Mortality, morbidity, and fertility after accidental electrical shock in a swine breeding and gestation barn

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Summary

Accidental electrocution occurred in a swine breeding barn, resulting in the immediate death of two sows and requiring euthanasia of four sows in the subsequent hours and days due to injury and hind-limb paralysis. The incident occurred on December 18, 2012, while transrectal ultrasound was being performed on a group of postweaned sows (Group 1, n = 23; average parity 1.7, range 0 to 6) to be inseminated December 18 and 19, and a second group (Group 2a, n = 15; average parity 2.3, range 0 to 7) that had been inseminated December 4 to 6 (13 to 15 days post breeding). An additional group of replacement gilts (Group 2b, n = 7), also bred December 4 to 6 with the same semen, were located in another room of the barn and not exposed to the electrical discharge. Among surviving Group 1 and Group 2a animals and the unexposed Group 2b sows, electric shock, breeding group, and parity had no detectable effects on farrowing rate or number of liveborn pigs ($P > .10$; ANOVA). Electrical safety for animals and humans should be evaluated in swine barns and steps taken to minimize risk of electrocution and electric shock.

Keywords: swine, electrocution, fertility, stress, safety

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Resumen - Mortalidad, morbilidad, y fertilidad después de un choque eléctrico accidental en una granja porcina de cargas y gestación

La electrocución accidental ocurrió en una granja de hembras de cargas y gestación, repercutiendo en la muerte inmediata de dos hembras y se requirió la eutanasia de cuatro hembras en los días y horas subsecuentes debido a lesión y parálisis del cuarto trasero. El incidente ocurrió en diciembre 18, 2012, mientras se estaba realizando el ultrasonido transrectal en un grupo de hembras post destete (Grupo 1, n = 23; paridad promedio 1.7, rango 0 a 6) para ser inseminadas en diciembre 18 y 19, y un segundo grupo (Grupo 2a, n = 15; paridad promedio 2.3, rango 0 a 7) que había sido inseminado en diciembre 4 al 6 (13 a 15 días post inseminación). Un grupo adicional de hembras de reemplazo (Grupo 2b, n = 7), también se inseminaron en diciembre 4 al 6 con el mismo semen; este grupo estaba localizado en otra sala de la granja y las hembras no fueron expuestas a la descarga eléctrica. Entre los animales sobrevivientes del Grupo 1 y 2a y las hembras que no fueron expuestas del Grupo 2b, el choque eléctrico, grupo de inseminación, y la paridad no tuvieron efectos perceptibles en el porcentaje de fertilidad o número de cerdos nacidos vivos ($P > .10$; ANOVA). La seguridad eléctrica para animales y humanos debe evaluarse en estas granjas porcinas y deben tomarse medidas para minimizar el riesgo de electrocución y choque eléctrico.

Résumé - Mortalité, morbidité, et fertilité suite à un choc électrique accidentel dans une bâtisse de saillie et de gestation de porcs

Une électrocution accidentelle est survenue dans une bâtisse de reproduction d'un élevage de porcs, causant la mort immédiate de deux truies et entraînant l'euthanasie de quatre truies dans les heures et jours subséquents à cause de blessures et paralysie des membres postérieurs. L'incident est survenu le 18 décembre 2012 alors qu'un examen échographique transrectal était effectué sur un groupe de truies en période post-sevrage (Groupe 1, n = 23; parité moyenne de 1,7 avec un écart de 0 à 6) devant être inséminées les 18 et 19 décembre, et un second groupe de truies (Groupe 2a, n = 15; parité moyenne de 2,3 avec un écart de 0 à 7) ayant été inséminées entre le 4 et 6 décembre (13 à 15 jours post-saillie). Un groupe additionnel de cochettes de remplacement (Groupe 2b, n = 7), également saillies entre le 4 et 6 décembre avec la même semence, était situé dans une autre chambre à l'intérieur de la bâtisse et non exposé à la décharge électrique. Parmi les animaux des Groupes 1 et 2a qui ont survécu et les truies du groupe non-exposé 2b, le choc électrique, le groupe de reproduction, et la parité n'avaient aucun effet détectable sur le taux de mise-bas ou le nombre de porcelets nés vivant ($P > 0,10$; ANOVA). La sécurité électrique pour les animaux et les humains devrait être évaluée dans les bâtisses d'élevage de porcs et des mesures prises pour minimiser les risques d'électrocution et de choc électrique.

