Pain in human and non-human animals caused by electricity

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Electricity, as a commodity, is a recent and pervasive technology which is necessary for many aspects of human endeavor including livestock production. In the 1830's the discovery that a conductor passing through a magnetic field generated an electric current led to a cascade of scientific inquiry and technical developments. Modern intensive livestock production, especially poultry and swine, is possible only with a failsafe electrical power system to provide ventilation, and deliver feed and lighting in temperature-controlled buildings. Lightning, for millennia considered a potentially fatal manifestation of cosmic forces, was demystified by the characterization of static electricity (1,2). Electrical energy can also cause pain when travelling through the human body and may result in thermal injury, and cardiac and respiratory arrest (3,4).

Livestock producers frequently implement new technology or procedures prior to scientific confirmation that the new process achieves the intended outcome. For example, tail docking of dairy cows was widely adopted based on the false belief that it increased cow cleanliness (5). Some countries have responded to this adoption of untested technology as an animal welfare risk by requiring livestock equipment manufacturers to apply for and receive authorization under the national veterinary animal welfare legislation prior to the marketing of novel technology that has the potential to negatively affect livestock welfare (6).

Pain has been used as a method to alter non-human animal behavior since earliest domestication with pain tools such as the ox-goad in biblical narrative (Judges 3:31), and as a symbol of power as the flail and crook (sheep goad) of the Pharaohs. One of the earliest and most widely adopted modern pain technologies of behavioral modification in livestock production is the electric fence. An early application of lethal electric fencing was the border fence between Belgium and The Netherlands during the First World War (7). Pain caused by conducted electricity functions by directly stimulating the efferent axons of the nocioreception protective system and is not limited by the specialized pain receptors.

Animal pain has been defined as "an aversive sensory and emotional experience representing awareness by the animal of damage or threat to the integrity of its tissues. It changes the animal's physiology and behaviour to reduce or avoid the impending tissue damage, to reduce the likelihood of recurrence and to promote recovery" (8). The human or non-human animal responds to pain via everything from protective spinal reflexes to complex affective or avoidance behaviors (9). Normal pain functions to prevent avoidable tissue damage. For "normal" sources of pain such as pressure, heat, cold, puncture, and laceration, animals are equipped with specific receptors in the skin. Pain resulting from modern conducted electrical tools skirts this definition as it is pain not associated with significant tissue damage.

Livestock electric fences are designed to be nonlethal. They consist of low current (amperage) high voltage systems of around 10 000 V (10). The animal experiences an aversive sensation when the body completes the circuit from the live suspended wire to the ground (11). Although the electric current travels from the point of fence contact through the animals' body into the ground, the perception of pain is limited to the animal-fence contact point.

Electric livestock fencing, widely adopted in the late 1940's in North America, included many homemade systems that were occasionally lethal to livestock and humans. Many jurisdictions regulated electric fence manufacture and sale as a public health measure (12). Modern non-lethal electric fence systems are primarily used to contain livestock (13,14) but also effectively exclude wildlife such as white-tailed deer and feral pigs (15,16) and protect bee hives from bear predation (17). The lethal electric fence continues to be applied to contain humans in the prison-industrial complex (18,19).

Cattle quickly learn to avoid the negative experience of contact with a livestock electric fence; often within 24 hours of novel exposure and usually with less than 3 challenges (13,20). Exposure as calves will result in "trained" individuals which will not challenge recognizable electric fences even after overwintering in conventional buildings (21). The motivation of cattle to not re-experience contact with an electrical fence also allows controlled winter feeding of stored hay or other forage. Cattle will approach the "hot" wire in front of the feed source and reach over or under it to access forage; but, will not touch

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the wire even when strongly motivated by hunger (22). Cattle find electrical shock unpleasant and find increasingly powerful electric shock increasingly unpleasant (23).

Other electrical technology has been developed for the primary purpose of causing pain in human and non-human animals to control behavior. Part of the pain experience (24) results from primary afferent nociceptors, which are a group of specialized cells terminating in the skin, that signal different forms and intensity of pain to the brain (25). Electric shock was widely used in traditional aversive animal behavior studies and standardized as a scientific tool (26). In human psychiatric practice, electric shock has been used as an aversive training tool for mentally affected human animals (27).

The electric "cow trainer" was developed where tie-stall dairy cows were tethered with a chain and soft collar. Housed in long stalls, the tethered cow could back her head out of the manager to lie down. When standing with the head and neck in the manger, body position allowed for manure to fall on the lying area of the cow not in the gutter as the building was designed. A cow trainer is a horizontal electrified metal bar that is placed such that when the cow archers her back in positioning for excrement elimination, her dorsal spine at the shoulders will come into contact with the electrified bar (28). The resultant experience of electrical current flow through her body will result in the cow taking a step backward, away from the electrical contact and increase the probability of eliminating in the gutter. In North America, cow trainers were widely adopted in tie stall systems despite evidence that continuing threat of conducted electrical shock would interfere with production (29). Electrified equipment designed to control animal behavior such as the cow trainer may cause welfare problems if not designed, used, and maintained properly (30). The use of electric cow trainers in tie stall barns remains an accepted practice in Canada (31).

Hot-Shot® is a widely distributed brand of electric cattle prod in Canada. The company was started in 1939 in Savage, Minnesota, and was acquired in 2002 by Miller Manufacturing of Glencoe, Minnesota, USA (32). The company claims that in 1939, the Hot-Shot® *revolutionized the livestock handling industry as the first commercially available electric livestock prod.* The electric cattle prod has become a standard treatment in cattle research on aversion (33–36). At federal abattoirs in Canada, it is an offence to apply a goad or electrical prod to the anal, genital, or facial region of a food animal (37). Most Canadian codes of practice restrict or prohibit the use of cattle prods on livestock (38).

