Chapter 2

Nature of electrical accidents and dangers of electric current

2.1. Introduction

Electrical accidents are a significant threat due to the invisible and often underestimated dangers of electricity. Despite its widespread use, electricity remains a potent hazard because it is odorless, invisible, and cannot be detected by human senses. This lack of visibility contributes to complacency, leading many to overlook safety protocols.

2.2.Classification (direct and indirect actions of electric current)

Electric current can cause harm through both direct and indirect actions. Understanding these distinctions is crucial for safety measures and prevention strategies.

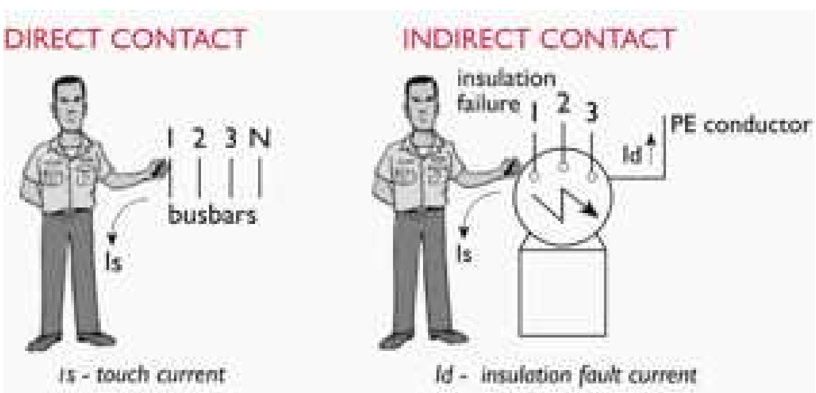

Figure 2.1. Direct and indirect actions of electrical current.

2.2.1. Direct Actions of Electric Current

Direct actions involve immediate contact with an electrical source, leading to the flow of electric current directly through the body. This can occur when touching live wires, faulty appliances, or exposed electrical components. The severity of injuries depends on factors such as voltage, current intensity, duration of exposure, and pathway through the body.

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- **Examples**: Touching a live wire or an improperly grounded appliance.
- **Effects**: Can cause cardiac arrest, burns (both internal and external), muscle spasms leading to falls or inability to release grip on conductors.

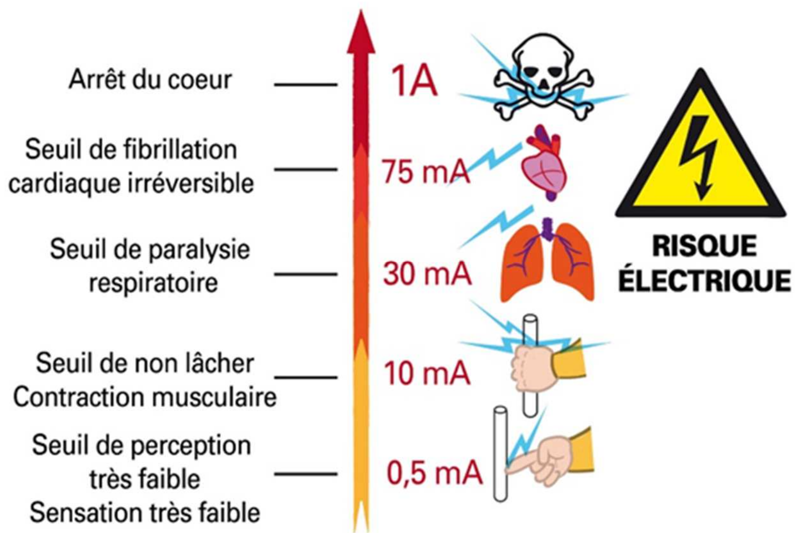

Figure 2.2. Direct action of electrical current.

2.2.2. Indirect Actions of Electric Current

Indirect actions, also known as indirect contact or secondary exposure, occur when a person comes into contact with a conductive object that has become energized due to a fault in insulation or other failures within an electrical system. This type of exposure is often less obvious but equally dangerous.

- **Examples**: Contact with metal fences near power lines during faults or touching grounded parts that have become energized due to insulation failure.
- **Effects**: Similar to direct exposure but may be less intense depending on the fault conditions; still poses risks like electrocution if not promptly addressed.

