality rate of 6.98% and seen in high voltage electric contact, majority of patients' hospital stay was 1-20 days. One case with 50 - 74% TBSA burn was recovered and discharged suggestive of internal electrical injuries more severe than visible external electrical burns. The path from upper limb to lower limb affects the renal parameters without serious external electrical injuries.

As spot/instantaneous death cases may be taken to regional PHCs for autopsy/legal formalities instead of bringing to referral hospitals, the individual hospital statistics may not be the same when compared with general statistics..

KEY WORDS: Electricity, voltage, injuries, exit, entry, burns, season, urea, creatinine.

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INTRODUCTION

"I shall make electric light so cheap that

Only rich will be able to burn candles"

Thomas Alva Edison.

WHO has defined injury as 'body lesion at the organic level resulting from acute exposure to energy (mechanical, thermal, electrical, chemical or radiant) interacting with the body in amounts or rates that exceed the threshold of physiological tolerance [1].

Electrical energy has gained wide acceptance since the middle of 20th century. It would be difficult to imagine that anyone in our society could have reached adolescence without having experienced some form of electrical shock. As there is rapid progress in industrialization and widespread utilization of electrical appliances, the electricity has become essential commodity even in rural India. The quantum of danger exists as much as quantum of electricity is in use. The lowest recorded voltage at which death occurred from an electric shock is 38 v [2]. Electrical injuries are most often accidental although suicidal and homicidal cases have been reported.

The first electrical fatality was recorded in France in 1879 when a stage carpenter was killed by an alternating current (AC) of 250 volts. The first electrocution death in UK was in 1880, close to Birmingham. The first U.S. fatality occurred in 1881, when a local inebriate, Samuel W. Smith, passed out on a similar generator in front of a crowd in Buffalo, New York [3]. In 1890 William Kemmeler was the first man to be put to death in New York State's electric chair [4].

It is estimated that electrical injuries cause 500 to 1,000 deaths per year, 3 to 5% of admissions to burn units are result of electrical burns. Electrical burns are the

fifth leading cause of death among workers. Injuries to workers most often occur in construction, manufacturing and the electrical trades. 1000 deaths per year are due to electrical injuries with a mortality rate of 3-5% in the United States [5].

Morbidity and mortality due to electricity is generally dependent on the power source (lightning or electrical), voltage (high or low voltage), and type of current (alternating or direct).

Electrical injuries can occur in a variety of settings. Adults often suffer from electrical injuries as a result of workplace accidents, whereas children often suffer these injuries at home. Electrical injuries represent a special type of thermal injury, with a pathophysiology depending on the voltage, current flow and resistance of the skin and also on several other factors including environmental factors. High-voltage electric current has irreversible localized and systemic consequences, with a high percentage of disability. Electrical accidents are at rise even with advancement of technology indicating that appropriate preventive and safety measures are not being practiced religiously. Nearly all cases of electrical injury eventually involve litigation for negligence, product liability, or workman's compensation.

Various studies have been conducted on electrical injuries, with respect to its types, pattern, epidemiology, mortality, burns etc.

This type of study on electrical injuries has not been conducted in this region in the recent past. Hence the present cross-sectional study is undertaken with the objective of "Understanding the injuries caused by electricity with a socio-forensic perspective". It will help in improving work conditions, preventive and safety measures to be taken and also for improving the safety of electrical appliances.

AIMS AND OBJECTIVES

1. To study pattern of electrical injuries coming to a tertiary health care centre.

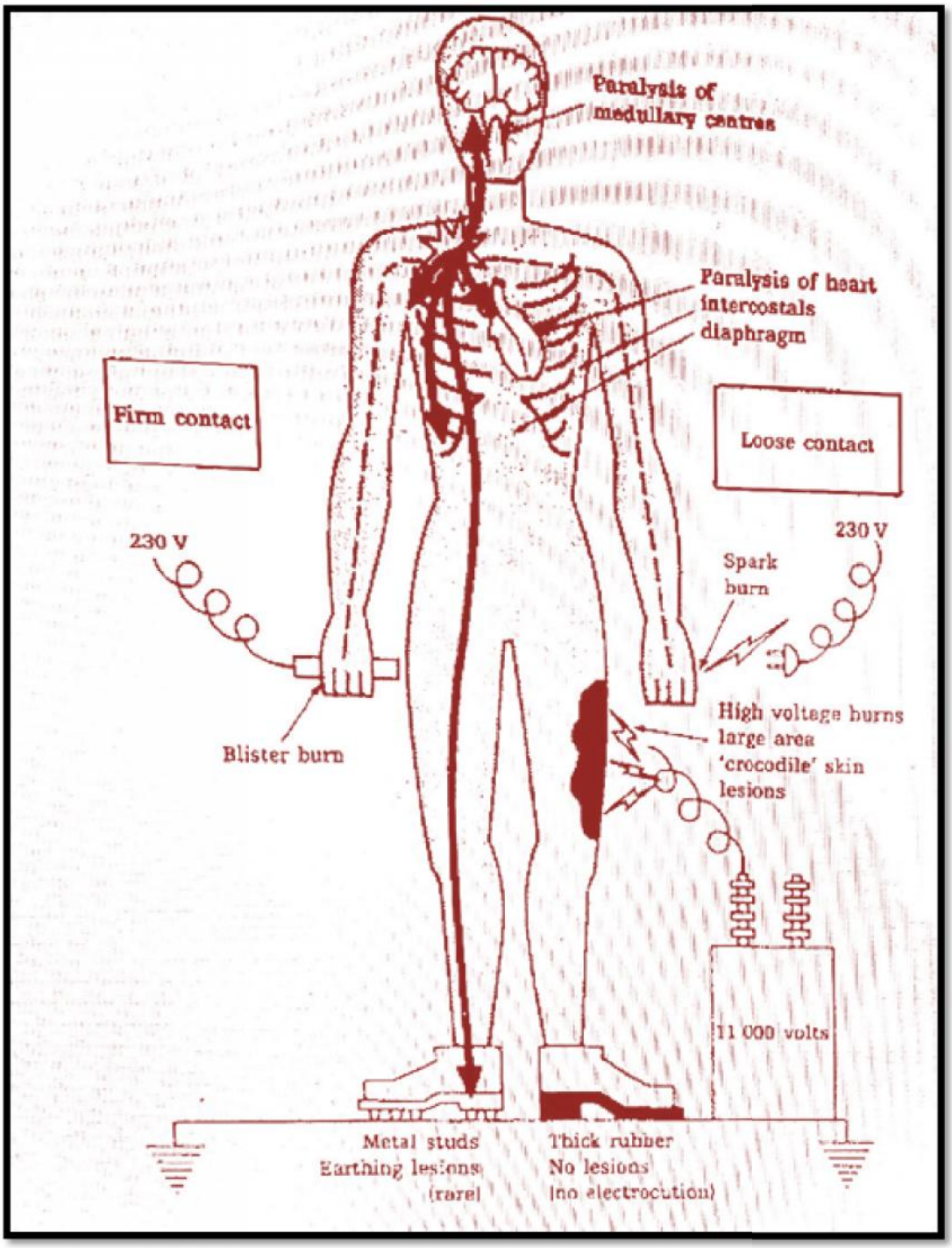
2. To study the relation between electrical injuries and influencing factors.

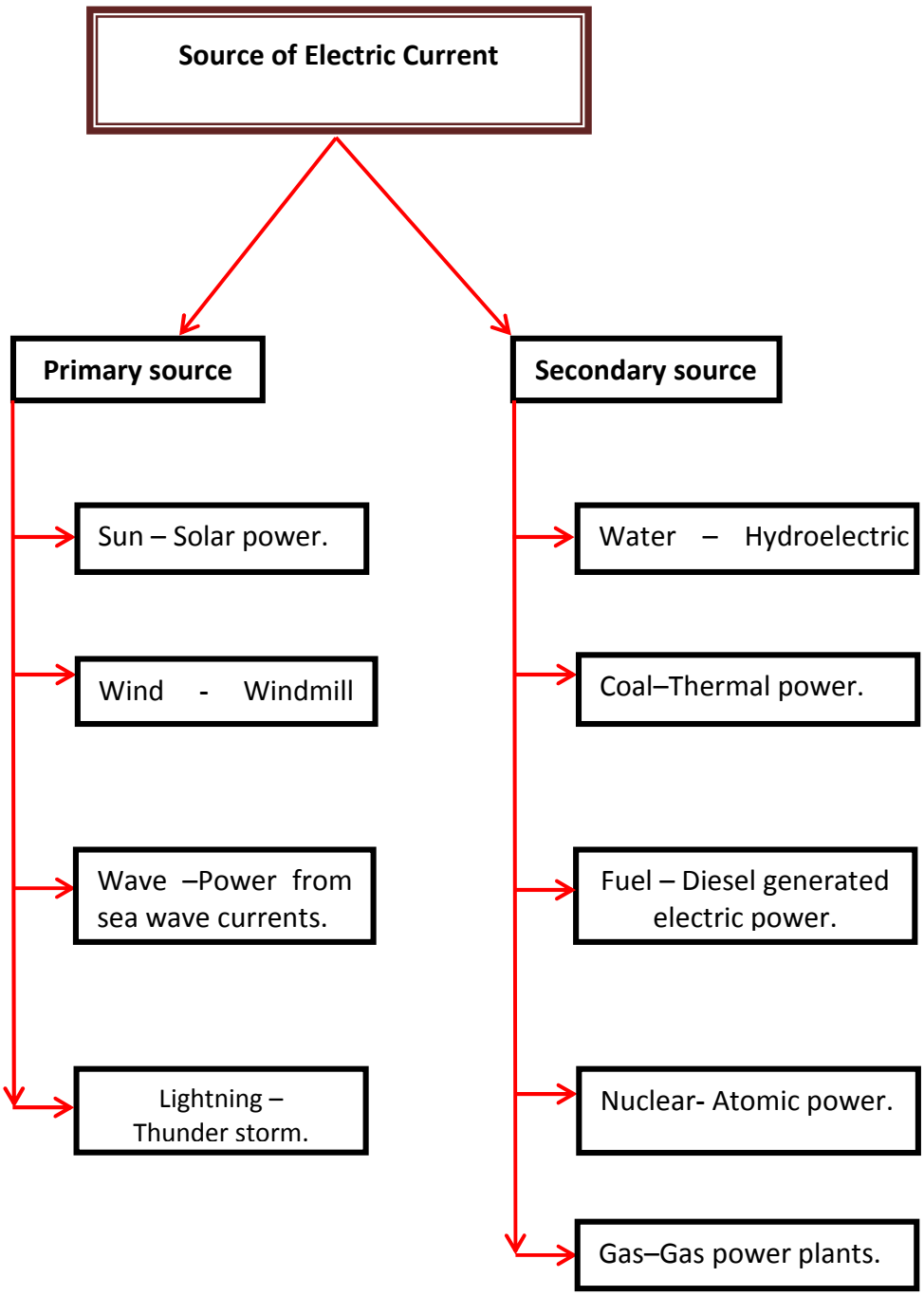
3. To know the burden of electrical injuries in our tertiary care centre and in the society.

ELECTRICITY AND INJURY

Electricity and Conduction: All substances are made up of atoms. Materials, which allow the passage of electricity, are called conductors. The atoms of these metals have loosely bounded electrons. **Electrons**, the outer particles of an atom, contain a negative charge. These electrons are free to move within the metal. These are called free electrons and are responsible for the conduction of current. More is the number of free electrons in the metal better conductor of electricity it is. If the current flows back and forth (a cycle) through a conductor, it is called **alternating current (AC)**. If current flows in one direction only (as in a car battery), it is called **direct current (DC)** [6]. At present large percentage of the electrical energy, being used for domestic and commercial purpose is generated as AC current. DC current is used for electro plating, charging of storage batteries, refining of copper and aluminum, production of industrial gases by electrolysis, metal rolling mills, high speed gearless elevators etc.

The negative charged free electrons move away from negative terminals and flow towards positive terminals. This flow of electrons is nothing but the electric current. Similarly, human body is a good conductor of electricity composed with loosely bounded electrons (Iron in the form of blood) flow through blood vessels, which is responsible for the conduction of current. Hence the drifting electrons cause the electricity to flow in human body.


Paralysis of
medullary centres
Paralysis of heart
intercostals
diaphragm
Firm contact
Loose contact
230 V
230 V
Spark
burn
Blister burn
High voltage burns
large area
'crocodile' skin
lesions
11 000 volts
Metal studs
Earthing lesions
(rare)
Thick rubber
No lesions
(no electrocution)


Source of Electric Current
Primary source
Secondary source
Sun – Solar power.
Wind - Windmill
Wave –Power from sea wave currents.
Lightning – Thunder storm.
Water – Hydroelectric
Coal–Thermal power.
Fuel – Diesel generated electric power.
Nuclear- Atomic power.
Gas–Gas power plants.

Mechanism of Electrical Injury [7, 8 & 9]: Electricity moves in a path with a tendency to pass to the earth where it gets neutralized. For common uses electrical energy is converted to some other form of energy like light, heat or mechanical energy. But its injurious effect is almost totally in the form of electrical energy with some minor effects as converted heat energy and to small extent as converted mechanical energy.There are basically four mechanisms involved in electrical injury:

1. Direct effect of current on body tissues, leading to asystole, ventricular fibrillation, or apnea;
2. Blunt mechanical injury from lightning strikes, resulting in muscle contraction or falling;
3. Conversion of electrical energy to thermal energy, resulting in burns; and
4. Electroporation, i.e. creation of pores in cell membranes by means of electrical current. Electroporation disrupts cell membranes and leads to cell death without clinically significant heating. This form of injury occurs when high electrical field strengths (defined as volts per meter) are applied.

Factors Influencing Electrical Injuries [4, 7, 8 & 9]:

1. Voltage or tension: It is the measurement of electrical force. 50 volts may be dangerous but around and over 100 volts is definitely dangerous.Voltage is often the only variable known with certainty after exposure to electricity and therefore is the most reasonable marker for categorizing electrical shocks.

Low voltage: Is less than 1000 volts. It is also known as indoor current which is between 220 – 240 volts in India.

High voltage: Is in thousands.It is usually seen in high tension street electric cables. Death is not must. Lightning strikes can produce 10 million V or more.

2. **Amperage (Intensity):** Most important factor in electrocution. It is the cause of "hold on" to conductors. A=V/R; Where A=amperage, V =voltage, R = Resistance of the conductor(measured in ohms).Danger increases when the amperage is between100 mA to 4A. Above 4 A, it arrests cardiac fibrillation; this is the principle of treatment with a defibrillator. High voltage with low amperage is less dangerous than moderate voltage with high amperage.

3. Density of the current: Density of the current depends upon the following

- Dry or moist skin: Dry skin of the palm have the resistance of 1-2 million Ohms. Sweating reduces the resistance from 30,000 ohm to 2500 ohm.
- When moistened with water or saline the density of current further drops between 1200-1500 ohms.
- Once the skin is burnt, resistance of the skin rises and that may cause a break in the circuit.

3. **Resistance of the body:** Resistance is greatest on the palms (of the laborers) and least on the inner sides of thighs. Average resistance of various body areas and tissues is:

Resistance of different Body Tissues-

Least	**Intermediate**	**Most**
Blood	Dry skin	Tendon
Nerves		Fat
Mucous membranes		Bone
Muscle		

• **Vascular areas like cheek are better conductors and most of the current passes through the blood vessels.**

5. Insulation: Stout rubber gloves and rubber boots in good condition gives considerable protection.

6. Contact with electric supply: Electrocution is normally the result of direct contact with current and closer the contact, greater is the danger. High tension currents throw or repel violently and the death may be due to the fall. Indirect contact with high tension current results in arcing and direct flow of current in an indirect fashion such as while urinating on a high-tension conductor.

The area of contact modifies external appearances such as:

- Conductor involving small surface area such as the end of a rod or wire produces circular hole in the tissue and simulates bullet injury.
- A wire wound around wrist produces linear grooves.
- A broad conductor closely applied may not leave any mark.

***In electrocution in a bath tub, flow of current occurs without generation of heat and no external injuries are produced.**

7. Duration of contact: The longer the time of contact, the greater is the amount of current that will pass through and consequently the greater the amount of tissue damage.

8. Site of contact: Electrical injuries on the face and arms are serious whereas those on the palms are less serious. When the path taken by the current is from left hand to

leg, 2-3 times more current is passed to the heart compared to the path taken from right hand to leg.

9. Kind of current: A.C. is more dangerous than D.C and the numbers of cycles in A.C are important. 40-150 cycles/second is dangerous, 50-60 cps is the critical frequency, and at frequencies more than 1700 cps heart becomes 20 times more tolerant. So as the frequency of cycles increases dangerousness decreases.This is exemplified in popular usage of diathermy.Very low(e.g.< 10) and very high (e.g.> 1000) cycles per second is harmless to the human body.

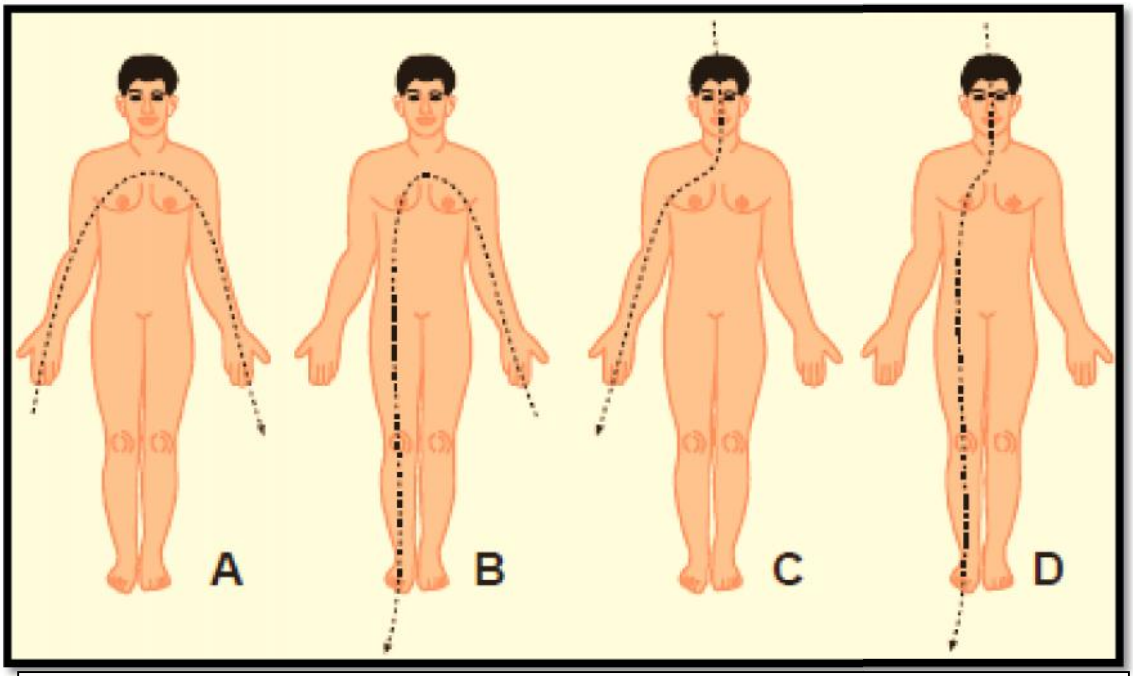
10. Sleep: Sleep increases the resistance to an electrical current.

