

Electrical Injury

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THE STORY IN ONE SENTENCE

Electrical injury occurs when current passes through the body, causing burns, heart rhythm problems, muscle damage, and organ injury that is often worse inside than it looks on the skin.

“How badly electricity hurts you depends on three things: how strong the current is (voltage), where it enters and exits your body, and how long it flows through you.”

Normal anatomy — the body's job

Skin has high resistance to electricity, acting like a barrier that stops small currents from entering the body. Internally, the body's tissues conduct electricity at different rates—nerves and blood vessels conduct easily, while bone resists strongly.

BODY'S JOB

Skin protects you by blocking most electrical current, like a rubber glove protecting your hand. Inside, your heart runs on its own carefully timed electrical signals that make it beat steadily. Muscles contract when nerves send them tiny electrical messages. Your kidneys filter waste from blood but are designed to handle normal proteins, not the flood that comes from damaged muscle. Each tissue has a job that depends on controlled, tiny electrical signals—not a surge of outside current.

1. Imagine your skin as a thick rubber mat covering your body, with high resistance that stops most electricity from getting in.
2. Inside, your nerves and blood vessels are like copper wires—they conduct electricity easily if current does break through.
3. Your heart is like a battery-powered pump with its own internal timer, sending precise electrical pulses 60–100 times per minute to keep blood flowing smoothly.

4. Muscles are bundles of fibers wrapped in tight sleeves (compartments), like sausages in casings—they are meant to contract gently when signaled, not violently all at once.
5. Your kidneys are filters, like coffee filters, designed to catch normal waste but not built to handle a sudden dump of muscle protein.

What breaks

When electrical current strong enough to overcome skin resistance enters the body, it flows through the path of least resistance—usually blood vessels, nerves, and muscles—burning and damaging everything along that path, while the heart's normal electrical rhythm gets disrupted or stops.

CLINICAL TERM

Electrical current bypasses skin resistance (especially if skin is wet or current is high voltage), travels through low-resistance tissues (nerves, blood vessels, muscle), and causes thermal injury (burns) from heat generated by resistance, direct cellular damage from current flow, and disruption of normal bioelectrical function (cardiac dysrhythmias, tetanic muscle contractions, neurological injury).

How the body compensates

Right after electrical injury, the body's stress response (adrenaline surge) can keep blood pressure and heart rate stable even while severe internal damage is happening. This 'looking okay' phase is dangerous because it hides life-threatening problems—cardiac arrest, compartment syndrome, and kidney failure—that may not show up for hours.

1. {'step': 'Adrenaline surge keeps vital signs stable initially', 'why': "The body's fight-or-flight response floods the bloodstream with adrenaline, temporarily maintaining blood pressure and heart rate even as internal organs and muscles are severely damaged."}
2. {'step': 'Skin burns underestimate internal injury', 'why': 'Surface burns may look small because skin has high resistance, but inside, the current has followed blood vessels and nerves, cooking deep muscle and organs along a much larger path—like an iceberg where you see only the tip.'}
3. {'step': 'Cardiac monitoring is essential even if initial rhythm is normal', 'why': 'Lethal arrhythmias (ventricular fibrillation, ventricular a fast heart rate (tachycardia)) can appear hours after injury as damaged heart muscle becomes electrically unstable, so continuous ECG monitoring is required for at least 24 hours after high-voltage or transthoracic current.'}

4. {'step': 'Aggressive IV fluid resuscitation prevents kidney failure', 'why': 'Large volumes of intravenous fluid dilute myoglobin in the blood and flush it through the kidneys before it clogs the filters, aiming for urine output of 1–2 mL/kg/hour (or until urine clears if visibly dark from myoglobin).'} }
5. {'step': 'Serial exams catch compartment syndrome before permanent damage', 'why': 'Swelling inside muscle compartments worsens over hours; checking every 2–4 hours for the 5 P's (Pain out of proportion, Pressure/tightness, Tingling or numbness (Paresthesias)/ numbness, Pale skin (Pallor), Pulselessness) allows fasciotomy (surgical release) before muscle and nerve die.'} }
6. {'step': 'Full trauma evaluation identifies hidden injuries', 'why': 'The force of electrical shock—either tetanic contraction or being thrown—can fracture bones (especially spine, shoulder, femur), dislocate joints, cause internal bleeding, or produce traumatic brain injury, so imaging and exam must look beyond the burns.'} }