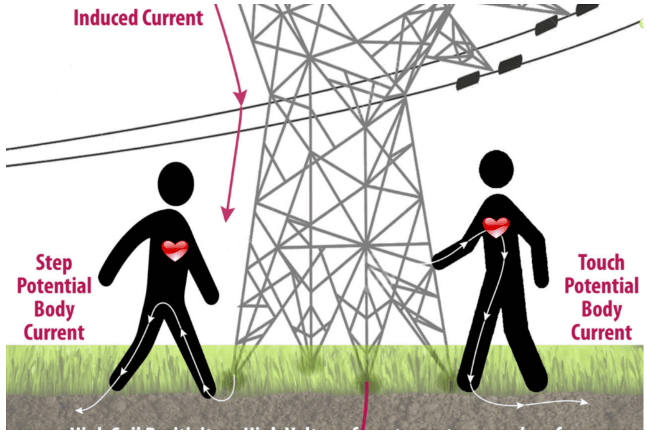

Figure 2.3. Indirect action of electrical current.

2.2.3. Safety Measures Against Both Types

To mitigate risks from both direct and indirect exposures:

- Use protective gear (e.g., gloves) when handling electrical equipment.
- Ensure regular maintenance checks for all electrical systems.
- Implement residual current devices (RCDs) for early detection and disconnection in case of faults1.
- Educate individuals about safe practices around electricity

Figure 2.4. Safety measures against direct and indirect actions of electrical current.

2.3. Impedance of the human body

The impedance of the human body is a complex concept that involves both resistance and reactance. However, in the context of electrical safety and shock, we often focus on resistance as a primary factor.

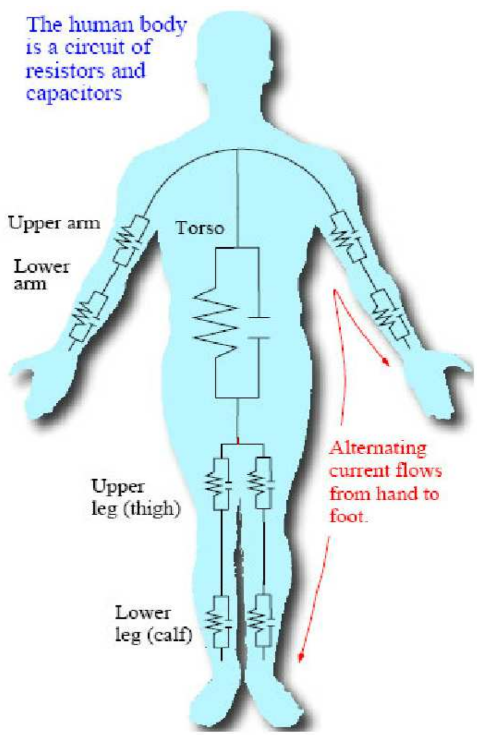

Figure 2.5. Impedance of the human body.

2.3.1. Electrical Resistance of the Human Body

1. Total Body Resistance: The total electrical resistance of the human body is typically estimated to be around 1,000 Ω (ohms) from hand-to-feet or hand-to-hand according to IEEE Std. However, this value can vary significantly based on several factors:
    - Skin Condition: Dry skin offers higher resistance (up to 100,000 Ω), while moist or sweaty skin reduces this significantly.
    - Internal Resistance: The internal body tissues have a lower resistance, approximately 300 Ω.
    - Pathway Through Body: The path electricity takes through the body affects overall resistance; longer paths increase total resistance.
2. Factors Affecting Impedance:
    - Skin impedance varies with contact voltage and moisture content.
    - Subcutaneous fat layer and deeper tissues contribute to overall impedance.
    - Electrode polarization can affect measurements at certain frequencies.
3. Implications for Safety:
   Lower body impedance means higher current flow during an electric shock, increasing injury severity. Protective equipment like voltage-rated gloves and EH-rated shoes help by adding external resistance at points of contact.

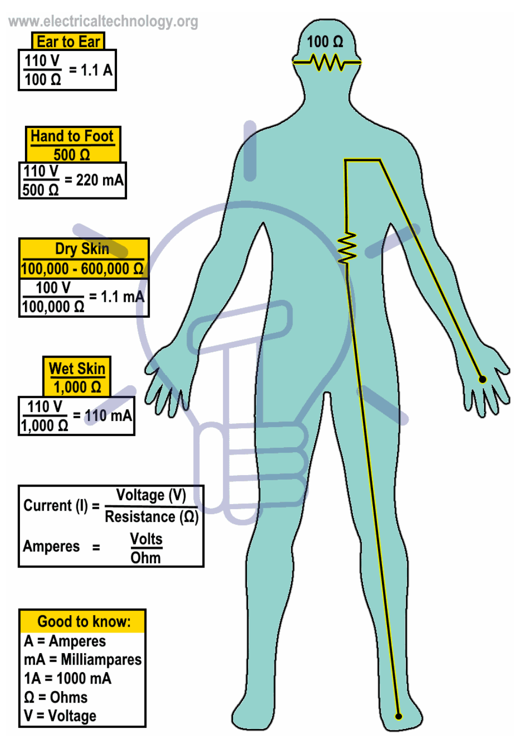

Figure 2.6. Electrical resistance of the human body.

