Electrical injury: are tasers the new wave?

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Introduction

Imagine this scenario: you are a primary healthcare provider working in the emergency room at the local hospital. You are nearing the end of a long day in which you have been extremely busy when you hear an incoming radio transmission from a paramedic unit. They are bringing in a 25-year-old male who has been hit in the chest with a Taser gun. The Taser gun was discharged three times for 5 seconds each. You have heard several theories on treating Taser victims, but most healthcare workers have not seen any concrete evidence on what is best. Do you know how to treat this patient?

The scenario described above is one that is becoming more common in almost all emergency departments across the U.S. The increase in electrical injuries from a Taser is due to the Taser X26 becoming more widely used among police departments. There is also an increasing number of Tasers available for private purchase and used for self-defense. There is not a special license needed, which makes using these weapons even more common, but less safe. If Taser deployment is becoming more common, then why isn’t there more information on how to treat a patient? With an increase in incidence there seems to be new problems arising. Recent research has been directed to determine if these problems are caused by the Taser, or if there are other explanations.

Now going back to the original question, how do we treat the patient in the scenario above? Do we just monitor the patient and send him/her home or admit to the hospital for observation? If we do admit, how long should the patient stay? Do we give any medications and if so which ones? Are there any other treatments or modalities we need to consider? There has been a lot of research done on the effects of the Taser under controlled conditions in an attempt to answer these questions, but there is still much that needs to be answered. This clinical review
of the literature will look at Taser data along with information on all electrical injuries and try to answer these questions. By putting this information together the primary healthcare provider will feel more empowered and confident the next time they find themselves in a situation involving Tasers or an electrical injury.
Electrical Injuries

Before any health care provider can accurately treat a Taser victim, they should first understand the basic principles of electrical injuries. Electrical injuries are a growing concern not only in law enforcement, but also in the residential and industrial environments. Common clinical presentation involves physical, cognitive, and emotional complaints (Pliskin et al., 2006). More serious injuries are also evident by the nearly 1000 deaths per year in the United States directly resulting from electrical injury, with up to a 15% mortality rate (Morse & Morse, 2005). The two mechanisms that electricity uses to injure a cell are electroporation and thermal tissue heating. These are usually cumulative in action and vary in their degree of contribution to the damage produced (Kalkan et al., 2004). Electroporation is mainly caused by high voltages with short shock duration. This causes damage to the cell membranes, changing their anatomical structures. Thermal tissue heating is mainly caused by high voltages with a long shock duration (Fan, Zhu, & Den, 2005). This leads to generation of heat along the current’s path and dissolution of the cell. Taser injuries do not reach voltages high enough to cause either type of injury. They involve alternating AC and DC currents which will cause muscle tetany, without this type of destruction.
Severity of Electrical Injury

There are several factors that need to be taken into account when determining the severity of an electrical injury. The voltage, resistance, the type and amount of current (AC or DC), duration and area of contact, systems involved, conductors, and even the gender of the patient all need to be considered.

Voltage can be divided into two major subgroups, high and low. High voltage is considered greater than 600 volts and greatly increases the risk of fatal electrical injury. It takes a particular pathway between its entrance point and the ground, diverging once entering the body, and converging as it exits (Kalkan et al., 2004). Low voltage is anything less than 600 volts, and will generally follow the path of least resistance through the body. Although low voltage is less lethal, it is far more common. This results in an equal number of high and low voltage injuries reported each year (Chinnis, Williams, & Treat, 2000).

Resistance is measured by a specific set value for whatever medium the current is flowing through. Resistance converts electrical energy into heat energy and extensive tissue damage can occur (O’Conor, 2003). This resistance can be altered by adding insulators or conductors. Fat and metals found in the body have a very low resistance. Bone and the skin surrounding our body both have relatively high resistance. Water is one element that when added to the skin acts as a conductor and will greatly reduce the resistance due to all the metals found within. This will cause an increase in the severity of any electrical injury that involves water.