11. Personal idiosyncrasies: Individual personality, physical condition and existence of mental or bodily distress influence the effect of shock.

12. Presence of diseases: Cardiac diseases may predispose to electrocution even at low tension current.

13. Anticipation of shock: In anticipation of shock, the individuals can sustain current better.

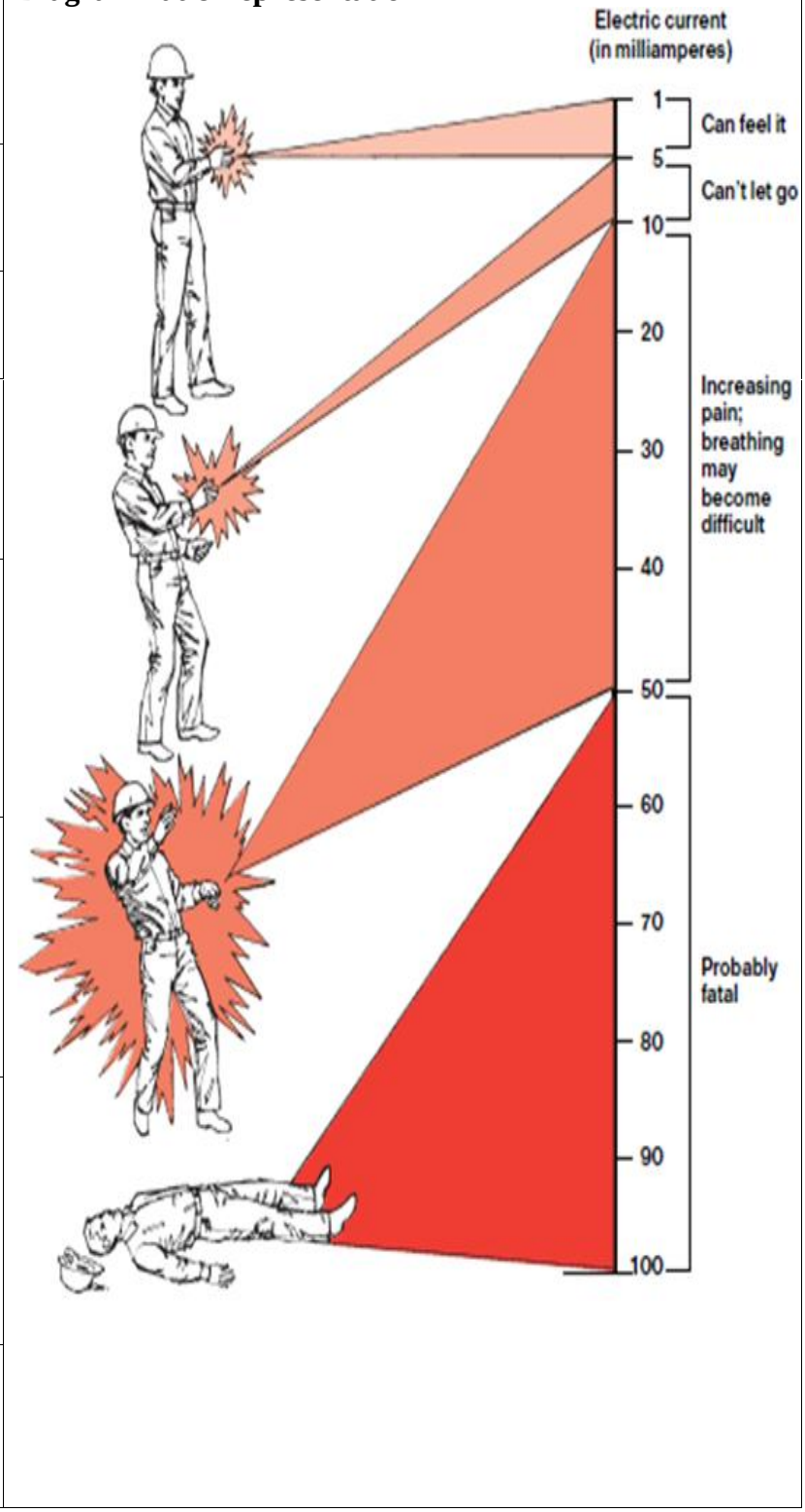
14. Passage of electric current through the body: Course of electric current in the body depends on the fluid content of the tissues. So, maximum amount of current passes through the blood vessels. However as a general rule the flow of the current in the body adopts the shortest route to the earth, or anything which is a good conductor and is in direct contact with the earth.



Diagrammatic representation of various Paths taken by the current:
A- Hand to hand. B- Hand to feet. C- Head to hand. D- Head to feet.

Moreover, the effect = Voltage ×Amperage ×Duration - tolerance and alertness.

Classification of Electrical Accidents Based on Amperage:

Group	Amperage	Effects on Body	Diagrammatic Representation
	1 or less	No sensation; probably not noticed.	
	1 to 3	Mild sensations not painful. Let go of electric line voluntarily.	
	3 to 10	Numbness, Slight stiffness, Paraesthesia, Tremor in muscles. May not voluntarily let go of electric line.	
Group I	10 - 25 ma (AC) 25 – 80 ma (DC)	Painful muscular contraction.Contraction of flexor muscles prevents release of electric line.	
Group II	25 - 80 ma (AC) 80 – 300 ma (DC)	Loss of consciousness, Arrhythmia, Respiratory spasm.	
Group III	80 - 100 ma (AC) 300 – 3a (DC)	Less time of exposure effect Similar to Group - II More time – ventricular fibrillation.	
Group IV	> 3 a	Tissue begins to burn. Heart muscles clamp and heart stops beating.	

Effect of Electric Current on various Organs of Human Body [8 & 9]:

A. Skin:

Most important indication of contact with electric current is current mark, known as **'Joule Burn'**. Layers of skin are relatively thin but show high resistance to passage of current. Resistance is not homogenous; there are points of poor insulation. Decreased tissue resistance allows current to penetrate the skin. Higher the voltage greater is the chance of skin penetration. Current marks are unusual to occur if contact of current is over a large body surface area and time of contact is only a few or fraction of a second and the amperage is less than 1.5. Reduced cutaneous resistance and decreased density of current are two factors that facilitate the traceless passing of current through skin. It is convenient to divide the injuries caused by current into two groups.

1. Due to low voltage (up to 1000 V) &
2. Due to high voltage (above 1000).

1. Due to low voltage (up to 1000 V):

Electric mark:

An electric mark can be seen at the point of entry of current where the electric energy is converted into thermal energy. The electric mark specifies contact with electricity, but is not fool proof of electrocution. The presence of electric mark gives strong indication of death due to electrocution, in fatal cases. Characteristically these marks are round to oval, shallow crater about 1-3 mm, bordered by a ridge of skin. Floor of the crater is lined by pale flattened skin. Occasionally there will be breech of skin within or near margin of crater, resembling that of a broken blister. As a whole

the skin of the mark look's distinctly pale, but there may be redness of immediate surrounding skin. Shape of the electric mark resembles the shape of the conductor or that part of the electrical source which is in contact with the skin.

Joule Burn (Endogenous burn)

When the contact with electricity is prolonged the skin acquires a brown tint and with further prolongation of contact, there will be charring. There will be crater formation, which is tough on palpation and the margins of crater is raised and the floor is depressed in the shape of the conductor causing the contact.These skin changes are due to burning, called Joule burn, a term which distinguishes it from exogenous thermal heat following contact with high voltage i.e.; flash burn. Joule burn is also termed endogenous burn, since electrical energy is converted into thermal energy within the tissues.

Electric marks and Joule burns are frequently found in the exposed parts of the body, particularly on flexor aspects of hand. Since skin over back of hand is loose, marks produced may take form of craters, which have ridged sloping external wall, suggesting that during production of mark the adjacent skin was pulled towards base.

The electric mark is specific for contact with electricity but not a proof of electrocution as an electrocution mark may be produced after death.

Skin Microscopic examination

The epidermis is flattened and there is distortion of the cells or massive degeneration of epithelium and collagen with typical micro blisters in epidermis, shrinkage of epidermis, vacuolation in deeper layers, coagulation necrosis of tissue proteins and metallization.Glister's Medical Jurisprudence liked to term electrical burns as **'electrical necrosis'**.

Exit marks:

Are variable but have most features of entrance mark.Also at the site of exit there may be generation of heat, to such an extent that there will be production of fire and flash which may result into burning etc. Instead of cracks they are often seen as splits. The tissue may be ruptured giving deep laceration like appearance.Microscopically there is honeycomb appearance of damaged tissue due to coagulation necrosis along with flattening of cells.

2. High tension injuries (Exogenous burns)

These injuries occur as a result of either direct contact or an indirect result of arcing or flash over. There is risk of severe thermal burns because of immense heat generated in flash and knock down by sudden and appreciable increase in local atmospheric pressure.

Multiple discrete lesions due to arcing are produced with the blast effect, called **crocodile burns**. There is risk of arcing if a person comes in close vicinity of high tension cables. In such cases the survival of victim shows that the current passed by and not through the body. Flash burns may be extensive and may be exaggerated by burns from ignited clothing. There might be considerable destruction of soft tissues, charring of bones or fusion into pearl like bodies.

Metallization:

This is a specific feature of electrical and lightning injury. This occurs as a result of penetration of metal from the conductor or electrode into the skin that may take place with both direct and alternating current. The colour of imprint left by metal depends on composition of electrode.

The metallized skin desquamates within few weeks. Metallization provides confirmatory evidence that injuries are produced due to electro-thermic force.

Acro-reaction test:

This is micro-chemical test for detecting metals in electric marks. It is based on the solubility of the metal in either hydrochloric acid or nitric acid.

B. Muscles and Tendons

Striated muscles possess great electric conducting power. There will be direct stimulation of neuromuscular junction, which results in muscular contraction. Local elevation in temperature causes electro-thermal injury. Contraction of flexor muscles will result in tightly holding on the line. Tearing of muscles is also seen, which is a rare phenomenon. Microscopic examination of skeletal muscle shows tears in the muscle fibers.

C. Bones and Joints

Violent muscular contractions may lead to fracture of bones and dislocations. In high voltage injuries electro-thermic effects cause osteonecrosis and melting of bone tissue so called **osseous pearls** of phosphoric acid calcium. They are the size of pea, greyish white and hollow and usually found on surface of injured bones. Late bone injuries may occur due to tissue ischemia.

D. Heart and circulatory system

On brief exposure to low voltage current cardiac function may transiently stop and start again after withdrawal of current. Exposure to high intensity current following long duration contact leads to ventricular fibrillation and cardiac arrest. With high voltage current ventricular fibrillation do not occur. Microscopic exam of heart shows myocardial haemorrhagic necrosis.

E. Nervous system

Death may occur instantaneously when current passes through the brain stem resulting in paralysis of respiratory center.

F. Endocrine system

Injury to endocrine system will result in perspiration or dryness of skin, pigmentolysis, herpetic eruption, graying and loss of hair, menstrual abnormalities, glycosuria, polyuria, weight loss and abnormal thyroid function.

G. Blood and haemopoietic system

Blood will become liquid and dark. There will be haemolyticanaemia leading to increased serum bilirubin levels.

H. Lungs

There may be pulmonary oedema and peticheal haemorrhages. Microscopic examination shows features of pulmonary oedema.

I. Liver

There will be elevation of serum bilirubin levels and bilirubinaemia.

J. Kidneys

Renal failure is frequently seen in high voltage shock. Microscopic examination shows congestion, DIC, necrosis of lower nephron in case of muscle degeneration.

K. Ear

Tympanic membrane, middle ear, and cochlea may show haemorrhages. Mastoiditis and sinus thrombosis and temporary or permanent hearing defects may occur.

L. Eye

Two categories of injuries are observed in the eyes. One is due to thermal effect resulting in burns. Second is due to light effect leading to photopsy, strabismus, ptosis, ocular muscle paralysis, disturbance in accommodation, scotoma, intraocular haemorrhage, thrombosis, retinal oedema, papilitis, optic nerve atrophy and cataract.

M. General Features

The moment of electrocution is painless. With the low voltage electrocution there may be momentary feeling of tingling and numbness, person may get stunned momentarily and fall on ground. With fatal or more serious contact, victim may lie unconscious for a varying period. A **suspended animation** like state may prevail for a considerable period. Many victims can be resuscitated from this state. But problems like mental confusion, lack of response, retrograde amnesia, partial deafness, defective vision, incontinence, vertigo etc may persist for some hours or days or as permanent sequelae.

Lightning [9]:

It is the discharge of atmospheric potential between clouds. Lightning strike is discharge between the cloud and earth or any mass on the earth. The voltage of electricity in lightning is 100 to 1000 million volts and amperage is varying between 10,000 to 2, 00,000.

Effects of lightning:

1. Due to high voltage current- results in spasmodic contraction of cerebral vessels causing instant death due to cerebral anaemia. Also there will be instant contraction of the heart muscle.

2. Due to heated air or flash and fire generated- may result into burn injuries of any degree.

3. Due to successive expansion and regression of the heated air surrounding the spark- may result into blast effect leading to severe mechanical injuries like lacerations and contusions. Also might cause gross distortion or mutilation of the body. Clothes may show multiple tears. Person might be thrown forcefully against a wall causing further injuries.

4. Due to compression of the air occurring constantly throughout the path, ahead of the high speed return stroke (lightning stroke) - it has similar effects but with less severity than that due to the expansion of air.

Lightning accidents are more common among farmers as compared to city dwellers. Majority of accidents occur in open fields, building tops, under a solitary tree, swimming pools etc.

Spencer describes external lesions caused by lightning into three types:

Linear burns

The size of linear burns varies from 3 to 30 cm in length and 0.3 to 2.5 cm in width.

Filigree burns

These are superficial, thin, irregular, tortuous markings on skin which resemble branches of a tree. This is usually found over shoulders or flanks. It is not associated with burning. It is caused by slight staining of tissues by hemoglobin from lysis of RBCs along the path of current and due to copper deposits in dermis. It disappears in 2-3 days if person survives.

First to third degree burns

Burn injuries caused by lightning vary from first to third degree. Death occurs in more than 50% of cases, cause of death is either paralysis of respiratory center or paralysis of heart.

Death due to electricity:

In most of the fatal cases of electrical injuries, death is caused by electric energy itself. Rarely electrical injury is associated with mechanical injury (secondaryinjuries). Three categories of death due to electrocution are instant death, death after a short interval and delayed death.

Causes of Instant & Immediate deaths [8 & 9]:

Ventricular fibrillation:

It is reversible if duration of contact is short and irreversible if contact time is more.

In exposure to low voltage current, death is caused by ventricular fibrillation. Heart is most vulnerable at the end of systole.

Tetanic asphyxia:

Current passing through chest, when sustained between 20ma to 30ma, can induce tetanic contraction of extrinsic muscles of respiration and thus cause death by mechanical asphyxia. These victims are likely to be cyanosed, while those who die of ventricular fibrillation are not.

Respiratory arrest:

If the path of current in the body of the victim is through the respiratory center, there may be paralysis of respiratory center and instant respiratory arrest. This is most likely when head is involved or current passes from one arm to the other arm.

Cerebral anoxia:

Prolonged ventricular fibrillation may cause brain damage from an inadequate blood supply leading to cerebral anoxia.

Neurological damage:

Passage of electric current through the central nervous system can cause tearing of brain parenchyma or shrinkage around small blood vessels leading to paralysis of or damage to the nerve centres.

Delayed death could be due to:

1. Gangrene and haemorrhage due to arterial damage and necrosis of the tissue.
2. Damage to spinal cord.
3. Aseptic necrosis and resultant depression of the bone marrow.
4. Angina pectoris or myocardial necrosis.
5. Eye injuries resulting in cataract and optic atrophy.
6. Septicaemia.

Circumstances of electrocution [8 & 9]:

Accidental electrocution:

Most of the electrical injury is accidental. The bulk of fatalities are as a result of accidental contact with low voltage of 110 – 250 V, i.e. indoor supply. Domestic electrical appliances, which are commonly involved, are water boiler, immersion coil, electric stove, electric iron, hair dryer.

Common causes of accidental electrocution are inefficient earthing of apparatus, defect in flexible wiring, faulty connection between mains and apparatus, amateur repairs, worn out insulation.

Suicidal electrocution:

Although it is easy to acquire material for self-electrocution, suicide by electrocution is rare.

Homicidal electrocution:

Murder by electrocution though it has been reported in the literature but is very rare.

Judicial electrocution:

The use of electrocution as a means of capital punishment dates back to the discovery of AC by Tesla. It was first introduced in New York. A current of 2000v and 7a, is passed for one minute through the body of the convicted person. After tetanic spasm and loss of consciousness, same current is passed for one more minute.

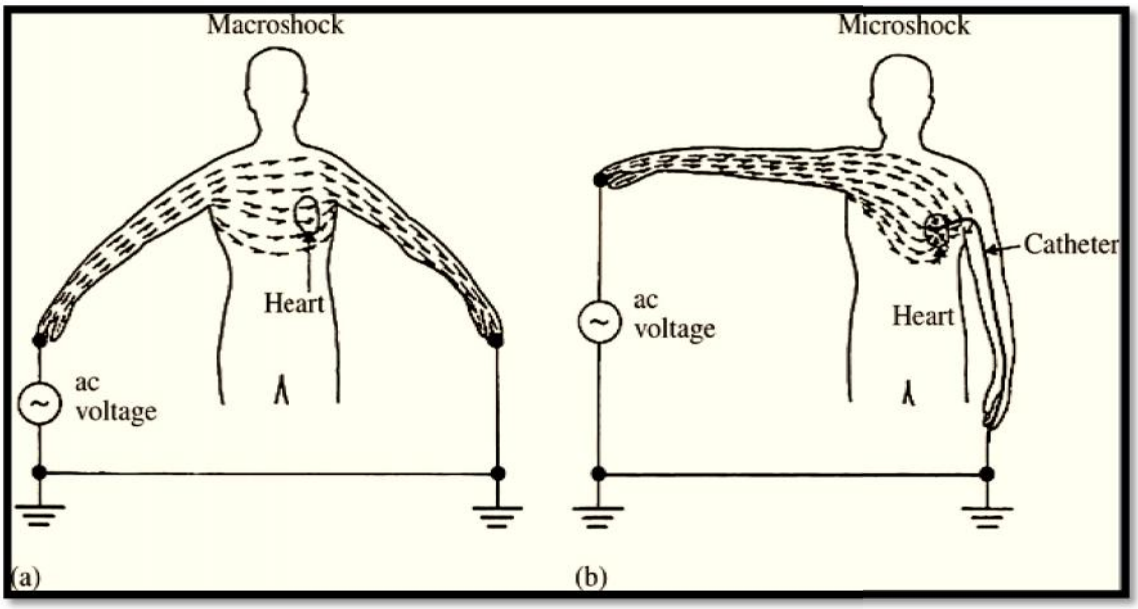
Autoerotic electrocution:

Also there have been cases of electrical stimulation as one of the modes of autoerotic practice similar to sexual asphyxia, which may become fatal. Victims are most commonly males either nude or clothed in female garments. Wiring is arranged in such a manner to include genitalia for stimulations. Number of such cases reported is small.