Domino effect

1. Current enters body and creates entry/exit burns — Electricity breaks through skin resistance at the contact point (entry—often hand or head) and exits where the body touches ground (exit—often foot), burning skin at both spots as current converts to heat.
2. Current flows through internal tissues along path of least resistance — Inside the body, electricity travels preferentially through nerves, blood vessels, and muscles (low resistance) rather than bone or fat (high resistance), heating and destroying cells along this path like a wire overheating.
3. Deep muscle and organ damage occurs, worse than skin shows — The same current that made a small skin burn has traveled through centimeters or meters of internal tissue, cooking muscle, blood vessels, and organs from the inside—thermal injury is proportional to tissue resistance and current duration, so deep damage is often massive even when surface burns look minor.
4. Heart rhythm disrupted or heart stops — External electrical current depolarizes the entire heart at once (like hitting 'reset' on the heart's pacemaker), causing ventricular fibrillation (chaotic quivering) or asystole (complete stop)—if current crosses the chest (hand-to-hand or hand-to-foot), the risk is highest because the path goes directly through the heart.
5. Tetanic muscle contraction causes fractures or throws victim — Electrical current makes all muscles contract maximally and simultaneously—flexor muscles are stronger than extensors, so the victim's hand clamps onto the source ('can't let go' phenomenon), or the whole body is thrown backward by extensor spasm, breaking bones (vertebrae, humerus, femur) or causing head trauma from the fall.

6. Rhabdomyolysis releases myoglobin into bloodstream — Cooked muscle cells rupture and dump their contents—including myoglobin (the oxygen-carrying protein inside muscle)—into the blood; myoglobin turns urine tea-colored or cola-colored and is visible evidence of massive muscle breakdown.
7. Myoglobin clogs kidney filters, causing acute kidney injury — Myoglobin is a large molecule that precipitates (clumps) in the kidney's filtering tubules, physically blocking urine flow like coffee grounds clogging a drain—this leads to acute tubular tissue death (necrosis) and kidney failure if not flushed out quickly with IV fluids.
8. Compartment syndrome develops as burned muscle swells — Damaged muscle swells with fluid (edema), but arms and legs are wrapped in tight, non-stretchable fascia (like shrink-wrap)—pressure inside the compartment rises, squeezing shut arteries and veins, which cuts off blood flow and oxygen to any remaining healthy muscle and nerve, killing more tissue and creating a vicious cycle unless the fascia is cut open surgically (fasciotomy).

Symptoms · what the patient feels, and why

- Skin burns at entry and exit points: Electricity flowing through the body turns into heat where it enters and leaves the skin, cooking the tissue like a hot wire touches plastic. High-voltage current can burn deep layers (muscle, bone) even if the skin looks okay on the surface.
- Muscle pain, swelling, or weakness in arms or legs
- Heart rhythm problems (arrhythmias) or cardiac arrest: The heart beats because of tiny electrical signals. A strong outside electrical current can scramble those signals, making the heart beat too fast, too slow, or stop completely. Even after the shock, the heart's rhythm can stay unstable for hours.
- Numbness, tingling, or loss of movement: Nerves use electrical signals to send messages. Electric shock can fry the nerve's insulation (myelin, the coating that helps signals travel) or kill nerve cells outright, so signals can't get through. This causes numbness or paralysis in the path the electricity took.
- Confusion, memory loss, or seizures: If electricity passes through the brain, it disrupts the normal electrical activity that lets you think and remember. High-voltage shocks can also cause brain swelling or bleeding, leading to confusion or seizures (uncontrolled bursts of brain activity).
- Dark or cola-colored urine: When muscle cells are destroyed, they release a protein called myoglobin into the blood. The kidneys filter it out, turning the urine dark brown or red. Too much myoglobin can clog the kidney filters and cause kidney failure.
- Broken bones or dislocated joints: Electric shock makes all the muscles contract violently at once (like a full-body cramp). This sudden, powerful squeeze can be strong enough to break bones or pull joints apart. Falls during or after the shock can also cause fractures.