Current is the amount of voltage divided by the resistance of the pathway through the body. The amount of current in a circuit is measured in amperes, and there are two types of current. Alternating current or AC has two poles and the electrical current alternates back and
forth between these poles at several times per second (Hertz). AC is the most common type of
electrical current and mostly found in household and industrial sources. This type of current
causes muscle tetany with the alternating current letting the body pull away from the source,
resulting in a shorter duration of contact. Direct current or DC is a continuous electrical current
in a single direction. DC current is found in batteries, medical defibrillators, or lightning. This
type of electrical current causes a single muscle spasm, contracting and pulling the victim
towards the electric source and lengthening the duration of contact (O'Conor, 2003). Current is
the most important element in determining the severity of any electrical injury. (See Table 1)

Recent studies have shown that gender may also provide a role in helping to determine
the type and severity of an electrical injury. Up to 93% of electrical injuries are found in males,
largely in part because men make up the majority of construction workers and electricians.
These types of injuries are often more severe and involve a higher voltage injury. Females are
more likely to be injured by nonindustrial voltages, such as those found in the home. These
lower voltage injuries are less likely to require emergency treatment (Morse & Morse, 2005).
While these trends can be seen in most cities, it is important not to rely solely on gender when
treating a patient with an electrical injury.
Affects on the Body

Electrical injury can have several affects on almost any system of the body. These systems include: Cardiovascular, neurological, dermatological, vascular, pulmonary, renal, gastrointestinal, muscular, skeletal, ophthalmologic, auditory, obstetrics, and many others. Each system needs a careful assessment in order to rule out hidden damage. The most important are summarized in the following paragraphs.

Cardiovascular system effects include sudden death from ventricular fibrillation or asystole. Also this can present as chest pain, ST segment abnormalities, myocardial damage, dysrhythmias, hypo or hypertension, and rarely as a myocardial infarction. Neurological complications can present in a multiple of ways including altered mental status, agitation, coma, seizures, cerebral edema, hypoxic encephalopathy, headaches, aphasia, weakness, paraplegia, quadriplegia, spinal cord dysfunction, neuropathies, insomnia, or cognitive impairment (Jarvis III, 2004). According to Pliskin et al, a study done to test effects from electrical injury on the CNS found those suffering from an electrical injury scored significantly worse on composite measures of attention and mental speed. However, the same tests showed similar results for working memory, verbal memory, and visuospatial memory between the test group and the placebo group. (Pliskin et al., 2006).

Dermatological injuries to the skin include contact burns, arc and flash burns, or secondary burns from clothing that catches on fire. Vascular injuries can present as thrombosis, coagulation necrosis, disseminated intravascular coagulation, delayed vessel rupture, aneurysm, or compartment syndrome. The lungs may also sustain injury and cause pulmonary arrest, aspiration pneumonia, pulmonary edema, or inhalation injury. The patient can suffer from renal failure secondary to myoglobinuria, or gastrointestinal problems such as ulcers or bleeding.
More common injuries include necrosis of any muscle affected by the electricity, and skeletal injuries including vertebral and long bone fractures, scapular fractures, or shoulder dislocations. These injuries are often the result of severe muscle contractions caused by the electrical current. Musculoskeletal injuries can also occur from the fall that occurs after the initial electrical injury. Other injuries include corneal burns and cataracts of the eyes, hearing loss, burning of the oral mucosa, slurred speech and facial deformities. Pregnant patients run the risk of increased incidence of spontaneous abortions or fetal death (Jarvis III, 2004).
Assessing and Treating Electrical Injuries

Assessment of a patient that has an electrical type injury can prove to be difficult due to a decreased level of consciousness often associated with severe electrical injuries. It is very important to gather information from all resources available, as this may be your only chance to a history of the events. Airway, breathing, and circulation are the health care provider’s number one concern. After that, spinal stabilization and mental status need to be evaluated (O’Conor, 2003). High-flow oxygen should be started, as well as pulse oximetry, blood pressure measurements, an EKG, and IV fluids. Continuous cardiac monitoring and two large bore IV lines are appropriate in patients with high voltage injuries.

Only once the patient is stable should the health care worker continue with assessment and treatment. Tetanus prophylaxis should be given, however prophylactic antibiotics are not usually needed. Laboratory studies should include a complete blood count, electrolytes, calcium, blood urea nitrogen, creatinine, coagulation studies, myoglobin, creatinine kinase, and CK-MB. Arterial blood gases can also be done with high voltage injuries, but are not necessary in low voltage incidents.

Physical exam should be thorough and include reduction and splinting of any fractures as well as treating any skin burns with silver sulfadiazine cream after irrigation and cleaning. Peripheral nerve function should be assessed in any high voltage injury, as thirty percent of patients with this type of injury will develop a deficit to a peripheral nerve (Fan, Zhu, & Den, 2005). A general surgeon should be consulted if there is evidence of systemic or deep tissue injury (Jarvis III, 2004). A detailed list of systemic injuries that need to be assessed for can be found in the previous section.
Asymptomatic patients whose electrical injury involved household voltage (110V-220V), a normal EKG, no cutaneous involvement, no urinary heme pigment, and an unimpressive physical exam can be discharged home after a short period of observation. Patients with high voltage injuries, any arrhythmia, or an increased clinical suspicion should be admitted to the hospital for overnight observation.