The patent history of the cattle prod innovation and the application of electro-shock pain technology to policing and military uses have been intertwined (39). In 1964 Hot Shot Products Co. applied and received a patent for a "Night Stick with Electric Shock Means" (40). The conformation of this tool, designed for both delivery of physical injury and conducted electric pain was directed at the military, policing and prison markets, not the livestock handler. Arguably, a human animal being goaded into "pain compliance" (41) by conducted electricity without tissue damage, is a superior outcome to being beaten into submission using the traditional night stick techniques (42). Human justice organizations, especially Amnesty International, have identified concern with the widespread adoption and abuse of the shock baton and similar devices in global use of human torture (41–46).

It has been known that electrical current could immobilize humans from clinical experience of accidental electrocution. Significant research was conducted in assuring the safety of common electrically driven hand tools. The "let-go current" refers to the maximum electricity that could pass through a human so that the human was able to let go of the conductor and not "freeze." Freezing is the general term for electro-immobilization of the muscles of the forearm or higher in situations of accidental electrocution. The flexor muscles of the forearm and hand are stronger than the extensor, conducted electricity stimulating both muscle groups causes the hand to be unable to let go. The threshold 60 Hz let-go current for humans is between 6 and 9 mA (47).

In March 1996 a strategic planning meeting of the Animal Welfare Committee and Canadian Veterinary Medical Association (CVMA) council identified livestock electro-immobilization as one of the four major priority areas for the committee for the upcoming year (48). The primary trigger for the CVMA concern with electro-immobilization was that the growing Canadian cervid industry was using it for veterinary procedures, specifically the removal of soft antler (49). This year (2016) the position statement on electro-immobilization is up for its 4th renewal. The primary concern at the time of first drafting was the pain associated with this technology (48,49). Although the exact mechanism of action of electro-immobilization was not widely known at the time, veterinary research in the early 1980's indicated the use of electro-immobilization in non-human animals was severely aversive for the animals so immobilized (50–53). In the past 20 years, electro-immobilization technology has been rejected by the cervid industry itself (54). The CVMA has not adopted a position statement on electric fences, the electric prod or cow trainers.

As the veterinary community was recommending prohibition of electro-immobilization of non-human animals, the police and military industries were investing heavily in research on less-lethal weapons. One innovation was Conducted Energy Weapons (CEW). These weapons are designed to function as a powerful pain device (electric prod) (45,55,56) or to immobilize a person (50). The different outcomes, pain only or pain with immobilization, are a function of how far apart the 2 electric contacts are on the target.

An early commercial CEW, the Taserton, US Patent 3 803 463 in 1974 (TASER® International, Scottsdale, Arizona, USA) was essentially a pain compliance device designed for use on humans. It had fixed contact electrodes less than 10 cm apart (57) delivering local pain without immobilization of the body. To achieve whole body immobilization with a CEW, the electric contact darts need to be far enough apart on the body to create an electronic field that captures a significant volume of skeletal muscle (58). With several decades research in the development, improvement and production of Conducted Energy Weapons there is now a good understanding of the physiology of electro-immobilization in mammals (59–61). Mechanically, "stun

guns" such as the TASER® fire fine wire tethered darts using compressed gas. Ideally the darts will penetrate the skin and fix in the target 40 to 50 cm apart. Skeletal muscle is activated by excitation of the afferent α-motor neurons. The α-motor neurons are very sensitive to electric fields. The majority of skeletal muscle captured in the CEW electrical field is activated indirectly via the motor neuron system (62). When captured in a CEW electric field the α-motor neurons are isolated from dorsal root ganglia moderation and the person experiencing electro-immobilization no longer has voluntary control of her body. Injury subsequent to falling to the ground is a significant risk as the person cannot extend his arms to brace for the fall (57). This risk of injury by uncontrolled fall has been creatively called "gravitational dysreflexia" (63). The intense pain associated with the human experience of CEW results from direct stimulation of the efferent nerves associated with pain detection (9).

The concept of pain in humans is complex with aspects of culture, environment, perception and central processing (64). What an individual non-human animal experiences as pain is unknowable, but presumably is in some way similar to human animal pain. Humans have episodic memory, which refers to the memory of an event as an "episode" and allows individual humans to mentally travel back in time to re-experience an event from the past. Memory of pain, however, appears to be impossible as pain is in "real time". Although humans may remember the circumstances and unpleasantness of previous painful stimulation, the pain cannot be re-experienced by remembering (65) as positive affective states can be. Attempting to convey the experience of electro-immobilization by humans, one individual describe it as "*I never want to go through it again. Trying to convey that sense of pain…is quite difficult*" (42).

Electro-immobilization is a remarkably painful experience for the human animal and presumably for non-human animals. In retrospect, it appears that the original CVMA concern and resulting position statement discouraging the use of electro-immobilization of animals was appropriate and useful at the time.

Other uses of pain technologies to modify the behavior of livestock have not been widely discussed within the profession. In a recent attempt to further clarify the concept of "cruelty," Tanner suggests there are two types of cruelty. Cruelty can be manifest as the commonly imagined sadistic event, where willful pain is caused for another's enjoyment. However, much more common are situations in which humans are indifferent to the pain of others even when brutal (66). The profession may need to re-examine the use of common pain technologies and review whether the justification is sufficient to maintain their use.

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