Iatrogenic electrocution:

A number of cases of electrocution have been reported in course of investigation and treatment of patients with electrical apparatus. Electric current is used in electroconvulsive therapy, cautery and in other various diagnostic and

therapeutic procedures carrying risk of electrocution which can be fatal if proper care is not taken.



a) Macroshock: Externally applied current spreads throughout the body.
b) Microshock: All the current applied through an intra-cardiac catheter flows through the heart.

(From:Weibell JF. Electrical safety in the hospital. Annals of biomedical engineering 1974; 2: 126–148.)

LOW VOLTAGE DOES NOT MEAN LOW HAZARD!

REVIEW OF LITERATURE

Anything you plug into the wall or put batteries in, uses electricity. Electricity wasn't invented – it occurs naturally, for example, through lightning – but inventions such as light bulbs, motors, televisions and batteries, which give different effects to the electrical energy, have revolutionized society.

Inventions in Electrical Energy:

Knowledge of electric current dates back to **600 B.C.** when, a Greek philosopher **Thales of Miletus**, recorded that when he polishes amber with a piece of wool or fur, a static electric charge is created, attracting straw or feathers. **Otto von Guericke** is credited with building the first electrical machine in **1663**, a rotating frictional generator [10]. This form of electricity precedes electromagnetic energy, which dominates today.

The landscape for today's electricity usage practices bloomed from **1831 to 1846 A.D.** with theoretical and experimental work from **Faraday**, **Weber** and **Gauss** in the relationship of current, magnetic fields and force. These theories enabled the design of modern motors and generators. From **1880 to 1900 A.D.** there was a period of rapid development in electrical machines when **Thomas Alva Edison** invented electric bulb by DC current while **Nikolas Tesla** invented the AC current, allowing electricity to be distributed longer distances than the two miles possible with direct current generators of Edison. **Everyone but Edison agreed, AC is superior to DC**. AC turned out to have such an advantage (no neighborhood power plants required) that it completely won out over Edison's DC. Even Edison's own company – **Edison Electric Company**, now called **General Electric** – eventually switched to AC. **Tesla**

got the support of **George Westinghouse**, and their system turned into the one we use today. **All electric motors today run on principles set out by Tesla** [10 & 11].

The year **1895 A.D.** marks the beginning of an era of large-scale power distribution when water flowing over **Niagara Falls** is diverted through a pair of high-speed turbines. American inventor and industrialist George Westinghouse won the contract to construct the generators after purchasing Tesla's patent for generating alternating current. In **1904 A.D.** General Electric completed a second power station at Niagara Falls. In **1935 A.D.,** U S president **Franklin D. Roosevelt** signed a legislation establishing, the Rural Electrification Administration and making federal funds available for rural electric service. In **1951 A.D.** a nuclear reactor built at Arco, Idaho, powers a generator, producing the first electricity generated by atomic energy [10 & 11].

The first tidal power plant (average tidal range 8 meters) was completed at the mouth of the La Rance estuary on the Brittany coast of France in **1966 A.D.** [12]. Later other forms of electric power generation like Wind Power - Electricity, Wave Power, Solar Power, Thermoelectric power (heat energy to electrical energy) etc., came into use.

The International Energy Agency (IEA) estimates that as of 2005, approximately three quarters of the Earth's population (4.8 billion of 6.4 billion people) has access to electricity [13].

Electrical Execution and Fatality:

Edison initially did not accept Tesla's AC generation and tried to defame him by demonstrating that AC is unsafe, by electrocuting animals in the public and also electrocuting prisoners who were awarded death sentence, after convincing the State of New York to switch from hanging its condemned inmates to electrocuting them. Later Edison was successful in convincing the authorities that this method of execution was more humane, and since he had become such a man of influence and importance to the scientific society and the general public that, later death by electrocution was accepted as a mode of capital punishment by many provinces of U S, without any pathophysiological explanation of the mechanism of electrocution, of which Edison had no idea.

The first electrical fatality was recorded in **France** in **1879 A.D.** when a stage carpenter was killed by an alternating current (AC) of 250 volts. The first electrocution death in **UK** was in **1880 A.D.**, close to Birmingham. The first U.S. fatality occurred in **1881 A.D.**, when a local inebriate, Samuel W. Smith, passed out on a similar generator in front of a crowd in Buffalo, New York [3].In **1890 A.D.** William Kemmeler was the first man to be put to death in **New York** State's electric chair [4].

Laurie Ahern and Eric Rosenthal (President and Executive director of Mental Disability Rights International) published a report in the year 2010 regarding routine use of electric shock as a means of punishment in the United States in Judge Rotenberg Center Program for behavior modification and aversive treatment of children and adults, which constitute ill-treatment or torture as per the UN Convention against Torture [14].

As per Amnesty International's 2012 study report regarding torture in Syria, three forms of electric shock torture were described by the former detainees: a) dousing the victim or cell floor with water, then electro-shocking the victim through the water; b) the "electric chair", where electrodes are connected to parts of the body; and c) use of electric prods [15].

Studies on various aspects of Electrical injuries:

Various studies have been conducted on electrical injuries, mainly with respect to its types, pattern, epidemiology, mortality, burns etc.

Foreign studies:

In a study carried out in Turkey, between 1965 and 2006, 945 cases years were reviewed, of which, 351 electrocution cases were identified. Electrocution accounted for 37.14% of all studied electricity- caused injuries. The average age of the victims was 35.25 years. The average age of male victims was 36.19 years and of female victims was 32.55 years. Male sex (74.07%) showed a significant prevalence. Among the circumstances leading to electrocution, household accidents (78.06%) prevailed over occupational accidents (13.39%). Suicides were significantly rarer (7.41%). and 66.10% of all electrocution cases occurred during the summer period from June through September [16].

In a study carried out by Fatovich DM in Western Australia between 1976 and 1990, there were 104 victims of electrical injury. Most death occurred in young men exposed to low voltage current during summer, and nearly half the fatalities occurred in the workplace. 52% of fatalities showed presence of water [17].

In a 22 year retrospective study carried out in Northern Ireland from January 1, 1982 to 31st December 2003, 59 cases of electrocution were identified. Out of which, 50 were accidental and 9 were suicides. No case of homicide was encountered. Accidental electrocutions were common in young and middle-aged male adults with deaths occurring more frequently in the summer months. 60% of the cases were work related. High and low voltage related deaths occurred with similar frequency and electrical appliances were responsible for approximately one third of accidental electrocutions [18].

A 20 year study done in Zagreb, Croatia, from 1991to 2010, a total of 89 electrocution cases were identified. An electrical mark was detected in 79% of the cases, whereas no detectable changes on the skin were in the remaining 21% of the cases. 43% of the cases showed entry wound, both entry and exit wounds were found in 20%, while in 16% of the cases with extensive burns neither entry nor exit point could be detected. Most victims of fatal electrocution were men aged between 20 and 50. Most cases were accidents (83%) and the rest were suicides (14%) or the manner of death was undetermined [19].

In a study carried out in Berlin by Bockholdt B and Schneider V, between 1995 and 1999, 41 cases of death by electrocution in the bathtub were investigated. A clear cutaneous electric mark was described in 16 cases and the "border-zone-phenomenon" a pale stripe on the skin corresponding to the water level on the skin was found in two cases. The histological investigation of this region (in one case) provided no typical signs of a cutaneous electric mark. 19 cases were males (46%) and 22 females (54%). The median age for males was 46 years and for females 59 years. In 75% of cases electric appliance was a hair dryer, in one case two hair dryers

and in another a table lamp and telephone were found in the bath tub. A relevant blood alcohol level was found in 9 cases. 30 of the cases were suicides (75%). In One case was a homicide, 6 cases were declared as "accidental" and in 4 cases the autopsy findings and the inquiries of the police did not allow a clear determination of the circumstances of death [20].

In another study in Nigerian regional burn centre from January 1995 to December 2004, out of twenty four (24) case files, electrical burns constituted 2.8% of total burn admissions. Patient´s age ranged from 15 months to 42 years. Male: Female ratio was 4.8:1. Seven had high voltage injuries, mostly work-related. Sixteen had low voltage injuries while one had a lightening injury. Fourteen presented or were referred more than 24 hours post injury. Fifteen had a form of surgical treatment with wound debridement (33%) skin grafting (38%) and amputations (29%) being the commonest ones. The mortality was 12.5% with septicaemia as the leading cause of death [21].

In a study carried out in the period 1995 to 2009 in the district of Stara Zagora, Bulgaria, 98 cases of death due to electrocution were analyzed. 87 cases (88.8%) were male, while 11 cases (11.2%) were female. Predominant number of accidents occurred during the summer months – June, July, August – 55.1% of all cases, while there were none in December. The average age of the deceased was 40 years. There were 3 cases of suicide with electric current (3.3%) and all of them were male who used low-voltage current. Homicidal deaths were nil. Death from low voltage – 63 cases (65.6%), and from high voltage – 25 cases (26.0 %). Theft of cables and live power equipment, took 9 victims (10.0 %) of all deceased [22].

In a retrospective study of non-lightening electrocution deaths carried out in Diyarbakir, Turkey between 1996 and 2002. All 123 deaths investigated were accidental. The age range was 2 to 63 years with a mean age of 20.7 ± 15.3 years. Eighty-six victims (69.9%) were male. The upper extremity was the most frequently involved contact site in 96 deaths (48%). No electrical burn mark was present in 14 (11.4%) cases. Home accidents were responsible for 56 cases deaths (45.5%). Deaths were caused most frequently by touching an electrical wire (52 cases, 42.3%). There was an increase in electrocution deaths in the summer (47 cases, 38.2%). One hundred one cases (82.1%) were dead on arrival at hospital. The unique findings of our study include younger age (0-10 years) of victims (39 cases, 31.7%) and a means of electrocution (electrical water heaters in bathroom) in 23 cases (18.7%) [23].

A study was done retrospectively on 25 electrically injured patients, admitted to Ain Shams University Burn Unit Egypt in the period from 1996- 2002. 24 patients were males (96%) and one only was a female (4%). Age range was between 2 and 46 years (average 24.4 years) and the surface extent of burn ranged from 0.5 to 46% TBSA (average 8.86% TBSA).15 had low-voltage injuries and 10 patients had high-voltage injuries. Two cases died from complications of associated thermal burns. One had low-voltage and the other had high-voltage injury. The causes of death being inhalation injury and burn wound sepsis [24].

In a study carried out by Gunduz T, Elcioglu O, and Cetin C in Turky between 1997 and 2005, electrical injuries. Males constituted 89.1% of the electrical burn patients. Forty-one of the injuries were due to high voltage whereas 14 injuries were due to low voltage. Complications were most common in the high-voltage group.

Mean length of stay was longest in this group, at 33.69±21.13 days, and the patients in this group also required the most operations [25].

In a study carried out in Ankara, Turkey by Akcan R, Karacaoglu E, Keten A, Aysun BO, Kanburoglu C, Tumer AR, et al over a period of 11 years (1998 to 2008) out of 12,263 autopsy cases,100(0.8%) were secondary to electrocution. 94 were male and 6 were female. Victims' age ranged from 1 year to 76 years, with a mean age of 33.5 years. In 74 cases, entry lesions were localized on the upper extremities. 3 cases showed no electrical marks. 71 cases were of workplace accidents. An increase in electrical fatalities was seen in the summer (n = 58, 58%). All of the deaths were recorded as accidental except for one suicidal death [26].

In a study of high voltage electrical injury from January 1 1999 to December 31 2009 carried out in Brno Czech Republic, there were 58 cases, 2 of whom were female. Electrical burns (caused by both low-voltage and high-voltage electric current) made up 1.10% of all burns cases and high voltage electrical injuries represented 0.42% of all burn injuries. Average incidence of high voltage electrical trauma was 0.21 cases/100,000 inhabitants. The average age of the patients was 28.59 years. Nine (15.52%) patients died. The average duration of hospital stay was 53.43 days. The average extent of burnt area was 35.01% TBSA [27].

In another study conducted in Gauteng, South Africa a total, 126 electrocution-related deaths were identified. There were 91casesof low voltage and 35cases of high-voltage-electrocution related deaths from 2001 to 2004. Of the91cases of low voltage electrocution related deaths, Asians were two; blacks were 71, whites 16 and mixed-ethnic descent – two deaths.69 were male and 22 female, fatalities included 35 cases younger than 25years; 46 cases aged between 26 and 50

years and 3 in the age group between 51 and 75 years, summer (Dec, Jan, Feb) 31 deaths, autumn (Mar, Apr, May) 18 deaths, winter (Jun, Jul, Aug) 17 and spring (Sep, Oct, Nov) 25 deaths,69 of the deaths occurred indoors and 19 of the deaths occurred outdoors. All cases were considered non-intentional, except for two which were deemed suicidal. Out of 35 cases of high-voltage-electrocution-related deaths, blacks were 25; whites7 deaths; and Asians and mixed-ethnic descent 3 deaths, 32 were male and three were female, six were younger than 25 years; 21 were between 26 and 50 years of age; three were in the age group 51–75 years and one case was in the age group 76–100 years; Summer 10, Autumn 9, Winter 8 and Spring 8 deaths; Four of the deaths occurred indoors and 31 occurred outdoors. All cases were non-intentional except for one case, which was suicidal. Twenty-two cases (24.18%) had some form of associated blunt-force trauma. Sixty-seven cases (73.63%) had no burns, two cases (2.20) had first-degree burns, 20 cases (21.98%) had second-degree burns, one case (1.10%) had third-degree burns and another case (1.10%) had a 'crocodile-skin' appearance [28].

In a study of non-lightening electrocution deaths in Tehran, Iran, between 2002 and 2006, of 295 deaths, 285 investigated were accidental. The remnants were suicidal. The age range was 11 months to 75 years with a mean age of 28.99 ± 12.58 years. 279 victims (96.6%) were males. The upper extremity was the most frequently involved contact site in 185 deaths (66.3%). No electrical burn marks were present in 16 (5.4%) cases. Work-related accidents were responsible for 188 deaths (63.9%) and home accident for 85 deaths (28.8%). Deaths were caused most frequently by touching an electrical cable (95 cases, 32.2%). There was an increase in electrocution deaths in the summer (119 cases, 40.3%). One hundred seventy- nine cases (60.7%)

were dead on the scene of accident and 94 cases (31.9%) were dead on arrival at hospital [29].

In a study carried out by Mashreky RS, Rahman F, Rahman A, Baset UK, Biswas A, Hossain J, regarding burn injuries in Bangladesh in the year 2003, among the total 1,999 injuries about 31% were due to electrical injuries, about 26% were due to flame, about 25% were due to hot liquid, over 16% by hot object, about 2% by chemical and less than 1% were due to explosives [30].

In another study carried out by Al B, Aldemir M, Guloglu C, Kara IH, Girgin S. in Diyabakir, Turkey, 165 patients (126 males; 39 females; mean age 21.1 years; range 2.5 to 62 years), who were admitted to the Emergency Department of Dicle University School of Medicine for electrical injuries, between January 2003 to April 2004, were retrospectively reviewed. Among these patients, 60 were under 12 years old; 95 were adolescents and adults, and 10 were aged, 29 were illiterate and 36 were educated. Ninety-seven patients were either graduates or still students of elementary, secondary or high school. The cause of exposure to electricity was accident in 99, and carelessness and parents' negligence in 66. Sixty-nine patients were exposed to high voltage and 96 to low voltage. Because of electrical injury 16 patients had first degree, 96 patients had second degree, and 86 patients had third degree burns. The most frequent complications were contractures of extremities (10.9%) and compartment syndrome. Mortality rate was 9.1%. 80% of the deaths were due to exposure to high voltage. Escharotomy was performed in 10 patients, fasciotomy in 16, and amputation in 9. Two of 5 patients who had intra-abdominal hemorrhage underwent surgery [31].

In a study conducted in Babylon City of Iraq between April 2004 to June 2006, 200 patients admitted to Hilla General Teaching Hospital were reviewed. The incidence of calvarial bone involvement was 100 % in electrical scalp injured patients while all patients with thermal scalp burn were partial thickness (bone free) during the study period. The mean age was eighteen years for the electrically injured patients (ranged from 14 to 30 years) and four years for the thermally burned patients (ranged from 2 to 8 years).Treatment was achieved with early bone debridement and immediate local scalp flaps coverage for electrical scalp injured patients while most of thermal scalp burned patients were healed spontaneously [32].

In a study carried out in Turkey, patients with electrical injuries admitted to the emergency department between January 2006 and 2010 were retrospectively analyzed. Eighty-four (57.1%) cases were exposed to low-voltage electricity (Group I), while 63 (42.9%) cases were exposed to high-voltage electricity (Group II). The majority of cases with electrical injuries were aged 26-45 years. Thirty of the women (85.7%) were wounded by low-voltage while 58 of the men (51.8%) were wounded by high-voltage electricity. Alanine aminotransferase, aspartate aminotransferase, lactate dehydrogenase, creatine kinase, and CK-MB levels were higher and the level of calcium was lower in Group II. Complications and the mortality rate were higher in Group II [33].

In a study carried out in Karachi Pakistan during January 2006 to December 2011, Out of total 371 electric burn injury patients, 336 (90.5%) were males while 35 (9.5%) were females. The mean age of electric burn injury patients was found to be 27.35 ±12.38. The proportion of age-groups most affected by electric burn injury was between 21 and 30 years [34].

In a cross sectional, descriptive study conducted between 2008 and 2011 in burn center of Sina Hospital, Tabriz, East Azerbaijan, Iran by Vahdati SS, Moradi N, Ghadim HJ, there were 229 patients; 204 (89.1%) men and 25 (10.9%) women. Moreover, among these cases the injury of 2 people was fatal and the others were treated [35].

In a study carried out on victims of flood disaster in Thailand in 2011, of 919 flood-related deaths, 83.4% were drowning, followed by electrocution (14.6%). Detailed information was available in 92 electrocution deaths. Median age was 47 years, male were 4 times higher than female. Seventy-seven percent died in household and 14.1% on street. Staying in capital city and neighboring provinces increased risk of electrocution deaths compared to rural provinces (RR=4.1; 95%CI=2.5-6.7). Major cause was intentional touched electric devices while body wet (36.5%), followed by staying within 1.5 meters distance from electric source (14.9%). Almost all (96%) electrocution cases did not shut off circuit breakers in houses [36].