Livestock production, whether indoors or outside, involves risks of accidental electrocution and shock for animals and humans.[1,2] Animals are particularly susceptible, since they not only lack any form of electrical insulation on their feet, which are often wet, but also have more contact than humans with surface materials.[3] Cases of electrocution and shock have been reported in a variety of animals outdoors as

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a result of lightning strike[4-6] and exposure to accidental electrical discharge from damaged power lines.[7] Indoor livestock facilities also pose serious risk of electrocution and shock as result of lightning strike[8,9] and exposure to accidental electrical discharge.[10-12] For animals housed indoors, accidental electrocution or shock has resulted[11] from catastrophic failure in the building's electrical supply, structure, and operating systems, and from faulty or improper use of electrical equipment. However, the greatest risk of accidental electric shock in a livestock facility would appear to be from non-catastrophic events involving the inability of electrical switches, connections, and outlets to function properly because they are loose, corroded, broken, moist, or dirty. Further, livestock buildings, especially swine confinement facilities, are likely to show damage to electric wire or electric cord insulation as a result of exposure to caustic gases, moisture, temperature, and rodents. Damage to the outer plastic cover may eliminate any electrical insulation or may expose the underlying electrical insulation to fray, crack, or break away. Regardless of the cause of the electrical failure, in each case, there is an opportunity for electric current to follow an alternative path of least resistance which could lead to accidental electrocution or shock.[13] In swine confinement buildings, the risks of electrocution and shock appear to be compounded by the presence of large amounts of water and moisture, metal, corrosion, rodents, and dust and dirt.

There are also numerous reports of low voltage shock (defined by the United States Department of Agriculture as < 10 V) in livestock facilities.[13] The term for low voltage shock is stray voltage, which has been reported in dairy[13] and swine[14] facilities and is associated with minor forms of stress in animals in contact with the flow of low current through conducting materials. However, stray voltage is often difficult to detect, and although not lethal, can result in reduced comfort, and in a few instances reduced performance and health.[15,16] Serious electric shock or electrocution, on the other hand, most often involves exposure to a discharge of electricity from an electrical source above 80 V and more frequently in the 110 to 380 V range, which are commonly used throughout the world in home and industrial settings.[17] The available data suggest that the electrical current reported as perceptible by humans as an unpleasant tingling at the 1- to 4- mA level[18] is the same current associated with a proportion of animals beginning to change their behavior.[15] The severity of the electrical shock is associated with increasing voltage, amperage, and duration of exposure, as well as lowered electrical resistance (Ω) of the animal and the pathway of the current through the body.[17,18] Depending upon the conditions of electrical exposure, organ system damage may be minor and transient, severe with multi-system involvement over a lifetime, or lethal. Survival of humans following electric shock or lightning strike that results in cardio-pulmonary arrest is possible if victims receive immediate medical life-support.[18] It has been reported that exposure of humans to currents of 10 to 20 mA results in skeletal muscle tetany, and at 30 to 50 mA, thoracic muscle tetany leading to respiratory distress. At levels of 50 to 100 mA, ventricular fibrillation can occur and may be associated with cardiopulmonary arrest, whereas exposure to currents above 100 mA are generally considered lethal. It is interesting to note that in most cases involving swine, and a few involving humans, severe electric shock from exposure to electric discharge or lightning strike results in posterior paralysis associated with fractures to vertebrae and long bones. These skeletal injuries are thought to occur as a result of violent muscle contractions that create excessive force on the bones and joints.[6,8-12,18]

Although there are existing data on the occurrence of electric shock and electrocution in swine, there are no available data on subsequent fertility performance in a group of sows or gilts after electric shock. The intent of this case report is to share information on how and why an electrocution incident in a group of sows occurred and the mortality, morbidity, and fertility outcomes for the animals in the affected groups, and to report changes made in the animal facilities and how personnel were educated to help prevent another occurrence.