- Lichtenberg figures (fern-like skin marks after lightning): Lightning spreads across the skin surface in branching patterns, rupturing tiny blood vessels under the skin. These marks look like fern leaves or tree branches and usually fade within a day or two. They prove lightning hit the person.
- Hearing loss or ruptured eardrums: Lightning and high-voltage arcs create an extremely loud blast wave (like an explosion). The pressure wave can tear the eardrum (the thin skin inside the ear that vibrates when you hear). Direct current through the head can also damage the inner ear nerves.
- Breathing stops or becomes very slow: Electricity passing through the chest or brain can paralyze the breathing muscles (diaphragm and ribs) or shut down the brain's breathing control center. Without help, the person can't take in oxygen and will die within minutes.

Focused exam

- Entry and exit burn marks on skin: Shows the path electricity took through the body. Deep damage to muscle, nerves, and blood vessels is almost always worse than what you see on the surface.
- Heart rhythm on monitor — regular, skipping beats, or stopped: Electricity disrupts the heart's own electrical signals and can cause deadly rhythms (ventricular fibrillation, asystole) or delayed arrhythmias hours later. This is the most common cause of death.
- Muscle swelling in arms or legs; skin tight, shiny, and painful: Electricity cooks muscle deep inside and it swells. The swelling is trapped inside tight compartments and squeezes blood vessels shut, killing tissue — this is compartment syndrome.
- Dark tea-colored or cola-colored urine: Damaged muscle cells spill myoglobin (a muscle protein) into the blood. Myoglobin plugs up the kidney filters and can cause kidney failure — this is rhabdomyolysis.
- Confusion, seizures, weakness, or trouble speaking: Electricity can travel through the brain and spinal cord, damaging nerves directly. Low oxygen from heart or lung injury also hurts the brain.
- Broken bones, dislocated joints, or bruises from a fall: Electricity makes muscles contract violently. The person may have been thrown backward or fallen from a height. Look for hidden fractures of the spine, skull, or long bones.

Diagnostics · every test answers a question

- Continuous cardiac monitoring (ECG, telemetry) for 24–48 hours → Is the heart rhythm stable, or is electricity still causing dangerous beats?
- Creatine kinase (CK) — blood test → How much muscle was cooked and broken down inside?

- Troponin I or T — blood test → Did the heart muscle itself get damaged by the electricity?
- Basic metabolic panel (BMP) — blood test for electrolytes and kidney function → Are the kidneys working, and are electrolytes dangerously out of balance?
- Urine myoglobin or urinalysis with dipstick → Is muscle breakdown spilling into the urine and clogging the kidneys?
- Complete blood count (CBC) → Is there bleeding inside, or is the body mounting an inflammatory response?
- X-rays of chest, spine, and any painful area → Are there broken bones, lung injury, or signs the person was thrown or fell?
- Compartment pressure measurement (if swelling is severe) → Is the swelling inside the arm or leg so tight that it is cutting off blood flow?

Treatment logic

- Continuous cardiac monitoring for 24–48 hours → Electricity can trigger deadly heart rhythms immediately or hours later. Watching the heart lets you catch and treat arrhythmias before they cause cardiac arrest.
- Aggressive IV fluids (lactated Ringer's or normal saline) to keep urine output > 200 mL/hour (in adults) → Damaged muscle spills myoglobin into the blood. Extra fluid flushes myoglobin through the kidneys before it clogs the filters and causes kidney failure.
- Check for compartment syndrome; perform fasciotomy if pressure > 30 mmHg or clinical signs are severe → Electricity cooks muscle and it swells inside tight compartments. Cutting open the skin and fascia (the tough layer around muscle) lets swelling expand outward instead of crushing blood vessels and nerves.
- Treat arrhythmias per ACLS protocols (defibrillation for ventricular fibrillation, pacing for heart block, medications like amiodarone or lidocaine) → Restores normal electrical signals in the heart so it can pump blood to the brain and body. Saves life if the heart has stopped or is in a deadly rhythm.
- Tetanus prevention (prophylaxis) (vaccine and/or immunoglobulin based on history) → Burn wounds are dirty and at high risk for tetanus (a deadly bacterial infection that locks muscles in spasm). Tetanus shot prevents this infection.
- Surgical debridement (cutting away dead tissue) and wound care; early surgical consult for high-voltage injury → Electricity creates charred skin on the surface and dead muscle deep inside. Removing dead tissue stops infection from spreading and lets healthy tissue heal.
- Ophthalmology referral if current passed near the eyes; monitor for cataracts for up to 3 years → Electricity can damage the lens of the eye immediately or cause cataracts (clouding of the lens) months to years later. Early exam catches problems before vision is permanently lost.