Follow up will be needed for any high voltage injuries. This becomes evident in a case report by Isao et al who found a case proving that this type of injury can lead to various neurologic sequelae (Isao, Masaki, Riko, & Seiichi, 2005). This case involved a 12-year old boy that suffered from a high voltage electrical injury and extensive burns to 60% of his body. Two months later, he suddenly developed seizures and MRI showed diffuse cortical damage in the left brain. Two months after that, motor aphasia appeared and a second MRI showed atrophy in the left temporal and frontal lobes (Isao, Masaki, Riko, & Seiichi, 2005). Although the patient recovered within eight months, this is an example of a delayed injury that may be missed at first, and the reason a detailed follow up is needed.
History of the Taser

The Taser or Thomas A Swift’s Electric Rifle was first available and used in 1974 by TASER international inc. in Scottsdale Arizona. Invented by Jack Cover, this gun uses darts and electricity to incapacitate its victims. The Taser was developed out of public interest for a less-lethal weapon used to control violent and dangerous subjects without the use of firearms (Levine, Sloane, Chan, Dunford, & Vilke, 2007). The electricity generated by the Taser is neither a direct nor an alternating current, but rather a combination of both which consists of a dampened, pulse sinusoidal wave (Levine, Sloane, Chan, Dunford, & Vilke, 2007). The Taser would appear to be considered a high voltage output with 50,000 V and a maximum current of 36 milliamps that is provided by eight AA batteries or a lithium battery pack. However, the low current prevents the device from being deadly. It does however cause instant (less than 1 second) incapacitation in 99% of cases (Jenkinson, Neeson, & Bleetman, 2006).

There are currently two models of the Taser being produced, the M26 and the X26. The M26 is an older model and currently available for private use for protection purposes. The Taser X26 is the newer model and the one used by law enforcement agencies. These models differ mainly in shape and size (Gary M. Vilke et al., 2007). The Taser gun is a handheld device with two darts in a compartment at the front of the gun. The trigger is pulled, and the darts are propelled by either a gunpowder discharge or a compressed nitrogen cylinder. The Taser deploys two harpoon-like electrode darts with connected conductive wires at a speed of 18.3 m/s and will hit a target 3-6 m away. The two darts each have a 2.9 mm needle with a fish-hook like barb at the end to help the darts stick into the skin. Once the darts strike the victim (or their clothes) they receive several short duration repetitive pulses (5-30 pulses per second) for a five second period. This high voltage, low current stimulation tetanizes the skeletal muscle while
leaving smooth and cardiac muscle unaffected, resulting in incapacitation (Ordog, Wasserberger, Schlater, & Balasubramanum, 1987). Often victims will recover from their incapacitated state quickly and may need to be shocked more than once before taken into police custody. The trigger can then be pulled again for additional five second cycles, or the barrel can be removed and the weapon applied directly to the victim with the same results.

While sounding like a weapon from a science fiction movie, the Taser is very real. This weapon is being used every day and with increasing incidence because of its effectiveness against combative individuals, especially those resisting arrest. Nearly 10,000 U.S. law enforcement agencies are using the Taser, which translates to over 225,000 officers carrying the device, and about 120,000 owned by U.S. citizens (Gary M. Vilke et al., 2007). While generally safe, Taser use has been linked to a number of reports of unusual injuries and sudden death. The Taser was first used by a police department in Florida in 1998 and has been under scrutiny for these reports almost from the beginning, including 167 cases since 1999 (Gary M. Vilke et al., 2007).
Increased Taser Use

Use of the Taser gun has increased in the U.S. as well as other parts of the world. This increase is due to the high efficacy and low injury rate associated with Tasers when compared to other law enforcement use-of-force options. Efficacy of the Taser has been shown repeatedly to be very high. Studies have shown up to a 99% efficacy rate, with most studies being in the mid to upper 90’s (Jenkinson, Neeson, & Bleetman, 2006). Also contributing to the weapons efficacy is the ability to Taser someone without the darts penetrating their clothing. The electrical waves will still cause incapacitation through six inches of clothing.