A study of Alterations in arterial function after high-voltage electrical injury reported from Seoul, Korea, studied in 25 male patients exposed to more than 20,000 volts in the year 2012 [37].

A study of functional changes of the myocardium in survivors of high-voltage electrical injury (HVEI), on twenty-three patients who had been exposed to HVEI (>20,000 volts) and preserved left ventricular ejection fraction (≥55%) was carried out in Gyeonggi-do, Korea in 2013. The systolic and diastolic blood pressure and the heart rate were significantly higher in the HVEI group compared with the control group at baseline and at six weeks, but not at the six-month follow-up [38].

Rare and Atypical Case reports:

Many rare and atypical cases have been reported in literature from various parts of the globe like, a case of **autoerotic electrocution** with electric burn marks on skin of abdomen and penis reported from Nedlands Western Australia in the year 1994 [39], a case report of **delayed reversible motor neuronopathy** caused by electrical Injury in a female reported from Taipei, Taiwan, R.O.C. in the year April 2005 [40], a case of Electrical Injury-induced **high-degree atrioventricular block** requiring a permanent pacemaker reported from Daejeon, Korea in the year 2006 [41], a case in which ocular injuries were sustained by impalement with a **TASER** dart by law enforcement officials was reported from Toronto, Ont. in 2008 [42], a case of **acute cerebral infarction** caused by cerebral vasospasm due to high-voltage electrical injury in Seoul, Korea reported in the year 2013[43], a case of **low voltage electrocution mimicking a high voltage injury** was reported from Sri Lanka in July 2013 [44].

In one more case reported from Tehran, Iran, in the year Jan 2013, A 16 months baby was brought to the Emergency department with **complete cardiorespiratory arrest**, without any obvious cause, on examination by forensic team revealed electrical injury mark on palmar surface of distal phalanx of right index finger, signifying the importance of history taking and physical examination in most of the clinical cases especially by the forensic medical specialist [45].

A case report of Survival after severe **intra-thoracic electrical injury** was reported by Schleich AR, Schweiger H, Becsey A, Cruse CW, from Division of Critical Care Medicine, University of South Florida College of Medicine, USA in the year 2009, when a 23-year-old white male electrician sustained a high voltage work

related contact injury when a power line carrying 70 kV made contact with a truck the patient was holding on to [46].

Various cases of **lightning injuries** have been reported from, United Kingdom between 1988 and 2004 [47], Cantabria, Spain in 2001[48], three cases from Denver, Colorado between 2004 & 2006 [49]and Nigeria in the year 2008 [50].

INDIAN STUDIES:

As per a study conducted by Aggarwal NK; Kohli A; Aggarwal BBL, there were 36 cases in 3 years span of Jan 1992 to Dec 1994 brought to mortuary of GTB hospital attached to University College of Medical Science for autopsy. All cases were males, 50% were accidental and 88.9% died on spot [51].

In a retrospective study conducted by Rautji R, Rudra A, Behra C, Dogra TD in South Delhi, 153 unselected autopsy cases of electrocution received from South Delhi were studied during the period 1996 -2001. The cases represented approximately 1.98% of all autopsy cases received from South Delhi at the All India Institute of Medical Sciences, New Delhi (India). Death occurred at the scene of the fatal event in 150 cases and three cases died in hospital. Three cases showed no electric burn marks on the body; the cause of death in one of these cases was polytrauma due to a fall from a height and one case had committed suicide [52].

In a study conducted by Gadge SJ, Shrigiriwar MB, Forty seven victims of lightning-related death were identified from the records of Department of Forensic Medicine, Yavatmal, for period 1996 to 2010. Lightning strikes occurred from June to September (normal monsoon rainfall period), and most strikes took place in the afternoon [53].

In another study conducted at Government Medical College, Miraj and General Hospital, Sangli, Maharashtra, India, with regard to electrical burn injuries between January 1999 and December 2000, a total number of 40 patients were studied. Electrical burns were responsible for 2% of all burn admissions; 67.5% of the burns were due to low voltage and 32.5% to high voltage. The extremities were involved in 52.5% of the patients, and 55% underwent surgery. Debridement was the commonest procedure, followed by escharotomy. The mortality rate was 25%. The commonest cause of death was cardiac arrest, followed by septicaemia and renal failure. Congestion of the brain and oedematous lungs were frequent post mortem findings [54].

In another study carried out from January 2001 to December 2006 in Nagpur Maharashtra India, out of 86 cases of electrocution, 69 were men and 17 were women. Age ranged between 3 years to 65 years. 97.67% cases were of accidental death and 2.32% cases were of homicides. Accidental death was more common in age group 21 to 30 years. Of all cases, 45.34% were of electric contact, 31.39% cases were of contact and heat and 9.30% cases were of flash burns. In 6 cases no electric mark could be identified. 20.93% of deaths occurred in labour class [55].

In a Study of electrical injuries in fatal cases at Victoria Hospital, Bangalore carried out from Nov 2003 to Oct 2005 by Chandru K; total numbers of 61 cases were studied in two-year period. 54% of cases belonged to high voltage electrocution. Low voltage electrocution constituted 46%. 56% deaths occurred in rainy season, 23% in summer and 21% in winter. Percentage distribution of place of occurrence was- workplace: 59%, domestic: 28% and miscellaneous: 23% High voltage electrocution mainly presented as flash burns, while low voltage electrocution presented with

contact mark. Typical histo-pathological changes were seen in skin and heart specimen sent for examination. Histo-pathological changes in kidney were nonspecific [56].

In another study carried out in M. P. Shah Medical College, Jamnagar, Gujarat, analysis of the Medico-Legal autopsies conducted during 2004 to 2008 was done. Total number of victims was 102. Most of the victims were male 75 and the remaining were female 27(26.47%). Most of these cases, 52(50.99%), were seen in the months of June, July and August. Age of the victims was over the range of 1 year to 70 years, most of them fell in the age group of 11-50 years. Most of the victims had suffered indoor electrical injury. In 48 cases (47.06 %), only entry marks were seen, while 34 cases (33.34 %) showed both the entry and exit marks. In 9 cases (8.82 %), no marks were seen. In 19 cases (18.62 %), there were additional marks (non-electrocution injuries). 13 cases (12.74 %) showed burns on the body and clothes. In 91 cases (89.21 %) Upper limbs showed the electrocution marks. This was followed by lower limbs 29 cases (28.43 %).In 68 cases, the surrounding area, at the site of incident, was damp or wet, while it was dry in 34 cases (33.33%). 98 (96.07%) victims died on the spot or declared dead when brought hospital. 3 cases (2.94%) survived the initial shock, though died within 24 hours of the incident. One victim died after 24 hours. All cases were accidental except one which was suicidal [57].

In a prospective and retrospective study from 2004 to 2009conducted by Patil SB, Khare NA, Jaiswal S, Jain A, Chitranshi A, Math M at Government Medical College, Nagpur, Maharashtra, India84 patients with electrical burn injuries were analyzed for their demographic profile, age, sex, occupation, rural-urban distribution, mode of injury, and place of injury. The most frequently affected age group was the

second decade of life (33.3%). Of 84 patients studied, 71 were male and 13 female. Fifty-nine patients were from the urban area, while 25 were from the rural area. Students including children and adolescents were the most common affected single group (22.5%). Contact with live wire or contact with an object that was in contact with a live wire (secondary contact) accounted for 43 of 84 cases (51%). Home was the most common location where injury occurred (51.2%). Twenty-one of 59 cases (35.6%) reported from the urban area and 3 of 25 cases (12%) from the rural area had specific knowledge about prevention of electrical burn injury. Forty-one patients (69.4%) from the urban area and 22 (88%) from the rural area believed that adequate information regarding electrical burn injury was not available. Thirty-six patients (61%) from the urban area and 24 (96%) from the rural area believed that they would have behaved differently if the information had been available [58].

As per a study, in Mamata General Hospital, Khammam, Andhra Pradesh, a total of 62 Electrical injury cases were admitted over a period of one year from October 2007 to September 2008. Males {57(91.93%)} outnumbered females {5(8.06%)}. In 21-30 years age group 24 cases (38.71%), with male preponderance of 22 (33.87%) and females 2(3.23%) followed by 31-40 years age group, only males victims 14 (22.58%) were seen. In the age group of 11-20 years only male victims were 13 (20.97%) and in 0-10 years age group female victims 2 (3.23%) and male victim only 1(1.61%). In the age group 51-70 years male victims were 2 (3.23%) and female victim 1(1.61%). The Low tension accidents were 42(67.74%) and high tension 20(32.26%) noted. The epidermal electrical burns are common. 34(54.84%) followed by dermo-epidermal 12(19.35%) and deep 3(4.84%). As per hospital stay most victims admitted were discharged within 3 days 40(64.51%), followed by 3-10days 16(25.80%), and more than 10 days 1(1.61%). The results reveal that after

treatment discharges were 40(64.52%), followed by referred cases 10(16.13%) and left against medical advice were 7(11.29%), lastly deaths were 5 (08.06%). Most of the electrical injury cases were entry wounds 47 (75.80%), followed by exit wound 24(38.71%) and both entry and exit wounds 22 (35.48%), next was flash burns 16(25.80%). In 13(20.96%) cases no signs of electrocution were observed. Only entry wound were 25(40.32%) and both entry and exit wounds were 22(38.48%) cases. Majority of entry wound were seen in right hand 25(40.32%) followed by left hand 9(11.51%) and head and neck 5 (8.06%), next is thorax 4(6.45%); lastly right feet in 1(1.61%). In 3(4.84%) cases both hands were involved. The most common site of entry wound was hand. Only exit wound were 2 (3.23%) and both entry and exit wounds 22(38.48%) were observed. Majority of exit wounds were seen in left feet 13 (20.96%), followed by right feet 6(9.68%) and left hand 4(6.45%), lastly left thigh 1(1.61%). The commonest site of exit wound was feet. 16 (25.80%) cases were flash burns. Majority of flash burns were effected on face and neck 6(9.68%) followed by thorax 3(4.85%) and upper limbs 3(4.84%) next is abdomen 2(3.23%), lastly whole body in 2(3.23%) cases were 95-98% of T.B.S.A. In all fatal cases, there was internal viscera congestion and in one case diffuse petechial hemorrhage in brain white matter was noted [59].

In a study carried out in Mamata General Hospital Khammam, Andhra Pradesh; from Sept 2007 to Oct 2008, eleven cases of electrical shock were analyzed histo-pathologically. Histo-pathological changes observed were nuclear steaming, dermo-epidermal separation and coagulative necrosis being the commonest features in skin with electric contact mark [60].

In a two year study from May 2007 to April 2009,carried out on 49 autopsy cases in Govt. Medical College Aurangabad,41 cases were male and 8 cases were female. The visible electrical entry mark was found in 79.59% cases and visible electrical exit mark was seen in 12.24% cases. Manner of death among the cases were accidental in 95.92% whereas 4.08% were homicidal [61].

In a study regarding electrocution deaths in Manipur, out of the 2463 medico-legal cases brought for autopsy during 2007 to 2011, twenty five cases (1.02%) were electrocution deaths and males outnumbered females. The maximum number of cases was in the age group of 21 - 30 years followed by 31- 40 years. Most of the victims were electrocuted on the road side (68%) and the remaining electrocuted in their houses. The most common causative agent was the high tension wire (60%) followed by the home appliances (28%). 80% of the cases died on the spot and the majority of these victims were electrocuted by the high tension wires. All the electrocution deaths were accidental cases and no homicidal or suicidal cases were observed [62].

In a retrospective study carried out in Northern part of India (Lucknow) over a period of 5 years from 2008 to 2012, out of 83 electrocutions related deaths, 71 investigated were accidental. The remainder was suicidal. The age range was 11 months to 75 years with a mean age of 28.9 ± 12.5 years. 65 (78%) were males and rest were females. The upper extremity was the most frequently involved contact site in 51 deaths (61%). No electrical burn marks were present in 10 (11.9%) cases. Work related accidents were responsible for 49 cases of deaths (59%) and home accident for 19 cases of deaths (22.9%).Deaths were caused most frequently by touching an electrical wire (35 cases, 41.9%). There was an increase in electrocution deaths in the

month of July–September (32 cases, 39%). About 50 cases(60.7%) were dead on the scene of death and 33 cases (31.9%) were dead on arrival at hospital [63].

In a study carried out in Union Territory of India (Puducherry) during the calendar year 2012, out of 1560 medico-legal cases, 23(1.47%) were fatal electrocution cases. Predominantly adult males in the age group of 21 to 40years (48%) were the victims. Majority of the victims belonged to rural area (65%), literates (61%), Hindu religion (83%), Married (57%) and middle income group (52%).Occupationally most of them were agricultural workers (26%), Labourers (22%) and housewives (17%). Upper extremity parts like hands and fingers (70%) were the most commonly affected body parts, lower extremity parts like soles and toes accounted for17%. The entry wound alone was found in 11(48%) cases, both entry and exit wounds were found in 7(30%) cases, whereas only exit wound was found in 3(13%) cases and no electrical contact marks in 2(09%) cases. All deaths were accidental, no suicidal and a homicide case was reported [64].

In a research paper published by Thaker NM, Phadke NB and Patel DP of the Institute of Engineering & Science, IPS Academy, Indore (Madhya Pradesh) in the year September 2013, there is a very high rate of serious injuries & fatal accidents due to improper handling of electricity in India in comparison with other countries [65].

Rare and Atypical Case reports:

A case of suicidal electrocution in Navy, the victim being the electrician [66], a case of high-voltage suicidal electrocution with **multiple exit wounds** [67], and also a case of **suicidal electrocution** from Kathmando, Nepal using a homemade electrocution device have been reported [68].

Rare cases of **homicidal electrocution** were reported by Chandrakant VH, Arun M, Pramod Kumar GN, Reddy A. in JSS Medical college Mysore [69];by Sharma L and colleagues from Rohtak Haryana in the year 2003 [70].A rare case report of **electrocution method to conceal homicide** was reported by Jambure PM, Tandle MR, Zine UK from Government Medical College, Aurangabad in 2012 [71].

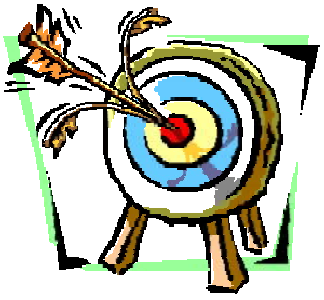
Eipe N, Pillai DA and Choudhrie R reported a case of **tracheo-oesophageal-cutaneous fistula** due to electric burn injuries to neck, in the year 2004from Padhar Hospital, Betul, Madhya Pradesh, India [72].

A case of Fatal burns due to **arcing current** was reported by Bakkannavar MS, Kumar A, Vijay V, Nayak CV, Pradeep Kumar G, Palimar V from Manipal, Karnataka India in the year 2014 [73].

An unusual case of high-voltage electrical **burn of the head** was reported from CSM (Earlier King George's) Medical University, Lucknow in the year 2009 [74]. Other unusual cases of electrical injury and dilated **cardiomyopathy**[75], **Jejunal perforation** following electric burns [76] and **acute ischaemic stroke and** acute myocardial infarction occurring together in domestic low-voltage (220-240V) electrical injury [77] have been reported.

Chandra Prakash and Ishwer Tayal have reported three cases of Victims of **Lightning during Thunderstorm** with different presentations, braught to the Government Medical College, Haldwani in the year 2013 [78].

Introduction



Objectives

Electricity And Injury

Review of Literature

Methodology

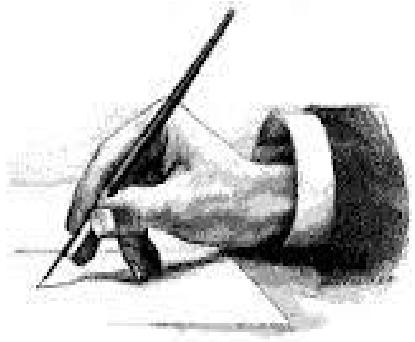
Results

Discussion

Conclusion

Summary

Bibliography



Annexure-I

Annexure-II

Annexure-III

Annexure-IV

MATERIAL AND METHODS

SOURCE OF DATA:

Data was collected from patients of electrical injuries visiting casualty/OPD/wards, their medical records and autopsy reports in fatal cases at KLESs Dr. Prabhakar Kore Hospital and MRC, Belgaum.

Study design: Hospital based study.

Study period: FromOct 2012 to Dec 2013.

Sample size: By universal sampling method.

All the victims/patients of electrical injuries visiting KLES´s Dr. Prabhakar Kore Hospital and MRC, Belgaum, during the study period were included.

Inclusion criteria:

All victims/patients of electrical injuries of- 1.All age group 2.Both the sexes 3.Accidental/Suicidal/Homicidal. 4. Natural source (lightning)/Manmade source. 5. Secondary injuries sustained due to electric contact, visiting KLES´s Dr. Prabhakar Kore Hospital and MRC, Belgaum.

Exclusion criteria: Patients with no clear history of electrical contact.

Follow up patients who had been already included in the study.

Method of collection of data:

Informed expressed consent (Annexure 1) was taken and a pre-tested proforma (Annexure 2) specially designed for this purpose was used for collecting the information.

Instruments used for data collection:

Proforma:

1. General particulars including the socio-demographic profile of the victims/patients.

2. Detailed particulars of the injury.

The electrical injury cases coming to the casualty were identified; properly explained about the objectives of the intended study and necessary details needed for the study were collected in the proforma, which includes a detailed description of all the general data of the victims/ patients. Their socio-demographic profile was taken to study the various types of electrical injuries in each age group, sex, socio-economic status and occupation. Detailed data with respect to the injuries was taken regarding the type of electrical injury, mode, place of occurrence, time of occurrence, degree of injury, factors causing the injury and secondary injuries suffered, by interviewing the patient/attenders and by examination of the injured.

Every day the data was collected from the casualty and follow up was done in the admitted cases. Outpatient cases were studied with the available records. Fatal cases studied at autopsy accordingly. The statistics were made weekly.