Medications

Intravenous Crystalloid (Normal Saline or Lactated Ringer's) · Isotonic fluid resuscitation

When electricity damages muscle, the muscle cells break open and spill a protein called myoglobin into the blood. Myoglobin is like a sticky sludge that can clog the tiny filters in the kidneys and cause them to fail. IV fluids flush the kidneys like turning on a garden hose at full blast—they push lots of water through the kidneys so the myoglobin gets washed out in the urine before it can clog anything. The goal is to make the patient pee at least 75 to 100 milliliters every hour (about half a cup), keeping the urine clear and the kidneys safe.

1. Crystalloid fluid enters the bloodstream through an IV line
2. Blood volume increases, which raises blood pressure slightly and improves flow to all organs
3. More blood reaches the kidneys every minute
4. Kidneys filter more water and push more urine into the bladder
5. Myoglobin (the muscle breakdown protein) gets diluted in the extra water and washed out in the urine before it can clump together and block the kidney filters

SAFETY WATCH

Too much IV fluid too fast can overload the heart and lungs, causing fluid to back up into the lungs (pulmonary swelling (edema)) and making it hard to breathe—watch for new shortness of breath, fast breathing, or low oxygen levels · Monitor urine output every hour; if urine stays dark (tea-colored) despite fluids, the kidneys may not be flushing properly and the patient may need even more aggressive fluid therapy or dialysis · Check for swelling in the arms, legs, or around the eyes; some swelling is expected, but severe swelling can signal fluid overload · In patients with heart failure or kidney disease before the injury, give fluids more slowly and watch closely because they cannot handle large volumes as well

Sodium Bicarbonate (Baking Soda IV Solution) · Urinary alkalinizer

When myoglobin (the muscle protein released after electrical injury) reaches the kidneys, it is more likely to clump together and clog the filters if the urine is acidic (low pH). Sodium bicarbonate makes the urine more alkaline (higher pH)—like adding baking soda to water to make it less sour. In alkaline urine, myoglobin stays dissolved and flows out more easily instead of forming harmful clumps. The target is to keep the urine pH above 6.5, ideally around 7 to 8, so the kidneys stay clear and functional.

1. Sodium bicarbonate is added to the IV fluid or given as a separate infusion

2. Bicarbonate enters the bloodstream and raises the blood pH slightly
3. The kidneys filter the bicarbonate along with water and waste
4. Bicarbonate appears in the urine, making the urine more alkaline
5. In alkaline urine, myoglobin stays dissolved and washes out instead of clumping and blocking the tiny kidney tubes

SAFETY WATCH

Too much bicarbonate can make the blood too alkaline (metabolic too little acid in the blood (alkalosis)), which can cause muscle twitching, confusion, or irregular heartbeats · Check urine pH with a dipstick every few hours; if pH goes above 8, bicarbonate may need to be slowed or stopped · Bicarbonate can lower calcium and potassium levels in the blood—monitor these electrolytes and replace them if they drop too low · In patients with heart failure, the sodium load in bicarbonate can worsen fluid overload—use cautiously and watch for shortness of breath or leg swelling

Mannitol · Osmotic diuretic

Mannitol is a sugar molecule that the kidneys cannot absorb back into the blood—it stays in the urine and acts like a sponge, pulling extra water into the urine. This creates a strong flow of urine (diuresis) that helps flush myoglobin out of the kidneys before it can clog the filters. Think of it like adding dish soap to a clogged drain to help push the blockage through. Mannitol also reduces swelling in damaged tissues, including muscles swollen from electrical injury, by pulling fluid out of the tissue and into the bloodstream where it can be urinated out.