Injury rates reported by the Los Angeles Police Department showed a lower officer and subject injury rate when compared with several other use-of-force options. Among these, flashlight use resulted in the highest subject injury rate at 80%, and punches thrown by police resulted in the highest officer injury rate at 36%. For both officer and subject injury rate, Taser use had a 0% injury rate (Jenkinson, Neeson, & Bleetman, 2006). Other large cities showed the same data, with Taser use being at or near the bottom, and other use-of-force options resulting in higher injury rates. Other research showed decreases in the deployment of firearms, and an overall reduction in injury rates from police departments once they incorporated the use of Tasers. According to Jenkinson et all, at all levels of deployment, the Taser carries a lower injury rate to officers and subjects than empty handed skills, CS spray, and batons (Jenkinson, Neeson, & Bleetman, 2006).

Another study done by Ordog et al at the King/Drew Medical Center in Los Angeles compared the morbidity and mortality of those shot with a Taser to those shot with a .38 caliber police handgun. Data was collected on age, sex, race, who shot the weapon, medical diagnosis, complications of the Taser, autopsy results, method of dart removal, and any treatment given.
With Taser deployment, Ordog et al found a mean age of 28 with 95% being male. Only 39% needed paramedic escort to emergency room, others were brought in by police officers. Reasons for Taser use included bizarre and uncontrollable behavior (76%), bizarre and extremely combative behavior (40%), and bizarre and uncontrollable behavior with nudism (5%). According to this study 86% of patients had abused PCP that day and 4% had used cocaine. Injuries were seen in 38% of patients, with most coming from the violent behavior associated with PCP. The study had 3 patients arrive in the emergency department in asystole and pronounced dead. All three had high levels of PCP and went into arrest at 5, 15, and 25 minutes after coming in contact with the Taser, with no response to ACLS treatment. All darts were removed with a scalpel blade and no suturing was required. When comparing these statistics to those of the handgun, the handgun had much more severe results. The study on handguns found a 50% mortality and permanent morbidity in those that did survive the gunshot including paralysis, brain damage, and loss of limb. Ordog et al concluded that Taser guns are a much safer option than the .38 caliber handgun being used by police officers (Ordog, Wasserberger, Schlater, & Balasubramaniam, 1987).

Taser use becoming more common among police forces has led to an increase in problems associated with the weapon. Recent and unexplained deaths have been seen after application of the Taser on some individuals. These deaths being linked to Taser usage has caused an uproar among the media and an increase in bad publicity for the Taser. Strote and Hutson conducted research on Taser related deaths occurring in the U.S. between 2001 and 2005 to try and determined if these deaths were truly caused by the Taser or if there was another explanation. They found all the Taser related deaths reported over a four year period and requested autopsy reports. These reports were analyzed for patient demographics, preexisting
cardiac disease, toxicology, evidence of excited delirium, if restraints were used, and listed cause of death (Strote & Range Hutson, 2006). All available reports were men from 18 to 50 years of age. Cardiovascular disease was found in 54.1%, illegal substances in 78.4% (84% were stimulants), excited delirium in 75.7%, with Taser use being considered a potential or contributing cause of death in 27% of patients. Strote and Hutson concluded that most of the patients that were reported as being killed by a Taser may have in fact died from excited delirium or restraint related causes (Strote & Range Hutson, 2006).
Mechanism of Taser Injuries

There are three different mechanisms of injury from which a patient can be injured after being struck with a Taser. Each mechanism can cause considerable damage, and there has been cases reported of serious injury from each. Even though the Taser is considered a less lethal weapon and appears to be a much safer alternative than other forms of force, medical personnel and law enforcement officers should be aware that these weapons are still associated with injuries. A person can suffer injury from the associated fall or incapacitation, a mechanical injury from the dart itself, or an electrical injury from the tetanizing shock that is delivered.

The most common mechanism of injury seen with Taser use is caused by the fall associated with the incapacitating effect. These injuries are usually simple lacerations and abrasions. They occur when the victim falls to the ground, unable to protect themselves from impact. This can be made worse by preexisting or toxic conditions. The injuries often do not require medical treatment, usually just proper bandaging. While more serious injuries can occur, they are very uncommon, and a clinician is unlikely to experience a situation like this.

The second mechanism of injury often reported with Taser use is a mechanical injury, usually from the darts associated with Taser deployment. These harpoon-like darts are most often rather harmless. They can be removed in the emergency room without any anesthetic. The skin around the embedded dart should be pulled taught, and then the dart pulled straight out. These should be carefully removed from the skin because of the barbed end that sticks in the patient (Dobrowolski & Moore, 2005). While usually painless, these darts can cause considerable pain, and even further problems if the patient is struck in a sensitive area.