2.3.2. Radio Frequency Impedance

At radio frequencies (RF), such as above 100 kHz, skin behaves similarly to muscle electrically. This simplifies predictions for RF applications but is less relevant for typical electrical safety considerations focused on lower frequency AC or DC currents. In summary, while specific values for RF impedance are detailed in technical reports like those from Herman P. Schwan's work at U.S. Naval Weapons Laboratory, these are more specialized than what's commonly needed for understanding direct actions related to electrical accidents involving standard household voltages. For educational purposes regarding safety around electricity, focusing on factors affecting low-frequency AC/DC resistances provides practical insights into preventing electrocution risks associated with direct contact with live wires or faulty appliances.

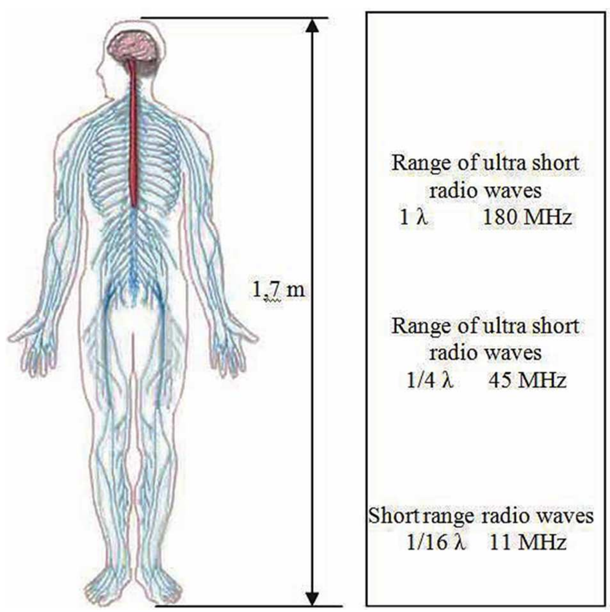

Figure 2.7. Radio frequence impedance of the human body.

2.3.3. Diagram Concept

To illustrate how these factors affect direct actions during an electric shock:

- Draw a person touching a live wire.

- Indicate arrows showing current flow through different parts of the body.
- Highlight areas where burns might occur due to high current density.
- Include symbols representing cardiac arrest risks if current passes through vital organs like the heart.

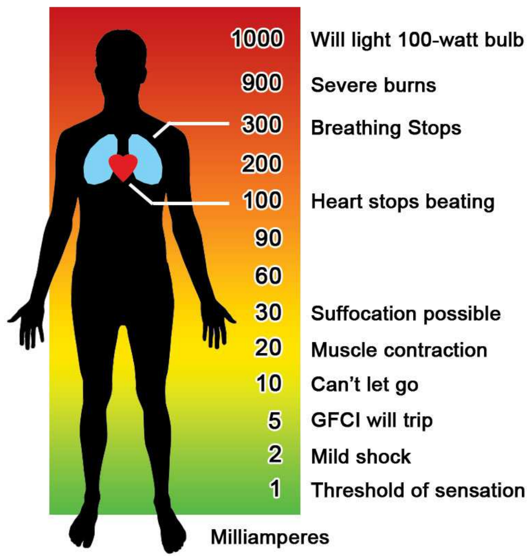

Figure 2.8. Diagram concept of the human body.

This visual aid helps convey how immediate contact with electrical sources poses significant risks due to uncontrolled current flow through various pathways within the human body.

2.4. Parameters of influence of human current

The resistance of the human body to electric current is influenced by several key parameters. Understanding these factors is crucial for assessing risks associated with electrical accidents.

Key Parameters Affecting Body Resistance

2.4.1. Skin Condition:

- **Moisture**: Wet or sweaty skin significantly reduces resistance, often to less than 1,000 Ω.
- **Cuts or Bruises**: Skin damage lowers resistance further by exposing internal tissues.

- **Calloused Skin**: Dry, calloused skin can have a high resistance of over 100,000 Ω.

2.4.2. Internal Tissue Characteristics:

- The internal body has a relatively low resistance of about 300 Ω due to its wet and salty nature.
- Different tissues have varying resistances; bone and fat are more resistant than muscle and nerves.

2.4.2. Pathway Through the Body:

The path electricity takes affects total body resistance; longer paths increase overall resistance.

2.4.4. Applied Voltage:

Higher voltages can break down skin more quickly, reducing effective body resistance at contact points.