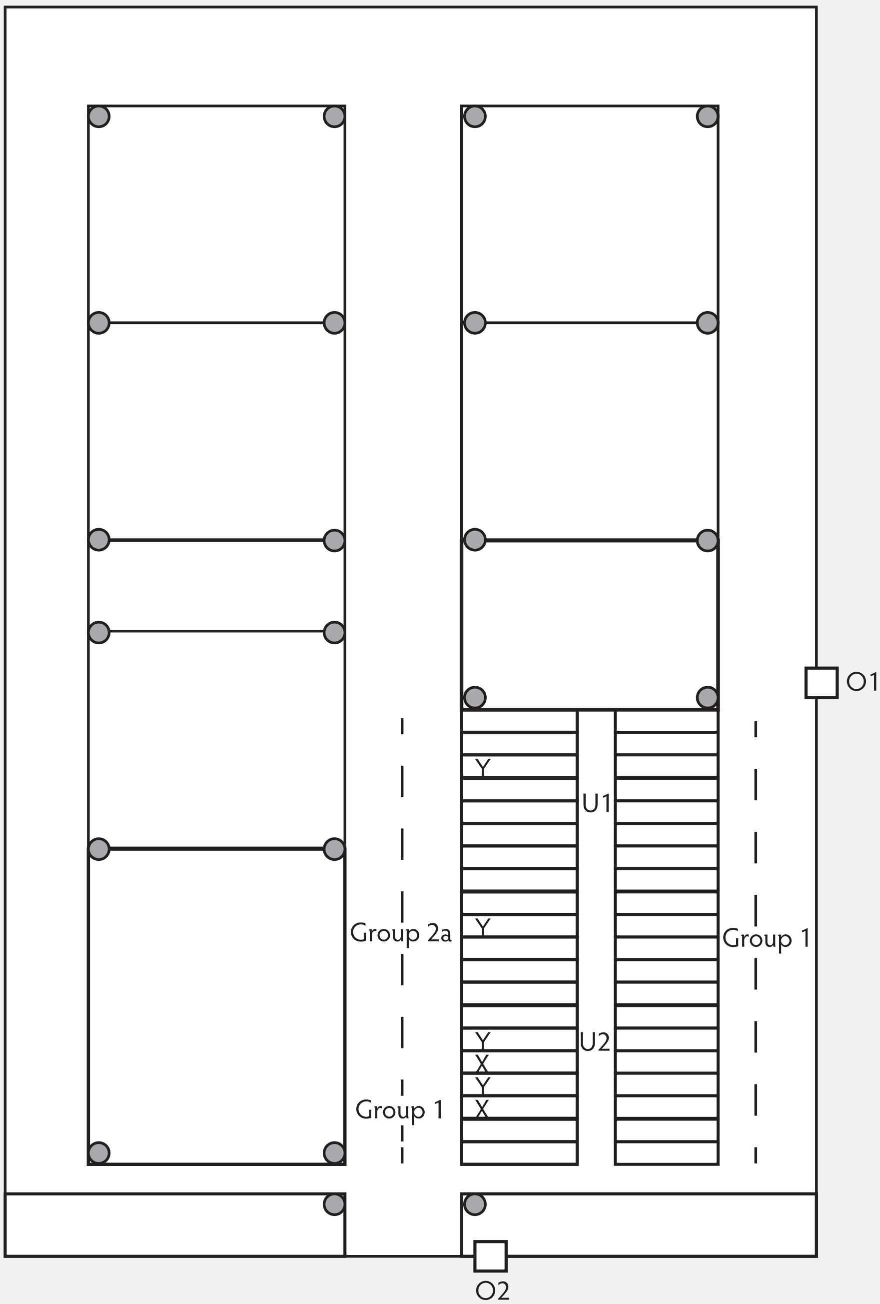
Animal shock and electrocution

On the morning of December 18, 2012, an accidental electrical shock and electrocution incident occurred, involving a group of post-weaned sows that were to be inseminated later that same day and in the subsequent days (Group 1: n = 23; average parity 1.7, range 0 to 6) and another group of sows that had been bred 13 to 15 days earlier (December 4 to 6; Group 2a: n = 15; average parity 2.3, range 0 to 7). An additional group of replacement gilts (Group 2b: n = 7), also bred 13 to 15 days earlier with the same semen as Group 2a, were located in another room of the same barn and were not exposed to the electrical discharge.