1. Mannitol is given as an IV infusion
2. It enters the bloodstream and travels to the kidneys
3. The kidneys filter mannitol but cannot pull it back into the blood, so it stays in the kidney tubules
4. Mannitol holds onto water molecules like a magnet, preventing water from being reabsorbed
5. Large amounts of urine are produced, flushing out myoglobin
6. In swollen muscle compartments, mannitol draws fluid out of the tissue space and into blood vessels, reducing dangerous pressure

SAFETY WATCH

Mannitol pulls fluid into the bloodstream first (before it is urinated out), which can temporarily overload the heart and lungs—watch for sudden shortness of breath, especially in patients with heart failure · If the kidneys are already failing and cannot make urine, mannitol can build up in the blood and make things worse—only use if the patient is still making some urine · Mannitol can cause severe dehydration and low blood pressure if too much is given—monitor blood pressure and replace fluids carefully · Check electrolytes (sodium, potassium) frequently, as mannitol can cause imbalances · Do NOT use mannitol if the patient has bleeding in the brain, as it can worsen swelling in the head

Tetanus Toxoid Vaccine (Td or Tdap Booster) · Active immunization (vaccine)

Electrical burns create open wounds, and any open wound can let tetanus bacteria (*Clostridium tetani*) enter the body from dirt or debris. Tetanus bacteria make a poison (toxin) that locks up the muscles, causing painful spasms and potentially fatal breathing problems. The tetanus vaccine teaches the immune system to recognize and attack the tetanus toxin before it can cause harm. If the patient has not had a tetanus shot in the past 5 years (for dirty wounds) or 10 years (for clean wounds), a booster dose is given to refresh the immune system's memory and provide protection.

1. Tetanus vaccine is injected into the muscle (usually the shoulder)
2. The vaccine contains a harmless piece of tetanus toxin (toxoid) that cannot cause disease
3. Immune cells recognize the toxoid as foreign and create antibodies against it
4. Antibodies remain in the blood, ready to bind and neutralize real tetanus toxin if it enters the body
5. If tetanus bacteria get into the wound, the immune system attacks the toxin immediately, preventing muscle spasms and lockjaw

SAFETY WATCH

Mild soreness, redness, or swelling at the injection site is common and goes away in a day or two · Some people feel tired or get a mild fever after the shot—this is the immune system responding and is not dangerous · Severe allergic reactions (anaphylaxis) are extremely rare but can happen within minutes; watch for hives, throat swelling, trouble breathing, or a fast heartbeat right after the injection · If the patient has had a severe allergic reaction to a tetanus vaccine in the past, do not give it again—consider tetanus immunoglobulin instead

Tetanus Immunoglobulin (TIG) · Passive immunization (antibody therapy)

Tetanus immunoglobulin is a solution of ready-made antibodies (proteins that fight tetanus toxin) collected from human donors who already have immunity. Unlike the vaccine, which takes days to work because your body has to build its own antibodies, TIG gives you instant protection by providing antibodies right away. These antibodies grab onto any tetanus toxin in the body and neutralize it immediately, like a fire extinguisher putting out a fire before it spreads. TIG is used for patients who have never been vaccinated, have an incomplete vaccination series, or have a very dirty or deep wound where tetanus risk is high.