Sensitive areas for Taser darts include the neck, face, eye, and groin. While uncommon, there have been cases of these areas being struck by the Taser darts. One case reported involves
a dart stuck in and almost completely through the distal phalanx of the index finger. The dart was removed without any major complications (Dearing & Lewis, 2005).

A more serious case reported a Taser dart that penetrated the skull of a 16-year-old boy. The dart penetrated through the right forehead, and caused the child to become unconscious for nearly five minutes. The presenting complaint was a slight headache and the patient being “shaken,” but he remained neurologically intact. A CT scan showed intracranial penetration, with the tip of the dart piercing the dura and into the brain. There was no hemorrhage present, but a small area of the dura was burnt from the electric current. The dart was removed in the operating room with a complete recovery and no neurological deficits. Intracranial dart penetration requires a neurosurgical consultation (Rehman, Yonas, & Marinaro, 2007).

Another serious case of a mechanical injury associated with Taser deployment involved a patient struck in the eye. A 21 year old man was struck in the left eye by a Taser dart while resisting arrest. The patient was shocked at least twice with the dart electrode still in the eye. The dart penetrated the globe and caused a vitreous hemorrhage, entered the temporal limbus, transversed the temporal iris and lens, and exited the inferior pars plana. The patient was immediately taken to surgery for extraction under general anesthesia. Nylon sutures were used to close the cornea and sclera. Post-operatively, a retinal detachment was also found. After complete repairs, the patient’s vision returned to a visual acuity of 6/18 with normal vision being 20/20 (Chen, Richard, Murthy, & Lauer, 2006).

The third and most dangerous type of Taser related injury is caused by the electricity used to tetanize the muscles of the weapon’s target. The Taser is designed to specifically affect only the smooth muscle of the body. However, there can be certain situations in which this
electrical device can cause serious electrical injuries and even life threatening damage to the victim.

One report of electrical injury was to a 35 year old male that was struck in the face with the dart of a Taser while forcefully resisting arrest. The victim suffered blunt trauma to the right eye, and an electrical cataract to the left eye. He presented to the emergency room 6 days after the injury with decreased visual acuity in both eyes, with bruising around the right eye and minor electrical burns on the left upper eyelid. Physical and neurological exam was normal other than a 20/100 acuity and an anterior subcapsular opacity in the left eye (Seth, Abedi, Daccache, & Tsai, 2007).

Several ocular injuries involving electricity have been recorded. These findings have included eyelid injury, mydriasis, iritis, cataract, macular cysts, and optic neuritis. The cataract and linear burn across the upper eyelid are classical findings in electrical eye injuries. While the Taser has been associated with mechanical injury to the eyes caused by dart penetration, this appears to be the first case of an electrical injury from a Taser causing damage to the eye (Seth, Abedi, Daccache, & Tsai, 2007).

Another injury caused by the electrical current of the Taser can occur from violent muscle contractions seen with skeletal muscle throughout the body. One case involving the paraspinous muscles of a 38 year old police officer has been reported. The officer was in a controlled environment at an instructors training class when he received the shock from his right shoulder to his left hip. The officer was supported so he never experienced any fall, only the expected pain and diffuse muscular contractions. Afterwards, persistent severe muscle spasms to his lower back caused the officer to go to the emergency room for further evaluation. He presented with a normal physical and neurologic exam, no history of falls, and no risk factors for
pathological fractures. However, standard radiographs of the thoracic and lumbar spine showed fractures at T6 and T8 (Winslow, Bozeman, Fortner, & Alson, 2007). While this type of injury is rare, it can happen with Taser use, and medical professionals dealing with these issues need to be well aware of this type of injury.

The greatest concern of the electrical aspect of Taser use is its effect on the heart. So far, no one has been able to prove that the effects are detrimental to the heart. However, the case illustrated below may prove that Taser use can be dangerous. A 51 year old woman with an implantable cardioverter-defibrillator (ICD) was hit and shocked by a Taser. The patient was struck by one of the darts in the sternum, and her ICD immediately read this incident as Ventricular Fibrillation (VF) and began charging for a shock. The woman never received a shock because of the limited (5 second) exposure time, and lack of a reconfirmation of VF (a built in safety device) by the ICD. However, a longer exposure time (several consecutive shocks) or a shorter charging time, and a shock by the patients ICD becomes a very possible reality (Haegeli, Sterns, Adam, & Leather, 2006). Other complications that could occur in patients with implantable pacemakers are damage to the circuitry, or a reprogramming of the device. While no problems were reported in this case, it does warrant consideration of these problems in anyone with an ICD after coming in contact with a Taser.