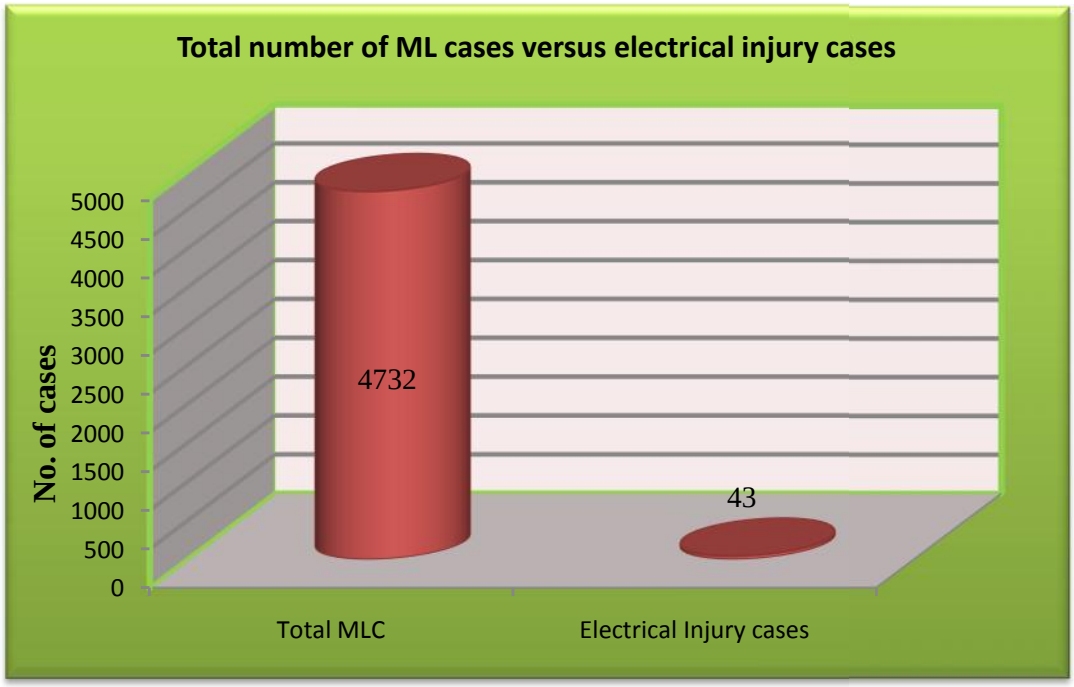
The data thus collected was analyzed and conclusions drawn. Percentage distribution of various types of injuries with respect to various factors influencing the injuries calculated.

RESULTS

Table 1: Showing total number of medico-legal cases versus electrical injury cases which came to our tertiary health care centre:

Total number of Medico-legal cases	Total number of electrical injury cases	Percentage
4732	43	0.91%

Graph 1:

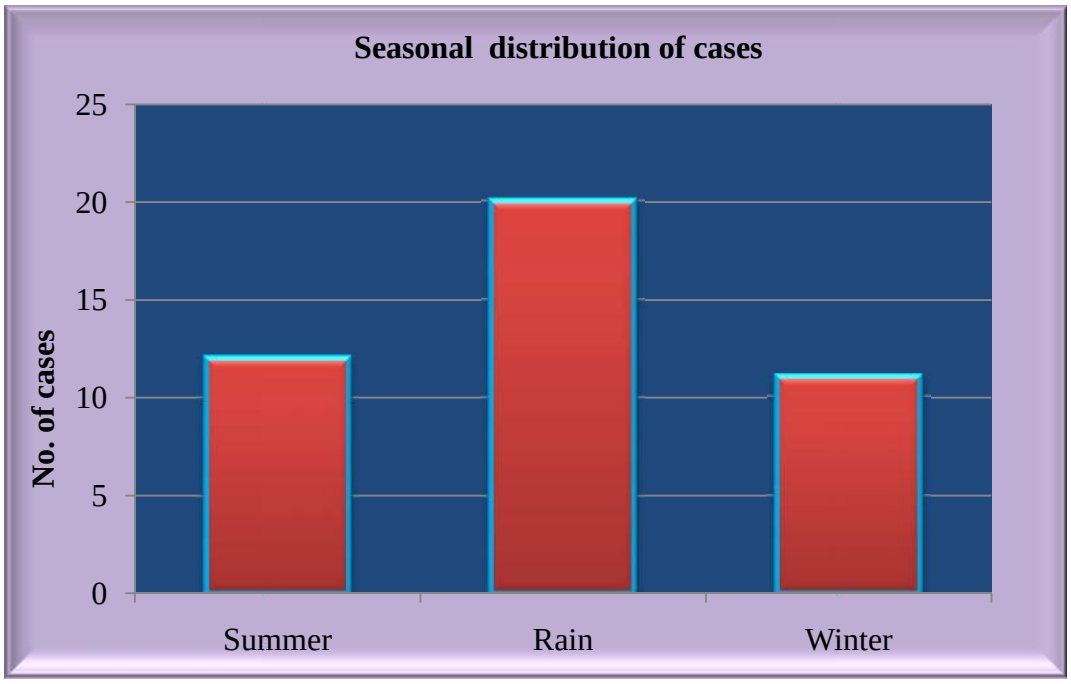


During the study period from October 2012 to December 2013, a total of 4732 medico-legal cases were registered at our tertiary health care centre out of which 43 cases were of electrical injuries, constituting to 0.91% of the total medico-legal cases. The same has been depicted in Table.no.1, and Graph no. 1

***Table 2*: *Showing seasonal variationof electrical injury cases*:**

Season	No. of Cases	Percentage
Summer (Feb, Mar, Apr, May)	12	27.91%
Rain (Jun, Jul, Aug, Sep)	20	46.51%
Winter (Oct, Nov, Dec, Jan)	11	25.58%
Total	43	100%

Graph 2:

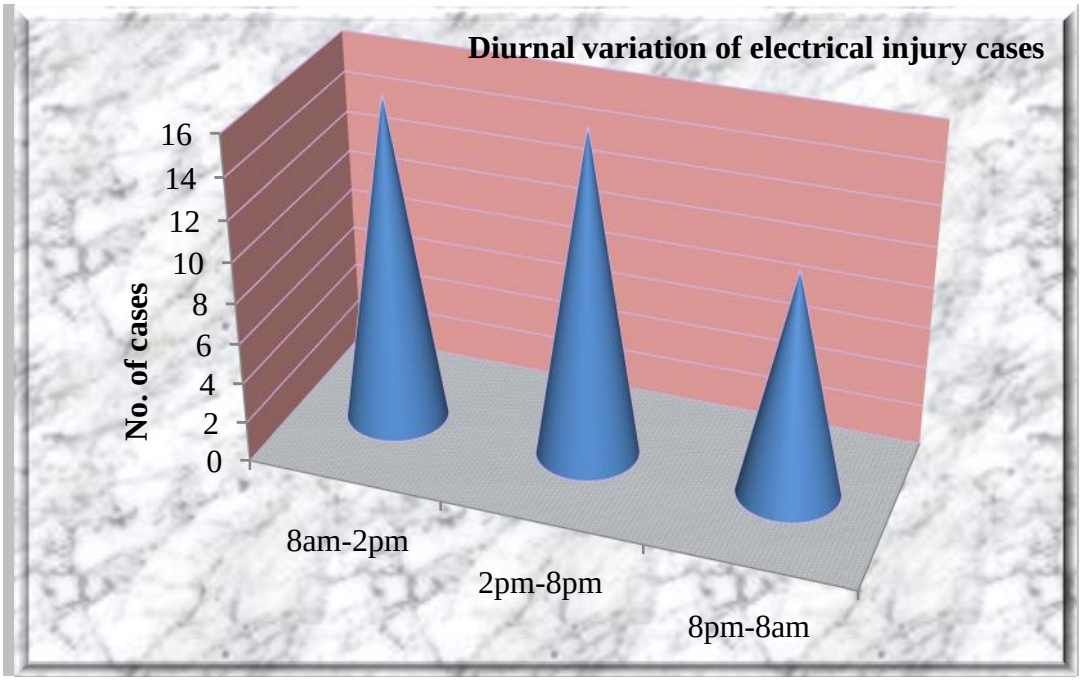


Out of the total 43 cases, season wise maximum no. of electrical injuries occurred in rainy season constituting to 46.51%, and minimum no. of cases was seen in winter with 25.58% (table no.2; graph no. 2).

Table 3: Distribution of cases according to diurnal variation:

Time	Cases	Percentage
8 am – 2 pm	16	37.21%
2 pm – 8 pm	16	37.21%
8pm – 8 am	11	25.58%
Total	43	100%

Graph 3:

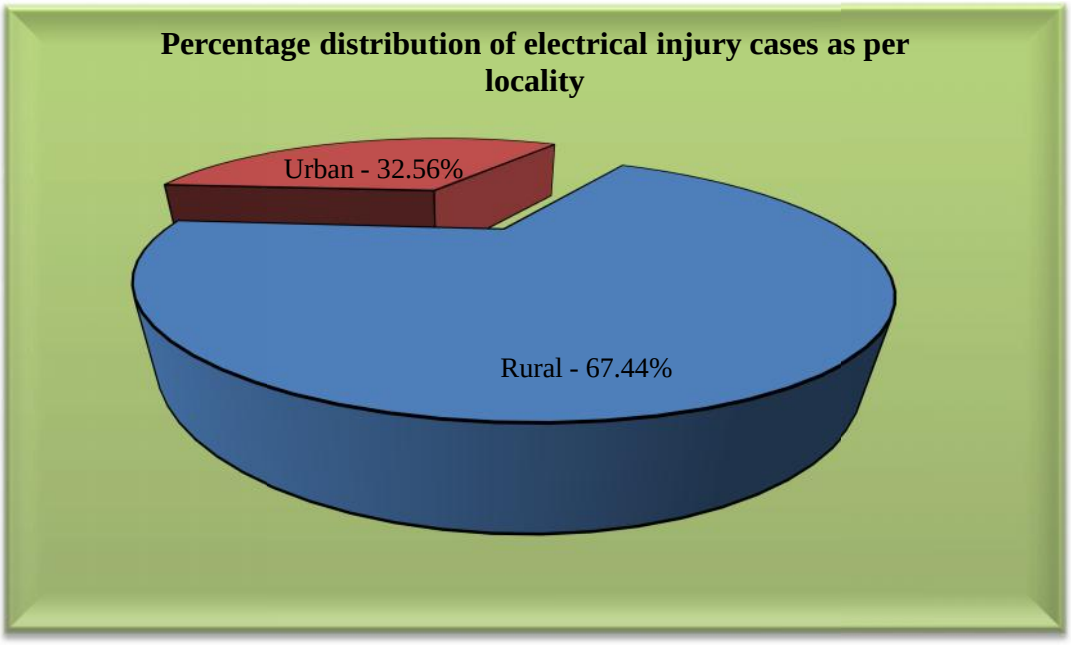


With respect to diurnal variation maximum no. of cases 74.42% sustained electrical injury between 8.00 am to 8.00 pm, followed by 25.58% cases which came between 8.00 pm to 8.00 am (table no.3; graph no. 3).

Table 4: Distribution of electrical injury cases according to educational status and domicile pattern:

Educational status	Urban	Rural	Total (43)
Toddler	00	01(3.45%)	01(2.33%)
School	13(92.86%)	28(96.55%)	41(95.34%)
Graduate	01(7.14%)	00	01(2.33%)
Postgraduate	00	00	00
Total	14(32.56%)	29(67.44%)	43(100%)

Graph 4:



The distribution of domicile pattern along with educational status of the victims showed that 14 (32.56%) were from urban areas and 29 (67.44%) cases from rural areas (table no. 4; graph no.4). Of 14 urban victims; 13 (92.86%) had either completed or were school going and one (7.14%) was graduate. Of total 29 rural victims 28 (96.55%) had either completed or were school going with one victim being a toddler (3.45%), (table no.4; graph no. 4).

Table 5: Distribution of electrical injury cases according to age, gender and marital status:

Details		Age group in decades							Total (43)
		1st	2nd	3rd	4th	5th	6th	7th onwards	
Gender	**Male**	06 (13.95%)	12 (27.92%)	08 (18.61%)	08 (18.61%)	05 (11.62%)	03 (6.98%)	00	42 (97.67%)
	Female	00	01 (2.33%)	00	00	00	00	00	01 (2.33%)
Marital status	**Married**	00	00	07 (16.29%)	08 (18.61%)	05 (11.62%)	03 (6.98%)	00	23 (53.49%)
	Unmarried	06 (13.95%)	13 (30.23%)	01 (2.33%)	00	00	00	00	20 (46.51%)

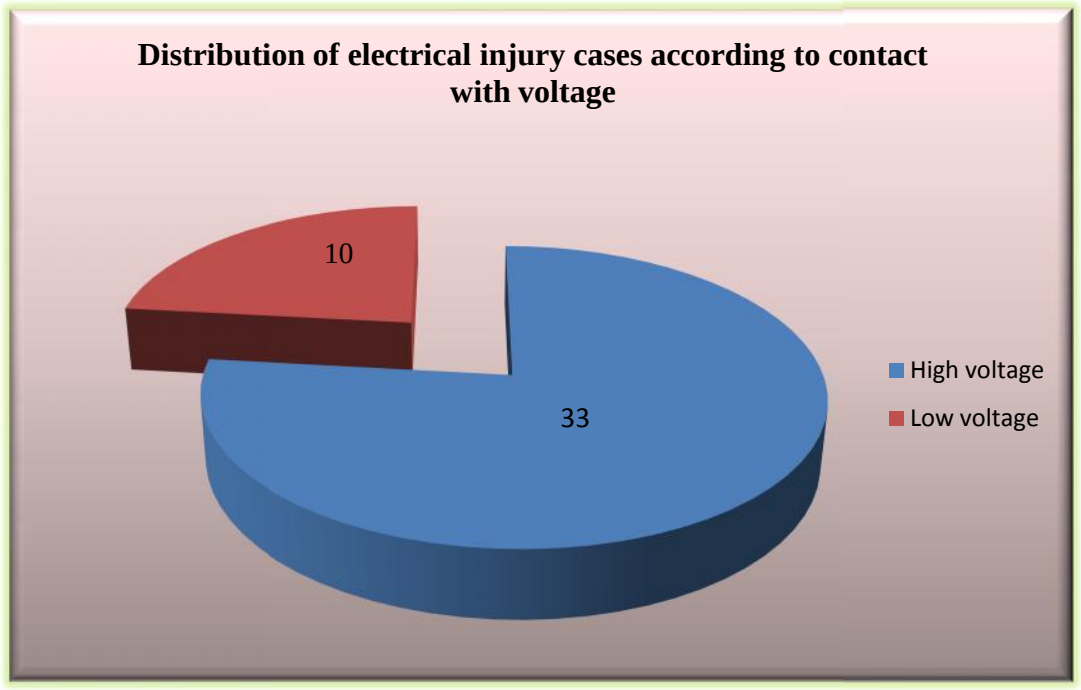
The distribution of electrical injury cases according to age, gender and marital statusshows that, maximum no. of victims 13 (30.23%) were in the age group of 11-20 years (2nd decade) followed by 3rd and 4th decade, each being 08 (18.61%) cases, 1st decade 06 (13.95%) cases, 5th decade 05 (11.62%) cases and in the 6th decade 03 (6.98%) cases. There were no cases in subsequent age groups. Out of total 43 cases one belonged to female sex (2.33%).

23 (53.49%) cases were married and 20 (46.51%) were unmarried out of total 43 cases of electrical injuries. Amongst married cases, maximum no. was in the 4th decade constituting 08 (18.60%) cases followed by 3rd 07 (16.29%), 5th 05 (11.62%) and 6th 03(6.98%) decades. All the cases in 1st decade 06 (13.95%) and 2nd decade 13 (30.23%) were unmarriedindicating no child marriages.In the 3rd decade 01 (2.33%) case was unmarried(table. no. 5).

Table 6: Distribution of electrical injury cases according to voltage, place of incidence, time of incidence and occupation:

Details		Voltage			Total
		High (33) (76.74%)	Low (10) (23.26%)	Total (43)(100%)	
Place of incidence	Home	05 (15.15%)	03 (30%)	08 (18.60%)	43 (100%)
	Work	15 (45.46%)	03 (30%)	18 (41.86%)	
	Public	13 (39.39%)	04 (40%)	17 (39.54%)	
Time of incidence	8 am-2pm	13 (39.39%)	03 (30%)	16 (37.21%)	43 (100%)
	2pm-8pm	12 (36.36%)	04 (40%)	16 (37.21%)	
	8pm-8am	08 (24.25%)	03 (30%)	11 (25.58%)	
Occupation	Electrician	09 (27.27%)	00	09 (20.93%)	43 (100%)
	Labour	06 (18.18%)	01 (10%)	07 (16.27%)	
	Other	18 (54.55%)	09 (90%)	27 (62.80%)	

Graph 5:



Distribution of cases according to voltage, place & time of incidence and occupation showed, totally there were 33(76.74%) cases of high voltage (HV) electrical injuries and 10(23.26%) cases were of low voltage (LV) electrical injuries. Of HV electrical injuries; maximum number of injuries occurred at work place 15 (45.46%) followed by 13 (39.39%) at public place and 05 (15.15%)at home. Of LV electrical injuries; 04 (40%) occurred at public place, 03 (30%) each occurred at work place and at home. Out of total 43 cases; 18 (41.86%) victims sustained the injuries at work place followed by 17 (39.54%) at public place and 08 (18.60%) at home.

Out of 33 HV injuries; 13 (39.39%) occurred between 8am-2pm, 12 (36.36%) occurred between 2pm-8pm and 08 (24.25%) occurred between 8pm-8am. Out of 10 cases of LV electrical injuries, 04 (40%) occurred between 2pm-8am and 03 (30%) each occurred between 8am-2pm and 8pm-8am. Of total 43 cases of electrical

injuries; 16 (37.21%) each occurred between 8am-2pm and 2pm-8pm followed by 11 (25.58%) cases between 8pm-8am.

Of 33 victims of HV electrical injuries; 06 (18.18%) were labours, 09 (27.27%) were electrician by occupation and 18 (54.55%) victims belonged to other profession. Of 10 victims of LV electrical injuries; 01 (10%) was labour and rest 09 (90%) belonged to other professions. Out of total 43 victims of electrical injuries; 07 (16.27%) were labours, 09 (20.93%) were electrician and 27 (62.80%) victims belonged to other professions. Of the three fatal cases of electrical injuries two (66.66%) were electricians and one (33.33%) victim was labour, and all the fatal victims were of HV electrical injuries(table.no. 6; graph no. 5).