On the morning of the incident, transrectal ultrasound training was being conducted for two technicians in a 250-sow breeding and gestation facility at the University of Illinois. The animals and protocol used for the training were approved by the Institutional Care and Use Committee of the University of Illinois. The building, a confinement facility with environmental control systems, included three rooms (East, Center, and West). Approximately 60 mature sows, gilts, and boars were located in the East room where scanning was being performed (Figure 1). The 10 pens and 40 gestation stalls in the East room (36.6 × 13.4 m) were made of steel and were located over partially slatted concrete floors with steel water lines.

The ultrasound machines were located on separate carts. One machine was attached to a surge protector connected to a 16-gauge, 100-foot (30.5-m) extension cord that was plugged into the building electrical wall outlet. The other ultrasound machine was connected directly to a 16-gauge, 50-foot (15.2-m) extension cord that was plugged into a separate wall outlet. The extension cords were positioned to remain away from the sows so they could not pull or chew on them. The building had a general electric panel with 120-volt outlets and 20-amp breakers. The ultrasound machines were located in a narrow alleyway (0.46 m) behind the two rows of opposing gestation crates. The trainer was located between the two trainees and their machines. After scanning 15 animals during a 90-minute period, it was necessary to move one of the machines and adjust the extension cord to allow movement of the machine. The 100-foot cord was anchored away from the sows by a loop around one steel corner post. After resuming scanning, the machine attached to the 100-foot cord flickered and went black and then came back on and went black again. At that time, the entire room of sows jumped up simultaneously and began screaming. Until then, it had been very quiet in the facility, with most of the sows lying down and only a few drinking, eating, or standing. The noise in the room became so loud communication was impossible, and was estimated to have

Figure 1: An accidental electrocution incident occurred in two groups of sows in a 250-sow breeding and gestation barn at the University of Illinois, resulting in the immediate death of two sows (December 18, 2012). An additional four sows were euthanized in the subsequent hours and days due to injury and hind-limb paralysis. On the morning of the incident, transrectal ultrasound training was being conducted for two technicians. Each technician had an ultrasound console unit that required an electrical supply. The figure shows the general layout of the pens and stalls. The outlet boxes (O1 and O2) and ultrasound units (U1 and U2) are marked. The U1 was connected to a 100-foot (30-m) extension cord and plugged into O1; U2 was plugged into O2 with the 50-foot (15-m) cord. The electrocution incident occurred when a damaged section of the 100-foot cord contacted the steel corner post of a pen. Corner posts are indicated by solid circles. The approximate positions of the electrocuted sows (X) and those that were euthanized (Y) are marked; the locations of all Group 1 sows (bred December 18-22) and Group 2a sows (bred December 4-6) are marked with dashed lines.



exceeded 125 dB. The sows in the stalls were frantically moving while those in pens were also screaming. After approximately 10 seconds, one of the trainees unplugged the 50-foot electrical cord. However, the sows continued their behavior and the trainee ran to the outlet for the 100-foot cord, about 12.2 m away, and unplugged it. All the sows stopped screaming and moving at once. The three technicians noted that two sows (each approximately 227 kg) were unconscious and another sow appeared unable to get up and was paralyzed. Several sows had minor abrasions from the frantic movement in the stalls. The farm manager and staff were immediately alerted and the institutional veterinarian was notified.