2.4.5. Gender and Physique:

Men generally have lower electrical resistance than women due to thicker limbs (more muscle).

2.4.6. Age and Health Status:

While not explicitly detailed in the search results, age and health status might influence tissue composition and thus affect overall body impedance.

2.4.7. Environmental Conditions (e.g., Humidity):

Environmental moisture can indirectly affect skin condition but is not directly listed as a factor in these sources.

2.5. Pathophysiological effects of the passage of electric current

The passage of electric current through the human body can have severe pathophysiological effects, primarily due to its interaction with biological tissues and systems. These effects are influenced by factors such as current intensity, duration, and pathway through the body.

Key Pathophysiological Effects

2.5.1. Nervous System Disruption:

- Electric current can interfere with normal nerve function by overriding natural electrical impulses in neurons. This leads to involuntary muscle contractions (tetany) and disrupts voluntary movements.
- The central nervous system, including the brain and spinal cord, is particularly vulnerable to these disruptions.

2.5.2. Muscle Stimulation:

- Muscle spasms occur due to stimulation of muscle fibers by electric currents. These spasms can cause falls or prevent individuals from releasing their grip on conductors.
- Direct current (DC) tends to cause sustained muscle contractions more frequently than alternating current (AC).

2.5.3. Cardiac Effects:

Electric currents passing near or through the heart can lead to cardiac arrest or ventricular fibrillation at relatively low intensities (e.g., 60-100 mA for AC).

The heart's central location makes it a common pathway for electric currents flowing through the torso.

2.5.4. Thermal Burns:

As electricity flows through tissues, it generates heat due to resistance within those tissues. This heat can cause both external skin burns and internal tissue damage without visible external signs.

2.5.5. Electroporation:

High voltage pulses across tissue lengths can damage cell membranes via electroporation, leading to significant cell death even from brief exposures.

2.5.6. Long-Term Consequences:

Survivors may experience latent effects such as nerve damage affecting sensation or movement and potential organ dysfunction depending on which organs were affected by the current path.

Factors Influencing Severity

- **Current Intensity**: Higher currents increase risk.
- **Duration of Exposure**: Longer exposure increases injury severity.
- **Pathway Through Body**: Currents passing near vital organs like the heart pose greater risks.
- Skin condition affects initial resistance; wet skin reduces this significantly.

Understanding these pathophysiological effects highlights why safety measures around electricity are crucial for preventing injuries.

2.6. Electrification without loss of consciousness

Electrification without loss of consciousness refers to situations where an individual experiences an electric shock but remains conscious. This can occur with mild shocks that do not disrupt the central nervous system (CNS) significantly.

2.6.1. Factors Influencing Consciousness During Electrification

1. **Current Intensity**: Lower currents are less likely to cause loss of consciousness. For example, currents below 10 mA typically do not lead to unconsciousness unless they affect critical pathways through the body.
2. **Pathway Through Body**: The path electricity takes through the body affects whether CNS functions are disrupted enough to cause unconsciousness. Cross-body shocks, where current passes from one side of the body to another, may increase risks of CNS effects like unconsciousness compared to same-side exposures.
3. **Duration and Voltage**: Short-duration exposures or lower voltages might result in electrification without significant CNS disruption.
4. **Individual Variability**: People's responses can vary based on factors like overall health and specific conditions at the time of exposure.

2.6.2. Symptoms Without Loss of Consciousness

Even if someone remains conscious after an electric shock, they may still experience symptoms such as:

- Muscle spasms
- Tingling sensations
- Painful shock
- Burns (both internal and external)
- Irregular heartbeat