Table 7: Distribution of cases according to the type of hospital visit and status of MLC registration in adults and children:

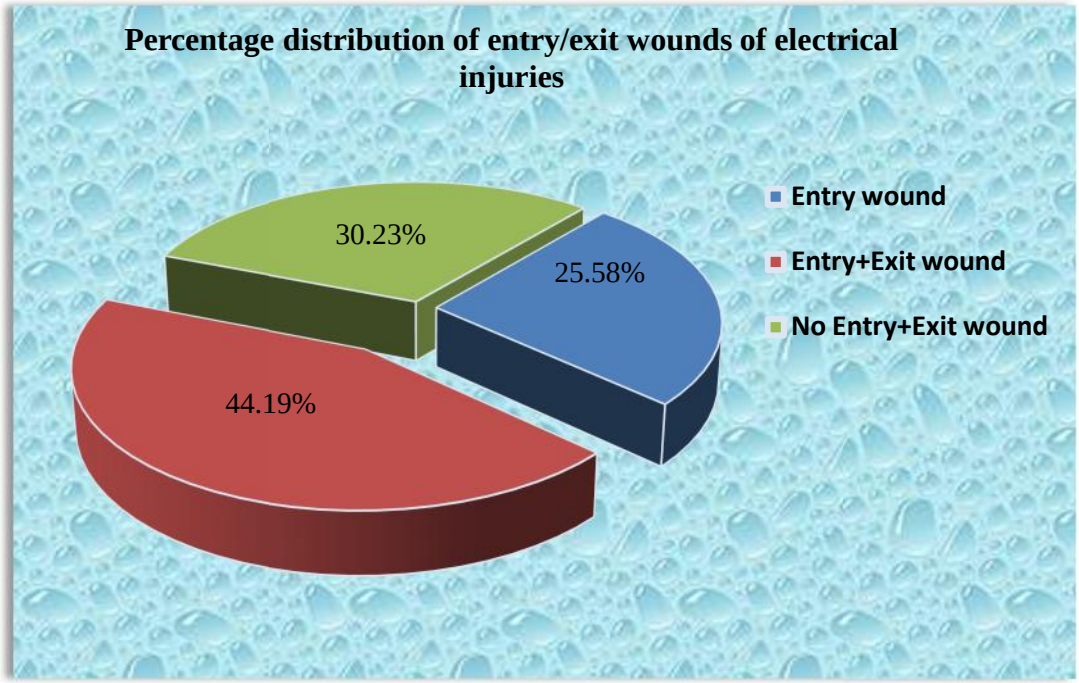
Type of hospital visit	Total	Adult		Child	
		Ref as MLC	Made MLC	Ref as MLC	Made MLC
Out patient	02(4.65%)	00	02(4.65%)	00	00
In patient	41(95.35%)	08(18.60%)	19(44.19%)	03(6.98%)	11(25.58%)
Total	43(100%)	08(18.60%)	21(48.84%)	03(6.98%)	11(25.58%)

As per type of hospital visit and status of MLC registration out of 43 cases, electricalinjuries in adults and children constituted 29(67.44%) and 14(32.56%) respectively. Two (4.65%) of the victims were treated on OPD basis while 41(95.35%) victims were admitted and were treated as inpatients. Of the 29 adult victims; 08(18.60%) were referred as medico-legal cases while 21(48.84%) victims were direct medico-legal cases. Of the 14 child victims of electrical injuries; 03(6.98%) were referred as medico-legal cases while 11(25.58%) victims were direct medico-legal cases (table. no. 7).

Table 8: Distribution of cases according to the wound of electrical injury:

Wound	No. of Cases
Only entry	11(25.58%)
Only exit	00
Both entry and exit	19(44.19%)
No entry /exit	13(30.23%)
Total	43(100%)

Graph 6:



Distribution of cases according to the wound of electrical injury showed that, 30(69.77%) victims had entry wounds, 19(44.19%) victims had both entry and exit wounds, isolated entry wound was present in 11(25.58%) cases, there was absence of combined entry + exit wounds in 13(30.23%) cases while there were no isolated exit wounds (table.no. 8, graph no. 6).

Table 9: Distribution of cases according to the site of entry wound, associated burn injuries, mechanical injuries and duration of hospital stay:

Details		Entry wound								Total (43)
		Right UL	Left UL	Both ULs	Right LL	Left LL	Both LL	Other	No entry wound	
Total cases(43)		12 (27.91%)	07 (16.28%)	07 (16.28%)	00	00	00	04 (9.30%)	13 (30.23%)	
With burns		12 (30%)	07 (17.50%)	06 (15%)	00	00	00	04(10%)	11 (27.50%)	40 (93.02%)
With mech. injury		02 (12.50%)	01 (6.25%)	03 (18.75%)	00	00	00	03(18.75%)	07 (43.75%)	16 (37.20%)
Hospital Stay	OPD	00	00	02 (100%)	00	00	00	00	00	02 (4.65%)
	1 – 10 days	03 (20%)	04 (26.67%)	04 (26.67%)	00	00	00	02(13.33%)	02 (13.33%)	15 (34.88%)
	11 – 20 days	04 (28.57%)	02 (14.29%)	00	00	00	00	00	08 (57.14%)	14 (32.56%)
	21 – 30 days	01 (25%)	01 (25%)	00	00	00	00	00	02 (50%)	04 (9.30%)
	>30 days	04 (50%)	00	01 (12.5%)	00	00	00	02(25%)	01 (12.5%)	08 (18.61%)

During the study period out of total 43 cases of electrical injuries, 40 (93.02%) had associated burn injuries, 16 (37.20%) had associated mechanical injuries, 02 (4.65%) were treated on OPD basis, 15 (34.88%) had a hospital stay of less than ten days, 14 (32.56%) victims stayed between 11-20 days in the hospital, 04 (9.30%) victims stayed between 21-30 days and 08 (18.61%) of the victims stayed for more than 30 days (table no. 9).

Pattern of entry wounds of electrical injuries with respect to burns, mechanical injury and hospital stay showed that out of total 43 victims; 12 (27.91%) had entry wounds on the right upper limb, 07 (16.28%) each had entry wounds over left upper limb and both the upper limbs and 04 (9.30%) victims had entry wounds over the body parts other than extremities and 13 (30.23%) victims showed no entry wounds(table no. 9).

Out of 40 cases of burns, 72.50% had associated entry wounds while rest 27.50% of the victims had no entry marks(table no. 9).

Out of 16 victims with mechanical injuries, 56.25% had associated entry wounds while rest 43.75% of the victims had no entry marks (table no. 9).

Amongst 43 victims of electrical injury; out of two OPD cases both had entry marks on their body; out of 15 cases with hospital stay of 1-10 days, 86.66% had entry marks on their body; out of 14 cases with hospital stay of 11-20 days, 42.86% had entry marks on their body; out of 04 cases with hospital stay of 21-30 days, 50% had entry marks on their body; and out of 08 cases with hospital stay of> 30 days, 87.50% had entry marks on their body (table no. 9).

Table 10: Distribution of cases according to the site of exit wound, associated burn injuries, mechanical injuries and duration of hospital stay:

Details		Exit wound								Total (43)
		Right UL	Left UL	Both ULs	Right LL	Left LL	Both LL	Other	No exit wound	
Total cases(43)		02 (4.65%)	02 (4.65%)	00	05 (11.63%)	05 (11.63%)	05 (11.63%)	00	24 (55.81%)	
With burns		02 (5%)	02 (5%)	00	05 (12.50%)	05 (12.50%)	05 (12.50%)	00	21 (52.50%)	40 (93.02%)
With mech. injury		00	01 (6.25%)	00	02(12.50%)	02(12.50%)	00	00	11 (68.75%)	16 (37.20%)
Hospital Stay	OPD	00	00	00	00	00	00	00	02 (100%)	02 (4.65%)
	1 – 10 days	00	01 (6.67%)	00	02(13.33%)	01(6.67%)	02(13.33%)	00	09 (60%)	15 (34.88%)
	11 – 20 days	00	00	00	02(14.29%)	01(7.14%)	03(21.43%)	00	08 (57.14%)	14 (32.56%)
	21 – 30 days	01 (25%)	00	00	00	00	00	00	03 (75%)	04 (9.30%)
	>30 days	01 (12.50%)	01 (12.50%)	00	01(12.50%)	03(37.50%)	00	00	02 (25%)	08 (18.61%)

Pattern of exit wounds of electrical injuries with respect to burns, mechanical injury and hospital stay showed that out of total 43 victims; 02 (4.65%) each had exit wounds on the right upper limb, and left upper limb, 05 (11.63%) each had exit wounds over right lower limb, left lower limb and both the lower limbs, and 24 (55.81%) victims showed no exit wounds(table no. 10).

Out of 40 cases of burns, 47.50% had associated exit wounds while rest 52.50% of the victims had no exit marks(table no. 10).

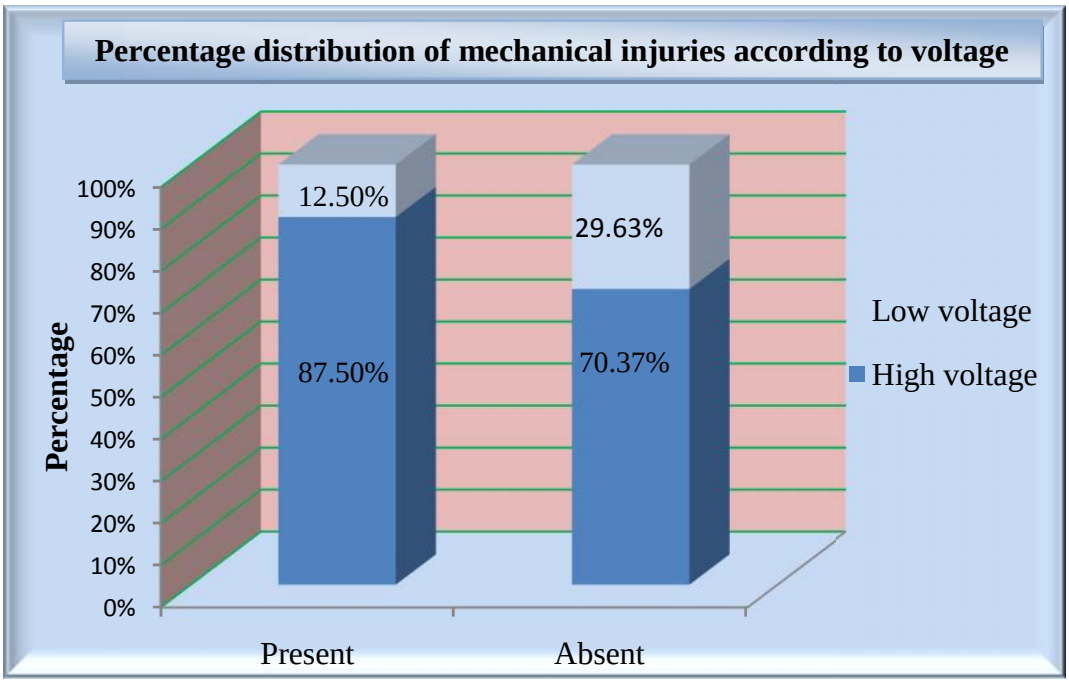
Out of 16 victims with mechanical injuries, 31.25% had associated exitmarks while rest 68.75% of the victims had no exit marks(table no. 10).

Amongst 43 victims of electrical injury; out of two OPD cases none had exit marks on their body; out of 15 cases with hospital stay of 1-10 days, 40% had exit marks on their body; out of 14 cases with hospital stay of 11-20 days, 42.86% had exit marks on their body; out of 04 cases with hospital stay of 21-30 days, 25% had exit marks on their body; and out of 08 cases with hospital stay of > 30 days, 75% had entry marks on their body(table no. 10).

Table 11: Distribution of cases according to the voltage and mechanical injury:

Voltage	Mechanical Injuries	
	Present	Absent
High	14 (87.50%)	19 (70.37%)
Low	02 (12.5%)	08 (29.63%)
Total (43)	16 (37.21%)	27 (62.79%)

Graph 7:

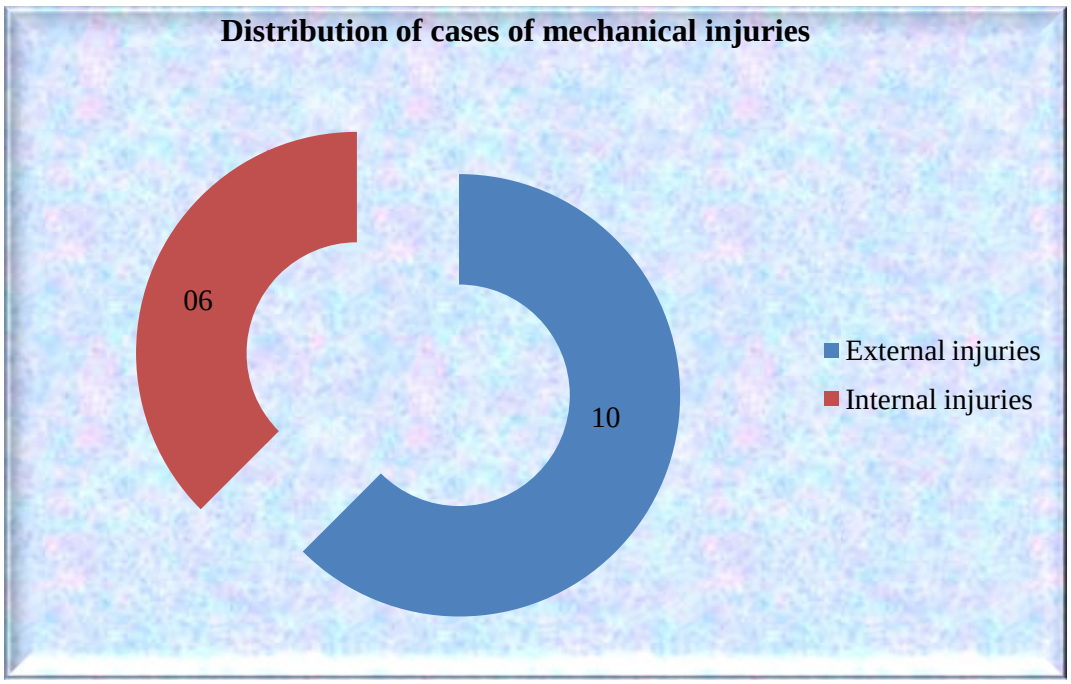


Among 16 cases of mechanical injuries, 14 (87.50%) victims sustained mechanical injuries due to high voltage and 02 (12.5%) sustained mechanical injuries due to low voltage electric contact. Mechanical injuries were absent in 19 (70.37%) cases of HV electrical injuries and in08 (29.63%) cases of LV electrical injuries (table no. 11 and graph no. 7).

Table 12: Distribution of cases according to the voltage and type of mechanical injury:

Voltage	Mechanical Injuries							
	External				Internal			
	Abrasion	Contusion	Laceration	Other	Cranial	Skeletal	Thoraco-abdominal	Other
High	03 (18.75%)	02(12.50%)	03 (18.75%)	00	02 (12.50%)	01 (6.25%)	00	03 (18.75%)
Low	01(6.25%)	00	01 (6.25%)	00	00	00	00	00
Total (16)	04 (25%)	02(12.50%)	04(25%)	00	02 (12.50%)	01 (6.25%)	00	03 (18.75%)

Graph 8:



Distribution pattern of cases according to the voltage and type of mechanical injury showed that, out of 16 victims with associated mechanical injuries;04(25%) had abrasions {03 (18.75%) due to high voltage & 01 (6.25%) due to low voltage},

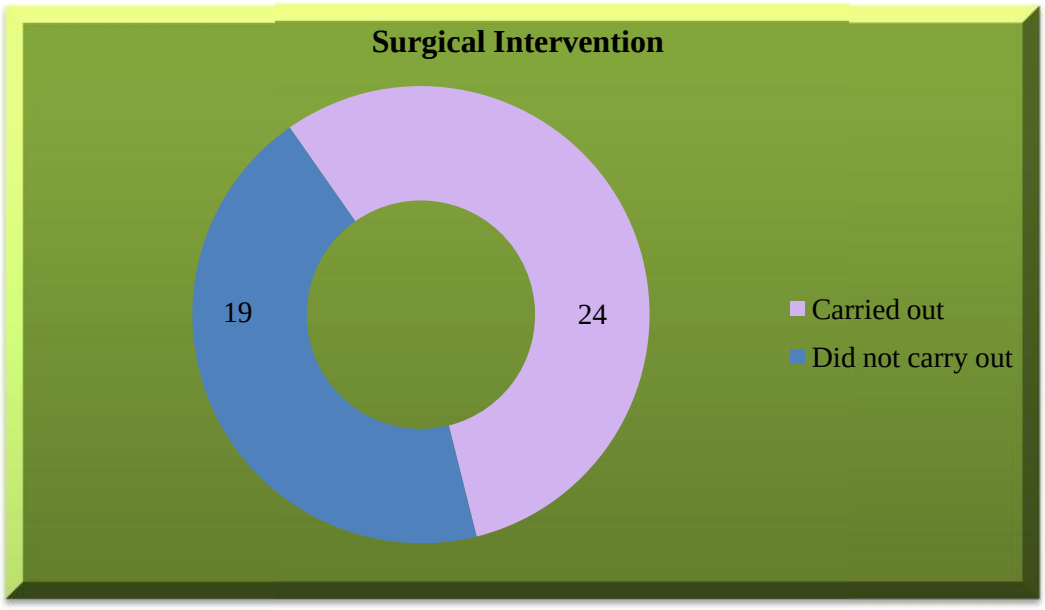
02(12.50%) had contusions {both due to high voltage}, 04(25%) had lacerations{03 (18.75%) due to high voltage &01(6.25%)due to low voltage}, 02 (12.50%) had cranial injury{both due to high voltage}, 01 (6.25%) had skeletal injury due to high voltage contact and 03 (18.75%) had sustained other internal injuries all being due to high voltage.

Out of 16 cases of associated mechanical injuries, 10(62.50%) had external injuries and 06(37.50%) had sustained internal injuries. There were no cases with injuries of thoraco-abdominal organs (table no. 12; graph no. 8).

Table 13: Distribution of cases according to surgical intervention in different type of mechanical injury:

Surgical intervention	Mechanical Injuries								Total (16)
	External				Internal				
	Abrasion	**Contusion**	**Laceration**	**Other**	**Cranial**	**Skeletal**	**Thoraco-abdominal**	**Other**	
Carried out	01 (14.28%)	00	03 (42.86%)	00	01 (14.28%)	01 (14.28%)	00	01 (14.28%)	07 (43.75%)
Did not carry out	03 (33.34%)	02 (22.22%)	01 (11.11%)	00	01 (11.11%)	00	00	02 (22.22%)	09 (56.25%)

Graph 9:



Surgical intervention was carried out in 24 (55.81%) cases out of total 43 cases of electrical injuries. Out of 24 cases, 07 (29.16%) had associated mechanical injuries in which surgical intervention was carried out and 09 (56.25%) cases out of 16, with mechanical injuries did not undergo any surgical intervention. Among the 07 cases of surgical intervention; 03 (42.86%) cases had lacerations and 01 (14.28%) each had abrasion, cranial, skeletal & other internal injuries (table no. 13; graph no. 9)

Table 14: Distribution of electrical injury cases according to percentage of burns,renal parameters, outcome and cause of death:

%age of Burns	Renal parameters(except in 02 OPD cases: one without burns & one with <25%burns)								Outcome (43)	
	Blood Urea				Serum Creatinine				Recov	Expir
	Incre	Decr	WNL	ND	Incr	Decr	WNL	ND		
Nil	00	00	02 (4.65%)	01(2.33%)	00	01 (2.33%)	01 (2.33%)	01 (2.33%)	03 (6.98%)	00
< 25	01 (2.33%)	03 (6.98%)	24 (55.81%)	01 (2.33%)	00	15 (34.88%)	13 (30.23%)	01 (2.33%)	29 (67.44%)	00
25 – 49	02 (4.65%)	02 (4.65%)	06 (13.95%)	00	00	10 (23.26%)	00	00	07 (16.27%)	03(6.98%)
50 – 74	00	01 (2.33%)	00	00	00	01 (2.33%)	00	00	01 (2.33%)	00
≥ 75	00	00	00	00	00	00	00	00	00	00
Total (43)	03 (6.98%)	06(13.95%)	32 (74.42%)	02(4.65%)	00	27 (62.79%)	14 (32.56%)	02 (4.65%)	40 (93.02%)	03(6.98%)

Distribution of electrical injury cases according to percentage of burns, renalparameters and outcome showed that, out of 43 cases of electrical injuries, 40 had sustained burn injuries. Three victims of electrical injury had no associated burn injuries. Renal parameters (blood urea & serum creatinine) were measured for all 41 admitted cases, except for two OPD cases.