Another study was done on a swine model to assess if dart placement would affect the ventricular fibrillation threshold. This study did show that a standard Taser discharge was not able to induce ventricular fibrillation even in the most sensitive locations. However, at an increased electrical current, ventricular fibrillation did occur more easily at positions located next to the heart. This study suggests that excessive Taser use on any person may in fact increase their chance of suffering a deadly cardiac arrhythmia (Lakkireddy et al., 2006). More
information on the effects of electricity on the heart is limited by a lack of research, and our inability to replicate the real life extenuating factors the heart goes through when hit by an electrical current similar to a Taser.
Assessment and Treatment of Taser Injuries

Now that we understand what a Taser is and how it works, we can look at how a clinician should assess a patient and how it differs from any other electrical injury. Each patient should be taken individually, as each situation will be different from the last. However, there are some basic guidelines that should be followed when a Taser victim presents in the emergency room.

The first thing that needs to be assessed when a Taser victim presents to the emergency room are their ABC’s. As with any electrical injury, we should first be worried about the airway, breathing, and circulation. These patients will often have underlying problems that have led to them being “Tasered”, such as drug use, which may affect their ability to function on their own. The patient may be touched while the darts are still attached, but stay away from the darts themselves or the area of skin between the darts. A cardiac monitor may be attached at this time to assess an initial electrocardiograph to ensure a rhythm that supports life. Only once the patient is stable should the clinician continue the following steps.

The next step involves getting a thorough history along with a physical exam. The history should include a detailed account of the events that led to the patient being struck with the Taser, as well as a good medical history. Almost all patients struck by a Taser will be able to give a history. However, if the patient is unable due to other circumstances, usually a police officer or family member should be able to help.

The physical exam should include assessment of any tissue damage along with other associated complications with specific attention to a detailed neurological and cardiac exam. At this time the patient needs to be assessed for a preexisting defibrillator or pacemaker, as this will cause an immediate increase in their risk factors, which will normally be very low. After the
baseline Electrocardiograph is done, any further cardiac monitoring is very controversial because of a lack of evidence that the Taser has any effect on cardiac muscle or rhythm.

The major problems that require medical treatment appear to be from preexisting injuries and a toxic condition usually due to PCP use or injuries sustained from the violent behavior associated with it (Ordog, Wasserberger, Schlater, & Balasubramanium, 1987). For this reason, a drug screen may be of use in determining immediate risks from a state of excited delirium.

der problems commonly seen with Taser victims and that should be assessed for include: contusions, abrasions, skin lacerations, mild rhabdomyolysis (no renal complications), testicular torsion, and miscarriage (Chen, Richard, Murthy, & Lauer, 2006). The patient also needs to be given tetanus prophylaxis unless their last booster was within five years.

If the patient is stable, the darts may now be removed if they are still attached. Always ensure the Taser is turned off before touching the darts. Generally these darts may be removed by pre-hospital care personnel, but those in sensitive areas such as neck, face, or groin should be removed in the controlled environment of the emergency room. Darts embedded in the eye or skull should remain in place and be removed by the proper specialty physician (Dobrowolski & Moore, 2005).

There are several ways to remove the darts. When a healthcare professional removes the darts, one should never pull forcefully on the dart or on the wire due to the barb at the end. One method involves pulling the skin around the dart taunt while pulling the probe straight out. Another method involves placing a 16-guage needle over the barb portion of the dart and gently backing the dart out. The third option involves numbing the skin with lidocaine, cutting down to the barb with a scalpel and removing the barb through the incision. This option provides sharp margins and the best results for healing (Koscove, 1985). The darts should be discarded into the
sharps container. Suturing is rarely needed, and infection rates are low with proper care. The wounds should be cared for and followed up the same as any other small dermal wound.
Factors Affecting the Heart

While Taser use is generally regarded as safe, concerns have been raised over possible cardiac damage and induction of dangerous dysrhythmias, as well as sudden death reported in association with its use. There have been several studies done on the effects a standard Taser has on the heart. These prior studies all come to the conclusion that this device operates at an electrical level below that of the threshold for ventricular fibrillation and no other cardiac rhythm disturbances or morphology have been identified (Levine, Sloane, Chan, Dunford, & Vilke, 2007). In fact, the only finding was a transient tachycardia that went away shortly after application. However, these tests are all severely limited, leaving several questions that are unable to be answered. All tests done on human subjects have been safe tests on healthy individuals without any variables. Factors that may increase the chance of injury to the heart include the positions of the darts, preexisting heart conditions, multiple discharges, and drug use. These variables may change the Taser from a very effective non-lethal weapon into a weapon capable of killing or severely injuring its target.