These symptoms depend on factors like current intensity and duration

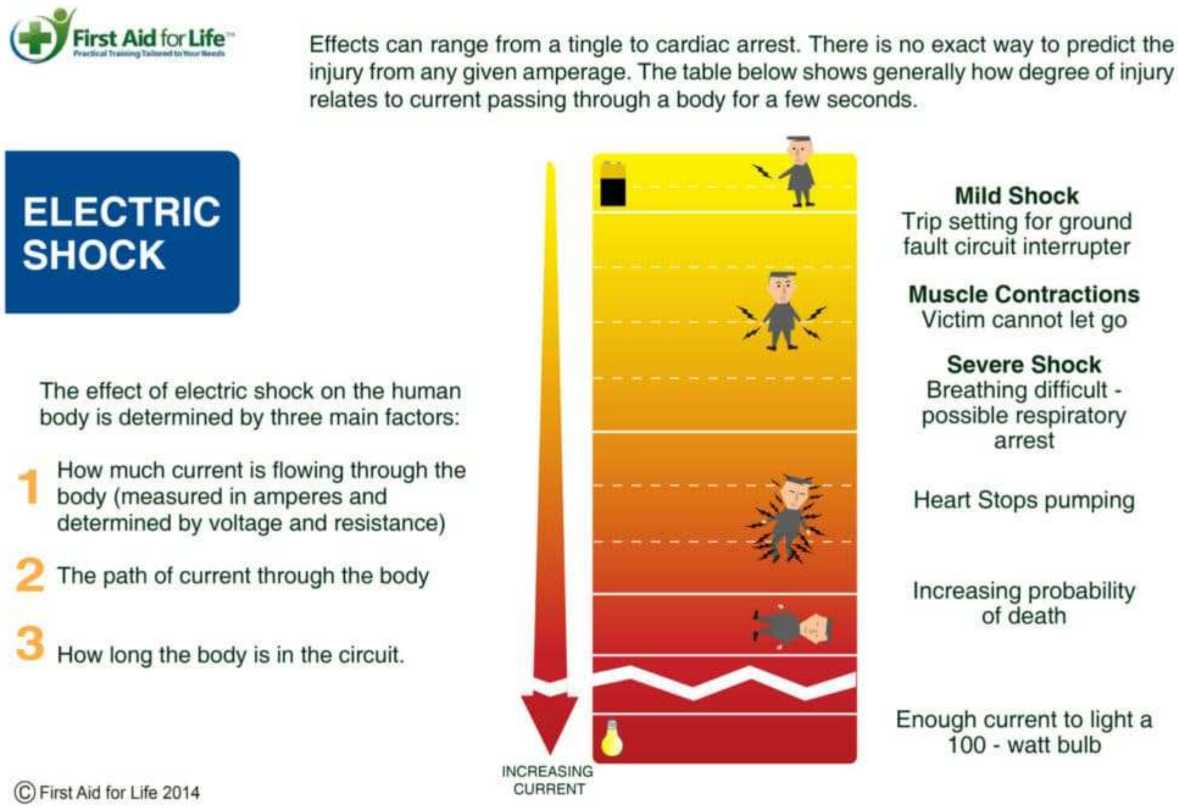

Figure 2.9. Symptoms Without Loss of Consciousness

2.7. Electrification with loss of consciousness (ventricular fibrillation).

Electrification leading to loss of consciousness often involves ventricular fibrillation, a life-threatening condition where the heart's ventricles contract chaotically and ineffectively. This can occur when an electric current passes through the chest, disrupting normal heart function.

2.7.1. Causes and Mechanisms

1. Electric Current Pathway: Currents passing through or near the heart are particularly dangerous. Even low currents (as little as 30 mA for AC) can induce ventricular fibrillation if they reach the heart during its vulnerable period.

2. Vulnerable Period: The timing of electric shock relative to the cardiac cycle is crucial; shocks during specific phases can trigger fibrillation more easily.

3. Current Type and Frequency: Alternating current (AC) at household frequencies (50-60 Hz) is more likely to cause ventricular fibrillation than direct current (DC). High-frequency currents have higher thresholds for inducing fibrillation.

2.7.2. Effects on Consciousness

- Immediate Unconsciousness: Ventricular fibrillation leads to rapid loss of consciousness due to ineffective pumping of blood by the heart.
- Cardiac Arrest: If not treated promptly with defibrillation, this condition results in death due to lack of circulation.

2.7.3. Treatment

Treatment involves immediate cardiopulmonary resuscitation (CPR) followed by defibrillation using an automated external defibrillator (AED). Prompt intervention is critical for survival.

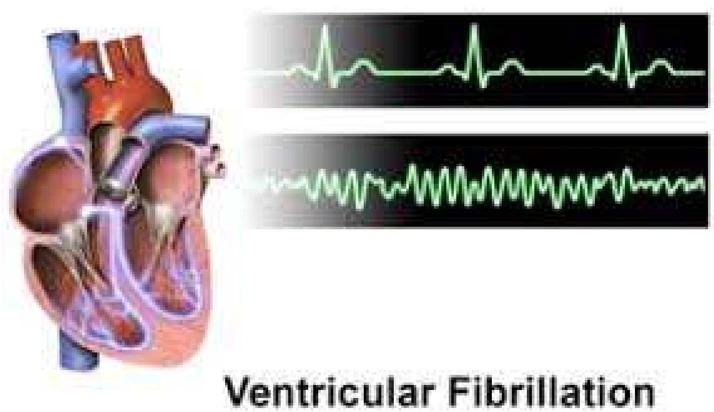

Figure 2.10. Electrification with loss of consciousness (ventricular fibrillation).