Out of three cases of electrical injuries without burns; blood urea was within normal limit (WNL) for 02 (4.65) cases and serum creatinine was decreased in 01 (2.33%) and normal in 01 (2.33%) case. Renal parameters (blood urea & serum creatinine) were not measured in 01 (2.33%) OPD case. All the three (6.98%) cases recovered after treatment.

There were 29 (67.44%) victims with less than 25% burn injuries. Blood urea was increased in 01 (2.33%), decreased in 03 (6.98%), was WNL in 24 (55.81%) cases and was not measured in 01 (2.33%) case. Serum creatinine was decreased in 15 (34.88%), was WNL in 13 (30.23%) cases and was not measured in 01 (2.33%) OPD case. All the 29 (67.44%) cases recovered after treatment.

10 (23.26%) victims had burn injuries ranging from 25 to 49%. Blood urea was increased in 02 (4.65%), decreased in 02 (4.65%) and WNL in 06 (13.95%) cases. Serum creatinine was decreased in all 10 (23.26%) cases. 07 (16.27%) cases recovered after hospital admission and treatment while 03 (6.98%) victims expired even after admission and treatment.

There was only 01 (2.33%) case of electrical injury associated with burn injury in the group of 50 to 74%, with decrease in both blood urea and serum

creatinine who recovered after hospital admission and treatment. There was no case of more than 75% burn injuries.

Out of 41 cases of electrical injury in whom renal parameters were measured, blood urea was, increased in 03 (7.32%), decreased in 06 (14.63%), WNL in 32 (78.05%); while serum creatinine was decreased in 27 (65.85%), WNL in 14 (34.15%).

DISCUSSION

In the present study total of 43 electrical injury cases were studied against 4732 medico-legal cases, constituting to 0.91%,is near similar to study done in post mortem cases by Ragui S, Meera T, Singh PK, Devi MP, Devi SA in 2013 [62].

Table no. D1: Showing comparative analysis of MLC burden of electrical injuries vs. total MLC registration:

Study / data by:	***Study in the year***	***Place***	***Electrical injury cases Registered asMedico-legal case***
Ragui S, Meera T, Singh PK, Devi MP, Devi SA [62].	2007 - 2011.	Imphal, Manipur, India.	1.02%
Present study - Husain MM and Manjulabai KH.	2012-13.	Belgaum, India.	0.91%

Though the number of electrical injury cases registered as MLCs are less compared to unintentional injuries and other medico-legal cases, but effective preventive and safety measures and awareness/education, are required from govt. as well as private agencies to decrease the unnecessary burden of electrical injury cases over the society.

Our study showed that the maximum number of cases 46.51% were seen in the rainy season-June to September, this is less when compared to study done in India by

Chandru K- 56% [56] and Gupta DB, Mehta AR, Trangadia MM- 50.99% [57], whereas its more when compared to Kumar S, Verma KA, Singh SU-39% [63].This suggests that wet surface plays major role in electrocution. In various studies done in foreign countries showed the maximum no. of cases were in summer [22, 23, 26, 28 & 29]. It is in contrast to present study. However, the studies compared are carried out in post mortem cases, while our study involved both antemortem and postmortem cases.

Table no. D2: Comparative analysis of seasonal distribution with other studies:

Study / data by:	***Study in the year***	***Place***	***Season***	***Seasonal distribution***
Dokov V, Miteva R [22].	1995 – 2009.	Stara Zagora, Bulgaria.	Summer	55.1%
Tirasci Y, Goren S, Subasi M, Gurkan F [23].	1996 – 2002.	Diyarbakir, Turkey.	Summer	38.2%
Akcan R, Karacaoglu E, Keten A, Aysun BO, Kanburoglu C, Tumer AR, et al [26].	1998 – 2008.	Ankara, Turkey.	Summer	58%
Blumenthal R [28].	2001-2004.	Gauteng, South Africa.	Summer	24.60%
Sheikhazadi A, Kiani M, Ghadyani HM [29].	2002 – 2006.	Tehran, Iran.	Summer	40.3%
ChandruK [56].	Nov 2003 - Oct 2005.	Bangalore, India.	Rainy	56%
Gupta DB, Mehta AR, Trangadia MM [57].	2004 – 2008.	Jamnagar, Gujarat, India.	Rainy	50.99%
Kumar S, Verma KA, Singh SU [63].	2008 – 2012.	Lucknow, India.	Rainy	39%
Present study- Husain MM and Manjulabai KH.	2012-13.	Belgaum, India.	Rainy	46.51%

In our study maximum no. of victims, 74.42% sustained injury during the day time between 8.00 am to 8.00 pm. The probable reason for this may be that in the day time people are more active and involved in personal and professional work. However, there is no comparative data available from others' study.

The results for urban area 32.66% of present study is in contrast to the study conducted by Patil SB, Khare NA, Jaiswal S, Jain A, Chitranshi A, Math M(study done in both antemortem and postmortem cases) 70.23% [58]. Whereas majority of victims 67.44% in present study belonged to rural areas and is comparatively similar to the recent study(done in dead victims) by Reddy A, Balaraman R, Kagne RN (65%) [64]. This shift of urban to rural could be due to gradual extension of electricity supply to rural areas without proportionate knowledge of sufficient safety measures.

Table no. D3: Comparative analysis of locality wise distribution with other studies:

Study / data by:	***Study in the year***	***Place***	Urban	Rural
Patil SB, Khare NA, Jaiswal S, Jain A, Chitranshi A, Math M [58].	2004 – 2009.	Nagpur, Maharashtra, India.	70.23%	29.77%
Reddy A, Balaraman R, Kagne RN [64].	2012.	Puducherry, Union Territory of India.	35%	65%
Present study- Husain MM and Manjulabai KH.	2012-13.	Belgaum, India.	32.66%	67.44%

We found that 97.67% had either completed graduation/school or were school going, while a study conducted by Al B, Aldemir M, Guloglu C, Kara IH, Girgin S. showed that 76.98% patients were either graduates or still students of elementary, secondary or high school [31](study done in both antemortem and postmortem cases).

In our study maximum no. of victims were male (97.67%) and maximum 30.23% were in the age group of 11-20 years (2^{nd} decade) followed by 3^{rd} decade (18.61%), and similar to the results of the similar study by Patil SB, Khare NA, Jaiswal S, Jain A, Chitranshi A, Math M [58]. Whereas, the results of the similar study by Guntheti KB, Khaja S, Singh PU showed that maximum of victims were males 91.93% and most frequently (38.71%) affected age group was 21-30 years (3^{rd} decade) [59].

The reason for this can be attributed to the fact that males form a majority of the population going out for work and have an inherent risk taking behavior, hence exposing themselves more.

Table no. D4: Comparative analysis of age group and sex wise distribution with other studies:

Study / data by:	***Study in the year***	***Place***	***Age group***	***Sex***
Patil S B, Khare NA, Jaiswal S, Jain A, Chitranshi A, Math M [58].	2004 - 2009.	Nagpur, Maharashtra, India.	2^{nd} decade (33.3%)	Male (84.52%)
Guntheti KB, Khaja S, Singh PU [59].	October 2007 - September 2008.	Khammam, Andhra Pradesh, India.	3^{rd} decade (38.71%)	Male (91.93%)
Present study- Husain MM and Manjulabai KH.	2012-13.	Belgaum, India.	2^{nd} decade (30.23%)	Male (97.67%)

Voltage: In the current study 76.74% of victims sustained electric injuries due to high voltage (HV) electric contact, while 23.26% of victims had low voltage (LV) electric contact. Similar studies with almost similar results have been done by; Gunduz T, Elcioglu O, Cetin C - 74.55% (HV) and 25.45% (LV) [25]; by Ahmad HAA, Iman Al-Leithy, Alfotoh SA - 96% (HV) and 4% (LV) electrical contact [24]. While contrasting results have been observed in similar studies done by Al B, Aldemir M, Guloglu C, Kara IH, Girgin S - 58.18% (LV) and 41.82%(HV) [31]; by Karadas S, Gonullu H, Oncu RM, Isik D, Canbaz Y- 57.1% (LV) and 42.9% (HV) [33]; by Subrahmanyam M - 67.5% (LV) and 32.5% (HV) [54]; by Guntheti KB, Khaja S, Singh PU - 67.74% (LV) and 32.26% (HV) [59]. Studies done in dead victims by Lucas J - 50% each HV and LV contact [18]; by Dokov V, Miteva R - 65.6% (LV) and 26.0 % (HV) [22];by Blumenthal R - 72.22% (LV) and 27.78% (HV); by Chandru K - 46% (LV) and 54% (HV) [56]; by Ragui S, Meera T, Singh PK, Devi MP, Devi SA - 40% (LV) and 60% (HV) [62] (All these studies carried out in dead victims only).

Table no. D5: Comparative analysis of voltage distribution with other studies:

Study / data by	*Place; study year*	*Voltage*		*Comparison with present study*
		Low	*High*	
Ahmad HAA, Iman Al-Leithy, Alfotoh SA [24].	Egypt; 1996- 2002.	4%	96%	More than our study
Gunduz T, Elcioglu O, Cetin C [25].	Turky; 1997 – 2005.	25.45%	74.55%	Similar to our study
Al B, Aldemir M, Guloglu C, Kara IH, Girgin S between [31].	Diyabakir, Turkey; January 2003 - April 2004.	58.18%	41.82%	Less than our study
Karadas S, Gonullu H, Oncu RM, Isik D, Canbaz Y [33].	Turkey; January 2006 – 2010.	57.1%	42.9%	Less than our study
Subrahmanyam M [54].	Sangli, Maharashtra, India; January 1999 - December 2000.	67.5%	32.5%	Less than our study
Guntheti KB, Khaja S, Singh PU [59].	Khammam, AP, India; October 2007 to September 2008.	67.74%	32.26%	Less than our study
Present study – Husain MM and Manjulabai KH.	Belgaum, India; 2012-13.	23.26%	76.74%	-

Place of incidence: In our study 41.86% victims sustained the injuries at work place followed by 39.54% at public place and 18.60% at home. Studies done in dead cases with similar trend but with more values compared to our study by Dokov W - 78.06% (home) and 13.39% (work related) [16]; by Lucas J - 60% (work related) [18]; by Akcan R, Karacaoglu E, Keten A, Aysun B O, Kanburoglu C, Tumer AR, et al - 71% (workplace) [26]; by Sheikhazadi A, Kiani M, Ghadyani HM - 63.9% (work-related) and (28.8%) home [29]; by Chandru K - 59% (workplace), 28% (domestic) and 23% (miscellaneous) [56]; by Kumar S, Verma KA, Singh SU - 59% (workplace) and 22.9%

(home) [63]. Similar study but with contrasting result by Patil SB, Khare NA, Jaiswal S, Jain A, Chitranshi A, Math M - 51.2% (home) [58].

Time of incidence: In present study 74.42% of injuries occurred between 8am-8pm (day time) while (25.58%) occurred between 8pm-8am. No similar studies were available for comparison with the present study. However, the results indicate that there is an increase in electrical injuries during the day time suggesting that incidence is more during usual working hours.

Occupation: Present study showed that 62.80% of victims belonged to occupation other than electrician/labour, while 20.93% victims were electricians by occupation and 16.27% were labours. In a study by Reddy A, Balaraman R, Kagne RN showed that agricultural workers - 26%, Labourers - 22% and housewives accounted for 17% of victims [64](Study carried out in dead victims only). From this comparison we could not conclude anything, however it indicates' that there is probability of lack of enough knowledge of electricity in the general population.

The correlation between maximum no. of victims sustaining injuries during day time (8am-8pm) i.e. working hours and an increased no. of injuries at work place and maximum no. of male sex involvement shows' that working male class is more prone for the electrical injuries.

Referred / Registered as MLC: Among the total cases, adults and children constituted, 67.44% and 32.56%, respectively. 74.42% victims were registered as direct MLC while 25.58% were registered as MLC somewhere else and then referred. Studies with similar data are not available for comparison. However this finding supports the previous one, that adult victims were involved more as they are the

principle working population. Majority of the victims were registered as direct MLCs, reason being that our hospital is a tertiary health care center.

Hospital stay: 4.65%of the victims were treated on OPD basis while 95.35% victims needed hospitalization. 34.88% for 1 - 10 days, 32.56%for 11 - 20 days, 9.30%for 21-30 days and18.61% victims had hospital stay of more than 30 days. In a near similar study by Guntheti KB, Khaja S, Singh PU - 90.31% of victims stayed in the hospital for less than ten days, while 9.69% stayed for more than ten days [59].

Majority of victims needed hospital stay between 1 to 20 days indicating increased burden on the hospital and increased economic burden on the society.

Wound of electrical injury: In the present study, 44.19% victims had both entry and exit wounds and only entry wound was present in 25.58% of victims, while 30.23% of the cases showed no entry/exit wounds. Contradicting results were showed in similar study by Guntheti KB, Khaja S, Singh PU - entry wound -75.80%, both entry & exit - 35.48%, neither entry nor exit point - 16% [59]. In various other studies carried out in dead victims by Kuhtic I, Bakovic M, Mayer D, Strinovic D, Petrovecki V - entry wound - 43%, both entry and exit - 20%, neither entry nor exit point - 16% [19]; by Gupta DB, Mehta AR, Trangadia MM - entry marks - 47.06 %, both the entry and exit marks - 33.34 %, neither entry nor exit point - 8.82 % [57] and by Reddy A, Balaraman R, Kagne RN - entry wound - 48% cases, both entry and exit wounds - 30% cases [64]. However, there were no similarities between results of all these studies and results of present study, the reason being unknown.

Table no. D6: Comparative analysis of distribution of wound of electrical injury with other studies:

Study / data by	***Place; study year***	***Wound***		
		Only entry	***Both entry and exit***	***No entry/exit***
Guntheti KB, Khaja S, Singh PU [59].	Khammam, Andhra Pradesh, India; October 2007 to September 2008.	75.80%	35.48%	16%
Reddy A, Balaraman R, KagneRN [64].	Puducherry, Union Territory of India; 2012.	48%	30%	22%
Kuhtic I, Bakovic M, Mayer D, Strinovic D, PetroveckiV [19].	Zagreb, Croatia; 1991 to 2010.	43%	36%	21%
Gupta DB, Mehta AR, Trangadia MM [57].	Jamnagar, Gujarat, India; 2004 to 2008.	47.06 %	33.34 %,	8.82 %
Present study - Husain MM and Manjulabai KH.	Belgaum, India; 2012-13.	25.58%	44.19%	30.23%

27.91% of total victims had entry wounds over the right upper limb (Rt UL), 16.28% of victims had entry wounds over left upper limb (Lt UL) & both ULs each and 9.30% had on other parts of the body. There was no entry mark in 30.23% of total victims. In a similar study with similar trend by Guntheti KB, Khaja S, Singh PU from October 2007 to September 2008 - right hand - 40.32%, left hand -11.51%, head and neck - 8.06%, thorax - 6.45%, right feet - 1.61% [59]. These results indicate that the victims were engaged in some kind of work at the time of electrical contact.

Out of 30 cases showing entry wounds, 86.66% of victims had involvement of upper extremities while 13.34% of victims had entry mark over other parts of the body, and none of the victims had entry marks on the lower extremities. Similar study with similar results but fewer values in comparison to our study has been conducted by Guntheti KB, Khaja S, Singh PU - 51.83%: upper extremity [59]. Studies on post mortem cases with similar results have been conducted by Sheikhazadi A, Kiani M, Ghadyani HM - 66.3%: upper extremity [29] and by Gupta DB, Mehta AR, Trangadia MM - 89.21 %: upper extremity [57]. Studies on post mortem cases with similar results but less values in comparison to our study, have been conducted by Tirasci Y, Goren S, Subasi M, Gurkan F - 48%: upper extremity [23]; by Kumar S, Verma KA, Singh SU - 61%: upper extremity [63] and by Reddy A, Balaraman R, Kagne RN - 70%: upper extremity [64]. Maximum involvement of upper extremities correlates with our finding that maximum no. of victims sustained injuries at workplace indicating that the victims were involved in some kind of manual work with the electrical appliances.

Table no. D7: Comparative analysis of distribution of entry wound of electrical injury with other studies:

Study / data by	*Place; study year*	*Upper extremity*	*Comparison with our study*
Guntheti KB, Khaja S, Singh PU [59].	Khammam, AP, India; October 2007 to September 2008.	51.83%	Similar study with similar results but fewer values.
Sheikhazadi A, Kiani M, Ghadyani HM [29].	Tehran, Iran; 2002 and 2006.	66.3%	Study on dead but similar values.
Gupta DB, Mehta AR, Trangadia MM [57].	Jamnagar, Gujarat, India; 2004 to 2008.	89.21 %	Study on dead but similar values.
Tirasci Y, Goren S, Subasi M, Gurkan F [23].	Diyarbakir, Turkey 1996 and 2002.	48%	Study on dead with similar results but fewer values.
Kumar S, Verma KA, Singh SU [63].	Lucknow, India; 2008 to 2012.	61%	Study on dead with similar results but fewer values.
Reddy A, Balaraman R, Kagne RN [64].	Puducherry, Union Territory of India; 2012.	70%	Study on dead with similar results but fewer values.
Present study – Husain MM and Manjulabai KH.	Belgaum, India; 2012-13.	86.66%	-

In our study exit wounds of electrical injury were present in 44.19% of victims. In a similar study conducted by Guntheti KB, Khaja S, Singh PU - 38.71% victims showed exit marks [59] showing almost similar results as our study. In studies on dead victims by Gadge S, Zine KU, Batra KA, Kuchewar VS, Meshram DR, Dhawane GS - 12.24% (exit mark) [61] and by Reddy A, Balaraman R, Kagne RN exit mark was seen in 13% [64].

Out of 19 cases showing exit wounds, 78.95% of victims had involvement of lower extremities while 21.05% had exit mark over the upper limb and none of the exit marks were present over other parts of the body. In a similar study done by Guntheti KB, Khaja S, Singh PU maximum 32.25% victims showed exit marks [59] showing similar trend as our study.