The position that the darts strike its victim is one factor that is still under debate. Human field studies have shown that the most common place for dart attachment is the posterior and anterior upper trunk regions (Lakkireddy et al., 2006). This is significant because this is where the heart is located. One study that tried to answer if this was a dangerous factor was done by Lakkireddy et al. This study used pigs to determine if there was any difference in the ventricular fibrillation threshold with different dart sites in proximity to the heart. They concluded that a standard five-second discharge is unlikely to cause ventricular fibrillation or any life threatening arrhythmias at any of the five tested sites in a normal heart. However, they did agree that in a small or thin human, a dart over the apex of the heart and one near the substernal notch could
lower the threshold for an arrhythmia. This positioning puts both darts within centimeters of the myocardium, and directs the current through the heart (Lakkireddy et al., 2006). Despite this study, there is still some concern when one or both darts strike the victim near the heart. This study only looked at one (5 second) discharge, which is often not the case. Also, there is some hesitancy in assuming the human body will act the same as the pigs, and there were no preexisting heart conditions in the swine.

Preexisting heart disease is another aspect that could impact how a Taser affects an individual. This would include any type of preexisting arrhythmias, previous myocardial infarctions, or cardiomyopathies. Also, structural diseases such as Aortic Stenosis, Aortic Regurgitation, or Mitral Stenosis may have unknown effects. All of these conditions may lead to an increased risk for a person struck by a Taser. Little research has been done on patients with these conditions, but it is believed that they would be at an increased risk for sudden arrhythmias or even sudden death. One case study by Cao et al looks at a rare event where a person with a dual chamber pacemaker was struck by a Taser. The victim showed no immediate symptoms, but presented one week later for nonspecific chest pain. Stored events from the pacemaker revealed two ventricular high rate episodes that corresponded to the exact time of Taser application (Cao, Shinbane, Gillberg, & Saxon, 2007). This raises a concern of safety when a Taser is used on an individual with a cardiac device that provides a preferential pathway to the myocardium.

The number of times a Taser is discharged is another variable that is not tested for in a standard human experiment. In human experiments this far, Taser application has been no longer than five seconds since this is the normal duration of one discharge. However, some factors can decrease the efficacy of the Taser and often require two or more discharges to subdue
a violent person. A decreased efficacy is usually seen in patients on drugs or severely intoxicated due to an increase in the person’s pain threshold. These people are still incapacitated for the five second shock, but then are able to get up and remain dangerous.

Testing of multiple or prolonged application of the Taser has only been done on animals. One study by Dennis et al exposed swine to two 40-second discharges from the Taser X26 model. The team monitored and compared blood levels and tests before and after exposure. With this prolonged exposure to the Taser, two of the swine died immediately after the discharge from ventricular fibrillation. In the remaining swine, clinically significant acid-base and cardiovascular disturbances were clearly seen (Dennis et al., 2007). This study would lead one to believe that a similar experiment involving human test subjects would show the same results, which would mean multiple Taser shocks can be very dangerous for the heart.

Another study done by Vilke et al looked at twelve lead electrocardiogram monitoring before and after voluntary exposure on humans to the Taser X26 model. This study involved healthy subjects receiving only one 5-second shock from the Taser. They were able to conclude that there were no clinically significant changes in cardiac rhythm and no ectopy. However, there was a clinically significant increase in heart rate and decrease in the PR interval after just five seconds (G. M. Vilke et al., 2008). If we are seeing a change in the electrical behavior of the heart after a normal duration, it can be assumed that the same results we saw on the swine model would carry over to this experiment. If this study had looked at a longer duration, the results might show a greater effect on the heart.

The most common factor affecting patient outcome after Taser deployment is drug use. Positive toxicology reports have been shown in up to 80% of Taser related deaths, with stimulant use accounting for 86% of these (Strote & Range Hutson, 2006). Excessive amounts of alcohol
or marijuana will often cause a person to have a decrease in pain perception and lower the
efficacy of the weapon. This can lead to additional applications in order to subdue the target. It
is also thought that stimulants such as cocaine and PCP amplify the effects of the Taser by
increasing heart rate, and even causing the person to enter a state of excited delirium. Most
victims that die after Taser application have been reported to experience this state of excited
delirium which involves decreased pain perception, increased strength, heavy perspiration, and
being warm to the touch (Manojlovic et al., 2005).