1. TIG is injected into a muscle (usually the thigh or buttock)
2. Antibodies enter the bloodstream within hours
3. Antibodies travel throughout the body, including to the wound
4. If tetanus bacteria release toxin, the antibodies immediately bind to it and block it from reaching nerve cells
5. The toxin is neutralized and broken down, preventing muscle spasms and lockjaw

SAFETY WATCH

Pain and soreness at the injection site are common · Mild fever or body aches can occur but usually go away within a day · Allergic reactions are rare but possible—watch for hives, itching, or trouble breathing after the shot · TIG is made from human blood, so there is a tiny risk of transmitting infections, though the product is carefully screened and treated to minimize this risk · If the patient has severe antibody deficiency (IgA deficiency), TIG can sometimes cause a serious allergic reaction—tell the care team if this is known

Red flags

- Heart rhythm is irregular, too fast, too slow, or the person has chest pain
- Urine is dark brown, red, or cola-colored (sign of muscle breakdown clogging the kidneys)
- Severe swelling, numbness, or pain in an arm or leg that gets worse (compartment syndrome building pressure)
- Confusion, seizures, or the person is unconscious or hard to wake up
- High-voltage exposure (power lines, industrial equipment) even if burns look small on the outside

Nursing priorities

1. Place patient on continuous cardiac monitor and obtain a 12-lead ECG immediately, watching for arrhythmias like ventricular fibrillation, ventricular a fast heart rate (tachycardia), or heart block. — Electrical current disrupts the heart's normal electrical system and can cause lethal rhythms even hours after injury—continuous monitoring for 24 to 48 hours catches life-threatening arrhythmias before they cause cardiac arrest.
2. Start two large-bore IV lines and run lactated Ringer's or normal saline wide open, aiming for urine output greater than 200 mL per hour in adults (1 to 2 mL per kilogram per hour in children). — Aggressive IV fluids flush myoglobin (muscle breakdown protein) out of the kidneys before it clogs the tiny kidney filters and causes acute kidney injury—high urine output washes the toxins away and protects kidney function.
3. Check urine color every void and send urine myoglobin level and serum creatine kinase (muscle enzyme) if urine is dark, tea-colored, or cola-colored. — Dark urine signals rhabdomyolysis where damaged muscles release myoglobin that is toxic to kidneys—tracking these levels tells us how severe the muscle damage is and whether our fluid treatment is working to protect the kidneys.
4. Assess all four limbs every 1 to 2 hours for the 6 P's of compartment syndrome: Pain out of proportion, Pressure or tightness, Pale skin (Pallor) (pale skin), Tingling or numbness (Paresthesias) (numbness or tingling), Pulselessness, and Paralysis (cannot move). — Electrical injury causes deep muscle swelling inside tight compartments surrounded by tough tissue—rising pressure cuts off blood flow and kills muscle and nerves within 4 to 6 hours unless relieved by emergency fasciotomy surgery.
5. Inspect entry and exit burn wounds, clean gently with sterile saline, apply sterile non-stick dressing, and do NOT apply ice or creams—document wound size, depth, and location with photos if available. — Electrical burns destroy tissue deep under normal-looking skin like an iceberg underwater—careful wound assessment without added trauma prepares for possible debridement surgery, and ice causes more tissue damage by reducing blood flow.
6. Perform hourly neurological checks including level of consciousness, pupil reaction, speech clarity, arm and leg strength, and ask about headache, vision changes, or memory problems. — Electrical current passing through the brain causes swelling, seizures, or bleeding—frequent neuro checks catch worsening confusion or new weakness early so we can get a CT scan and prevent permanent brain injury.
7. Keep patient on bedrest with fall precautions, call light within reach, and assist with all movement for the first 24 hours even if patient feels fine. — Arrhythmias can appear suddenly hours after electrical injury causing dizziness or fainting—bedrest prevents falls during sudden rhythm changes, and muscle damage may cause unexpected weakness when the patient tries to stand.

- 8.** Hold all food and drink (NPO status) until cleared by provider, because patient may need emergency surgery for compartment syndrome, burn debridement, or other internal injuries. — Electrical injury often requires urgent surgery that is safer on an empty stomach—having food in the stomach increases risk of vomiting and aspiration (breathing in stomach contents) during anesthesia, which can cause severe lung injury.

Sources

- American Burn Association
- AHA/ACC guidelines on cardiac arrest and arrhythmias
- National Institute for Occupational Safety and Health (NIOSH)
- Wilderness Medical Society practice guidelines for lightning injuries

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