Maximum percentile of upper extremities involvement in case of entry mark and maximum percentile of involvement of lower extremities with respect to exit mark indicates that probable path of the electric current inside the body is from upper extremities to lower extremities in most of the victims in our study. Also it indicates that the victims were in a standing posture at the time of contact with the current source, as the electric current adopts to shortest and least resistant path through the body.

Voltage vs. Mechanical Injuries: In our study out of 16 victims with mechanical injuries (non-electrical), 87.50% were due to HV electric contact while 12.50% had sustained mechanical injuries due to LV electric contact. In similar studies done in post mortem cases by Blumenthal R24.18% - mechanical injuries [28] and by Gupta DB, Mehta AR, Trangadia MM - 18.62 % of total cases had sustained non electrocution (mechanical) injuries [57]. These studies are not exactly similar to present study with respect to voltage and mechanical trauma. However, the results indicate that mechanical injuries are more commonly seen in high voltage electric contact.

Voltage vs. Type of mechanical injury: 62.50% of the victims had sustained external mechanical injuries and remaining 37.50% had internal mechanical injuries. Similar studies were not available for comparison with present study.

Surgical intervention: 55.81% of cases out of total cases of electrical injuries had to undergo surgical intervention while rest 44.19% of the cases did not require any surgical intervention. Amongst total cases requiring surgical intervention, 29.17% had associated mechanical injuries. Similar studies were not available for comparison with the present study. Higher percentile of surgical intervention points towards severity of electrical injury irrespective of associated burns.

Renal parameters vs. percentage of burns and outcome: Out of total victims of electrical injury, 40 (93.02%) had associated burn injuries, out of them 29 (72.50%) with less than 25% TBSA burn, 10 (25%) victims with 25 to 49% TBSA burn and only one (2.50%) with 50 to 74% TBSA burn. Renal parameters (blood urea & serum creatinine) were measured for all 41 admitted cases, except for two OPD cases. Out of total victims in whom renal parameters were measured, only one victim was a known diabetic with increased Hb-A1 C levels.

Out of 41 cases of electrical injury in whom renal parameters were measured, blood urea was, increased in 03 (7.32%), decreased in 06 (14.63%), WNL in 32 (78.05%); while serum creatinine was decreased in 27 (65.85%), WNL in 14 (34.15%).

Similar studies were not available for comparison. Since 78.05%of victims had blood urea within normal limit, a direct relationship could not be established between blood urea levels and electrical injuries. However from our study we could derive a direct relationship between electrical trauma and serum creatinine levels, as 65.85% of total victims had decreased serum creatinine which came to normal after treatment in the hospital. Also these findings support the probable path of electric current inside the body from upper extremities to lower extremities, as indicated by our previous results.

FATAL CASE REPORTS (See Annexure III for photgraphs):

Case.1:

Autopsy no.: 118/13

Date: 14.08.13

On 26/07/13 a 53 year old HESCOM employee (in-charge camp lineman) was working without protective measures on a transformer over an electric pole in the field five minutes before the line tripping time. Victim made electric contact, the movement he started tightening the screws with the spanner. Victim did not fall down as he was having support.

Admitted on 26.07.13 and was treated in our tertiary health care center and died on 14.08.13.

Cause of death: Septicemia consequent upon burn injuries sustained.

Case.2:

Autopsy no.: 127/13

Date: 26.08.13

On 21/08/13 a 33 year old HESCOM employee was trying to cut the branches of a tree which were hanging over the electric pole, without wearing protective gear, even after the cut off working time of 6 pm., suddenly the line got active and he sustained injuries. Victim did not fall down because he was having support. Immediately admitted to a local hospital on 21.08.13, from where he was referred to our tertiary health care center on 25.08.13 and expired on the same day.

Cause of death: Septicemia consequent upon burn injuries sustained.

Histo-pathology report:

- Both kidneys showed Acute tubular necrosis,
- Heart shows' congestion,
- Brainstem congested and,
- Aorta was normal.

Case.3:

Autopsy no.: 141/13

Date: 10.10.13

On 12/09/13 a 35 year old cleaner of a trolly truck was trying to loosen the back wheel tyre of the trolly truck struck in the mud with his left upper limb while supporting himself by holding the trolly with his right hand. As the cleaner was busy with his job, the driver of the trolly truck gradually raised the trolly which touched the overhead high tension electric cable causing severe injuries to the cleaner. After noticing and getting a jolt himself, the driver jumped out of the trolly truck and escaped unhurt. Immediately the victim was shifted to a local hospital from where he was transferred to our tertiary care center on 27/09/13 and expired on 10.10.13 even after treatment.

Cause of death: Septicemia consequent upon burn injuries sustained.

Microbiology report:

- Burn wound swab – Klebsiella pneumonia isolated.
- Spleenic swab – Klebsiella pneumonia & Escherichia coli isolated.

One case report similar to our third fatal case has been reported by Schleich AR, Schweiger H, Becsey A, Cruse CW, from USA in the year 2009 [46].

All the fatal (6.98%) cases had burn injuries ranging between 25-49% and cause of death in all the fatal cases was septicaemia. In a study conducted on electrical burn victims by Opara KO, Chukwuanukwu TO, Ogbonnaya IS, Nwadinigwe CU mortality was 12.5% with septicaemia as the leading cause of death [21].

In the first fatal case blood urea was increased while serum creatinine was decreased. In the 2nd fatal case both blood urea and serum creatinine were decreased. In the 3rd fatal case blood urea was normal but serum creatinine was decreased initially and gradually both blood urea and serum creatinine got raised. Cause of death in all the fatal cases was established to be septicaemia. All the fatal cases were due to human negligence and lack of protective measures.

In an unfortunate incident during Ganesh festival procession in the year 2013, 12 individuals became victims of electrical injury, out of which three died instantly and were taken to a govt. hospital for autopsy, six were admitted in our tertiary health care centre while one was admitted in the govt. hospital.

CONCLUSION

In the present study, electrical injury cases constituted to 0.91% of the total medico-legal cases; with majority consisting of adult males, with a total mortality rate of 6.98% seen in high voltage electric contact, with majority of patients having hospital stay of 1-20 days putting avoidable burden on the hospital and causing an unnecessary economic burden on the society. In our study all the cases of electrical injuries were unintentional. Economic status could not be ascertained with certainty, reason being inconsistent statements by the victims/attenders for the sake of getting compensatory benefits. There was no case of lightening injuries.

Our study is extended in various patterns of electrical injuries in both living as well as dead whereas most of the available studies are on the post mortem cases and that too with few parameters.

The maximum no. of cases occurred during day time (working hours), with male preponderance, at workplace and due to high voltage, as the males form a majority of the population going out for work and have an inherent risk taking behavior, hence exposing themselves more.

Maximum no. of cases belonged to the rural population. There is a shift from urban to rural. This shift could be due to gradual extension of electricity supply to rural areas with passage of time, without proportionate knowledge of safety measures.

When a person is in standing position the entry wound will be in uppe limb and exit wound will be in lower limb. In this the path of current involves kidneys

reflecting on renal parameters (blood urea & serum creatinine). However, it needs' further study.

One more unique finding of our study is that the serum creatinine levels were decreased in significant no. of victims of electrical injury which showed gradual shift towards normal with time and treatment, which needs' more evaluation in the future.

Percentage of body surface may not indicate severity of electrical injury i.e. electrical injuries can be severe without external signs of severity.

India is a country of festivals with many festivals involving processions. Processions can become disastrous if proper safety precautions are not taken. In such single incident, during Ganesh festival in the year 2013 when a truck carrying the Lord Ganesh idol, came into contact with the overhead high tension cable resulting in 12 victims of electrical injury out of which three were instantaneously fatal (all the fatal cases were taken to regional govt. hospital for autopsy and six victims were admitted in our tertiary health care center and other three with less severity were taken to nearest govt. hospital. However, all of the admitted recovered).Hence individual hospital statistics may not be same when compared with general statistics.

Increase in no. of high tension injuries even in present era is alarming. Thus there is a need for legislations of safety measures and its' implementation.

Recommendations& Suggestions:

Like in any other life threatening factors, knowing the cause is one of the prime objective to carry out preventive measures to reduce the morbidity and mortality among the victims of electrical injuries. Research and experience in the last few decades has shown that injuries are predictable and preventable. Broadly, the

interventions could be primary (injuries will not occur at all), secondary (minimize harm in the event of an injury) and tertiary (rehabilitate after an injury) and are aimed at people, products and environment through education, engineering, enforcement and emergency care. There is need for policies and programs that are evidence based and data driven to implement these preventive strategies.

At a time when we are trying to explore other planets with our space mission reaching Mars, it is the need of the hour to create awareness regarding knowledge and hazards of electricity so that our planet Earth can be made safe for the living beings.

Preventive measures:

A major reduction in electrical injuries and hospitalizations may be reduced by combined approaches of:

- Strict enforcement of stringent safety laws and regulations.
- Continuous teaching and awareness programs through social media; Increasing awareness in the society to accept safety as a part of life.
- Setting safety standards and strict implementation for construction of houses, factories, schools and public play areas.
- Careful (especially in kitchen and bathrooms) insulation of electric wires at homes.
- All electrical installations should be effectively earthed as per standard earthing practice.
- Parental supervision of young children in all places, specially play areas and while playing at home in balconies, staircases etc.

- Education and awareness regarding safety measures against electrical injury must be started at school level.
- Improved electricity supply system and supervision in public places.
- Electrical employees should be given proper education regarding hazards of electricity and wearing of protective gears while working with electrical appliances.
- All electrical establishments should have Miniature circuit Breakers (MCB) to limit the load.
- Installation of Residential Current Circuit Breaker (RCCB) to avoid fatal shocks.
- Strengthening of trauma care systems for early care, and public awareness activities on importance of following safety standards at home and in workplaces.

A surveillance program of the present nature provides clues on changing patterns and profiles, identifies broad characteristics and shows directions for program implementation, monitoring and evaluation, along with identifying areas for further research.

Developing better and sustainable systems of collecting regular injury data is important and needs to go hand in hand with training of human resources personnel who can conduct and analyze such information.

Combination of educational strategies, environmental modifications, legislation, and engineering techniques together with improvement of existing data sources by hospital- and population-based studies may help to bring down the morbidity and mortality.

SUMMARY

In the present cross sectional study conducted at a tertiary care centre, Belgaum for a period of one year and three months from October 2012 to December 2013, a total of 43 cases of electrical injury were studied. The aim of this study was to know the pattern of electrical injury cases with respect to age, sex, domicile, type/ pattern of electrical injuries, and to study the burden outcome of electrical injuries in our setup.

A predesigned pretested proforma was used to collect the required data, and the details were collected from the relatives, attenders, casualty medical officers, by examination of the victims in the casualty/wards and from the medical records of the victims and autopsy reports. Adults constituted the bulk. Majority of the case load was in the age group of 11-20 years followed by 21-30 years. Males formed the majority of the victims. Maximum 46.51% cases were seen in rainy season. 74.42% of victims sustained injuries during day time. 62.80% of victims belonged to occupation other than electrician/labour. High voltage contact formed the bulk of the current source contributing to 76.74%. Total of41.86% victims sustained the injuries at work place. Entry wound was present in 69.77% of total cases. Out of 30 cases with entry wounds, 86.66% of victims had entry wound over upper extremities. Exit wound was seen in 19 (44.19%) victims. Out of them, 78.95% had exit wound over lower extremities. Among the total 43 victims of electrical injuries 16 had mechanical injuries amounting to 37.21%. High voltage is the current source in 87.5% mechanical injury. Total of 40 (93.02%) victims, had associated burn injuries, out of them 29 (72.50%) with less than 25% TBSA burn, 10 (25%) with 25 to 49% TBSA burn and only one (2.50%) with 50 to 74% TBSA burn. Total of 67.44% victims had a hospital

stay ranging between 1-20 days. Total of 55.81% of cases had to undergone surgical intervention. The total mortality rate in our study is 6.98% (03 cases). Cause of death in all, being septicaemia consequent upon burn injuries.

Unique finding of our study was that, Out of 41 cases of electrical injury in whom renal parameters were measured, blood urea was, increased in 03 (7.32%), decreased in 06 (14.63%), WNL in 32 (78.05%); while serum creatinine was decreased in 27 (65.85%), WNL in 14 (34.15%). Of all these 41 cases, 24 victims had entry wounds in the upper extremity and 15 victims had exit wounds in the lower extremity. Thus needs further study in renal parameters in relation to path of electric current inside the body.

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ANNEXURE-I

INFORMED CONSENT

"STUDY OF PATTERN OF ELECTRICAL INJURY CASES AT A TERTIARY HEALTH CARE CENTRE - A CROSS SECTIONAL STUDY"

Investigators: _____

Introduction:

You have been invited to participate in this study, to understand the pattern of electrical injury cases at a tertiary health care centre i. e. KLES´s Dr. Prabhakar Kore Hospital and MRC, Belgaum.

Explanation of procedure: In the present study you will be asked some questions regarding your socio-demographic status, details of the injuries, causative agents and circumstances. It takes about 5 to 10 minutes. After collecting the information results will be analyzed.

Possible benefits: The investigator does not promise or guarantee that you will get direct benefit being in this study. It will benefit for the whole community because by this study we will know the various problems related with electrical injuries. This study will surely help in the future for development of safety measures for the community.

Confidentiality: You and/or your child's identity will not be revealed. All information will be collected and coded so that no one will know your identity.

Withdrawal: Participation in this study is voluntary. If you don't wish to participate in this study, you will not lose benefits to which you are entitled.

Cost of participation: The cost of the study will be borne by the researcher. There will be no additional cost to you for taking part in this study.

Payment of participation: No incentive will be paid to you for participating in this study.

Questions

If you have any questions about the research you may please contact:

1. Investigator, _____ Post Graduate student, Department of Ophthalmology, JNMC, Belgaum.
2. Guide, _____ Professor, Department of Ophthalmology, JNMC, Belgaum
3. _____ Principal, JNMC, Belgaum and Chairman, Institutional Ethics Committee.

Legal rights: By signing this consent form, you are not waiving any of your legal rights.

Publication rights: The results of the survey will be used for teaching and medical publications. However the participant's identity will be kept confidential.

CONSENT STATEMENT:

I volunteer and consent for the participation of myself and/or my child in this study. I have read the consent or it has been read to me. The study has been fully explained to me and I was given sufficient time to clarify my doubts.

Participant name: _____.Participant sign/thumb print: _____.

Investigator's name: _____Investigator's sign:_____

Witness´s name:_____Witness's sign:_____

If the patients/victims are minors(less than 18 years) the consent of the parents or guardians will be taken.

Parent's/Guardian´s name:_____

Parent's/Guardian´s signature/thumb print:_____

Place:_____Date:_____

ANNEXURE-II

"STUDY OF PATTERN OF ELECTRICAL INJURY CASES AT A TERTIARY HEALTH CARE CENTRE- A CROSS SECTIONAL STUDY"

SL NO: _____ OP /IP No: _____DOA_____ DOD/Exp:_____

Name&Address:

_____Urban/rural

Age: ____yrs **(Adult/child-<18yrs), Sex: M/ F Marital status:**

Occupation:Unemployed: student/housewife/retired

Employed: electrician (govt./private)/labourer/service/professional/others

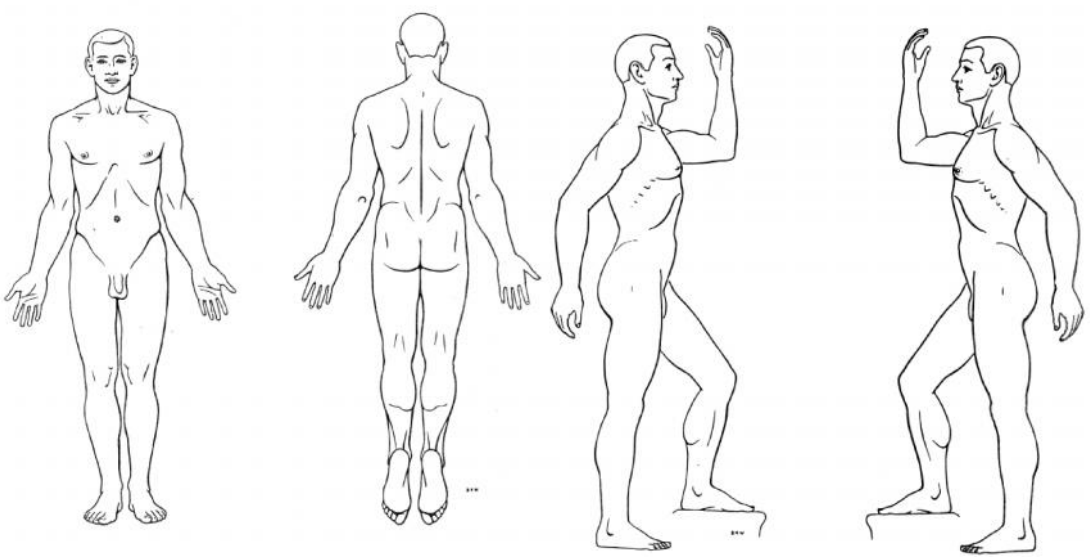
Educational status: uneducated/school/college/graduate/post-graduate

Religion: H/M/C/Others, Economic status:L/M/H, MLC: came as/made MLC

Consent: Y/N

II. PARTICULARS ABOUT THE INJURY:

1. **Place of occurence: Home/Workplace/Public place**
2. **Date and Time of occurrence:M / N / E**
3. **Manner of injury: Accidental/Suicidal/Homicidal**
4. **Power source: Natural (Lightening injuries) / Man made**
5. **Type of voltage involved: High/low/Lightning**
6. **Surgical intervention: Y/N**



7. Electric contact mark:-Primary injury

Type	**Site**	**Shape**	**Size**	**Add features**
Entry wound				
Exit wound				

B- Secondary injuries

External injury type & site	**Abrasions**	**Contusions**	**Lacerations**	**Burns**	**Others**
Internal	**Head**	**Skeletal**	**Visceral**	**others**	

Burns : sup/ deep/ TBSA: <25 / 25-50 / 50-75 / 76-100%.

III. Outcome of the case:

Recovered: OPD/ Ward.

Expired:

Cause of death: Electrocution / Electric burn /Septicaemia/Secondary injuries/ Others.

ANNEXURE III – PHOTOGRAPHS

A case of fatal electrical injury (survival period - 20 days) with below elbow amputation of Rt. UL and abdominal involvement (operated)

Above case showing electrical burns of back with amputation of Lt. UL due to high tension electric contact

Fatal case with exit wound of electric contact over medial aspect of calf muscle of Rt. LL.

Fatal case with exit wounds of electric contact over the medial aspect of both the thighs near scrotum which was in contact with the metal on which victim was sitting

Fatal case of electrical injury (survival period – 05 days) showing dermal deep burns at places and scorching of whole body.

Contracted left hand with entry wounds, of above case.

Above case showing entry wounds of Rt. Hand fingers due to electric contact.