One prospective case study by Ordog et al showed 86% of patients brought to the
emergency room after Taser deployment had abused PCP within 24 hours. This study also
showed that 24% had positive ethanol levels, and 4% with recent cocaine use. The study then
went on to show that there is a possible correlation between PCP use and Taser related deaths.
There were a total of three in custody deaths reported for this study, and all three had high levels
of PCP in their serum and liver (Ordog, Wasserberger, Schlater, & Balasubramanium, 1987).
There are no studies showing PCP use to be a direct cause of Taser related deaths. However,
there are a couple of theories as to why we see this correlation. One theory is that the stimulant
drug lowers the threshold for ventricular arrhythmias that are then caused by the Taser. The
other theory is that the patient goes into a state of excited delirium from the PCP drug use that
leads to death, and the Taser exposure is just a contributory factor.

While one stimulant such as PCP has been associated with Taser related deaths, another
stimulant showed to be protective in a recent study. One study done on the effects of cocaine
intoxication on the threshold for ventricular fibrillation by Lakkireddy et al contradicts the
suspected effects of this stimulant. This study done on a swine model showed an increase in the
threshold needed to induce ventricular fibrillation, and increased the safety margin by almost two
times in the presence of cocaine (Lakkireddy et al., 2006). While this may sound unexpected, there is a very good explanation for these results. Cocaine can also be an anesthetic and will affect the electrical action on the heart. The anesthetic will stop the voltage activated sodium channels and make it more difficult to trigger a muscle contraction (Kroll, Tchou, & Upson, 2007). This study would not produce the same effects if another stimulant was used. Cocaine is special because of its ability to also act as an anesthetic.
Today, Tomorrow, and the Future

The extent of an electrical injury is directly related to the magnitude, frequency, and duration of the current and the resistance of the tissue. Knowing what we now know about electrical injury, it becomes more apparent how such a high voltage delivered to a patient at such a small current through the resistance of the skin can be a safe and effective non-lethal weapon under controlled conditions. The research shows that when used properly, there are very few incidences of injury related to Taser use. However, when complicating factors arise, the weapon’s target may be at an increased risk for injury.

There is still a lot of room for research in the field of Tasers. Human research has not surpassed a one shock test to healthy individuals. Swine models have been used, but not in great numbers, and even these most of the time stop after one Taser application. I believe an ideal study is needed to further determine the exact safety of this weapon. However, we may never be able to truly exact a real world encounter with contributing factors such as excited delirium, drugs, and multiple uses of the Taser on a victim.

Hopefully after this article the average health care worker will be able to calmly and collectively handle a situation involving a Taser, or any electrical injury. Knowing the dangers associated with electrical injury and how to treat the patient confidently will greatly improve the level of health care provided the next time an individual presents to your emergency room with a Taser injury.
References


### Table 1

<table>
<thead>
<tr>
<th>Electric Current</th>
<th>Physiological effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1mA</td>
<td>Sensation threshold: tingling</td>
</tr>
<tr>
<td>5mA</td>
<td>Sensation: Painful</td>
</tr>
<tr>
<td>10mA</td>
<td>Muscular contractions, prevents voluntary control of muscles</td>
</tr>
<tr>
<td>30mA</td>
<td>Severe Shock, Diaphragmatic Paralysis/ Respiratory Arrest</td>
</tr>
<tr>
<td>100 mA</td>
<td>Ventricular Fibrillation (especially if prolonged exposure)</td>
</tr>
<tr>
<td>2 Amps</td>
<td>Cutaneous Burns</td>
</tr>
<tr>
<td>6 Amps</td>
<td>Sustained Ventricular Contraction/ Asystole – for duration of current (possible return of NSR)</td>
</tr>
</tbody>
</table>

Abstract

Objective: Electrical injury and Taser use is not well understood among healthcare providers. This paper looks at the mechanisms, assessments, and treatments for these types of injuries, along with safety and efficacy.

Methods: The databases searched to find references for the literature include MEDLINE, PubMed, and Science Citation Index.

Results: Electrical weapons are the newest less-lethal force being used by law enforcement. Studies have shown Taser use to be an effective and safe weapon. Studies done on humans have shown that Taser use is not dangerous to the heart, and have been associated with very few serious injuries.

Conclusion: All electrical injuries are becoming more frequently seen throughout healthcare. There are many areas that require further research in order to completely determine the safety of Taser use. Studies including extenuating factors seen with Tasers in real world applications are needed to provide accurate data on the safety of this weapon.