Mortality, morbidity, and fertility report

The outcomes for the animals involved in the incident are shown in Table 1. Two sows died immediately by electrocution, and two others were euthanized later that same day due to hind-limb paralysis. Two additional animals were euthanized because of injuries and hind-limb paralysis, 1 day and 3 days after the incident, respectively. The locations of the animals in Group 1 and Group 2a and those that died and were euthanized are shown in Figure 1. All of the animals that died or were euthanized were located in the row behind those being evaluated by ultrasound.

In the weeks and months after the incident, fertility of the sows in the breeding groups was monitored. Data were analyzed by ANOVA procedures in SAS (SAS Institute Inc, Cary, North Carolina) with continuous response measures analyzed using PROC GLM and differences between least square means identified using the *t* test. Binary response measures were analyzed using PROC GENMOD and significant effects of treatment identified using the chi-square test.

Farrowing rate and liveborn data were analyzed for the main effects of electric shock, group (1, 2a, and 2b), and parity (0 to 7) using GENMOD and GLM procedures of SAS for binary and continuous response variables, respectively. Significant differences were identified at $P < .05$ and nonsignificant differences at $P > .10$.

Fertility results are shown in Table 2. The majority of the Group 1 sows were expected to be in estrus and receive their first service later the day of the electrical shock or the day after the shock. The standard farm

Table 1: Breeding dates, morbidity and mortality data, and numbers of sows housed in a breeding and gestation barn where an accidental electrocution incident occurred on December 18*

Breed group	East room	Center room	Breeding dates†	Died	Euthanized
Group 1	23	0	December 18-22	1	0
Group 2a	15	0	December 4-6	1	4
Group 2b‡	0	7	December 4-6	0	0

* The electrocution incident (described in Figure 1) involved groups of sows located in the East room of the barn and scheduled to be inseminated later that day (Group 1) or in the following days, or sows (Group 2a) and replacement gilts (Group 2b) that had been inseminated 13-15 days previously.

† All sows were inseminated twice: once at the onset of estrus (day 1) and again 24 hours later.

‡ Group 2b, a group of replacement gilts for Group 2a, were not exposed to the electrical shock.

Table 2: Fertility data from the breeding groups in a breeding and gestation barn relative to an electrocution incident*

Breed group†	Days relative to estrus‡	Sows remaining	Parity	Pregnant	Open	Farrowed	Farrowing rate (%)	Liveborn	Stillborn	Mummies
1	-4 to 1	22	1.7 ± 0.5	20	2	20	90.9	11.9 ± 0.9	0.2 ± 0.1	0.9 ± 0.2
2a	13 to 15	10	2.3 ± 0.7	9	1	8	80.0	13.3 ± 1.1	0.4 ± 0.2	1.5 ± 0.6
2b	13 to 15	7	0	6	1	6	85.7	11.2 ± 1.3	0.2 ± 0.2	0.8 ± 0.4

* Electrocution incident described in Figure 1. Breeding data described in Table 1. Mean and standard error reported for parity and numbers of liveborn and stillborn piglets and mummies.

† Group 1 and Group 2a were housed in the East room and were involved in the electrical shock incident. Group 2b were replacement gilts for Group 2a, housed in the Center room of the same building and not affected by the electrical shock incident. Farrowing rate and liveborn data were analyzed by ANOVA for the main effects of electric shock, group (1, 2a, and 2b), and parity (0 to 7). There were no effects of exposure to electric shock, group, or parity on measures of farrowing rate or liveborn pigs ($P > .10$). Significant differences were identified at $P < .05$ and nonsignificant differences at $P > .10$.

‡ All sows were inseminated twice, once at the onset of estrus (day 1) and again 24 hours later.

breeding protocol was to inseminate all females twice, once on the first day of estrus (day 1) and again the next day if still standing. All Group 1 animals were located in the East room. Of the surviving animals in Group 1, 90.9% of bred sows farrowed, producing an average of 11.7 pigs born alive. Breeding Group 2a sows, also located in the East room, were at day 13 to 15 of gestation, the time of embryo signaling and start of implantation. Of the surviving Group 2a females, 80.0% farrowed, producing an average of 13.3 pigs born alive. The replacement gilts for Group 2b, housed in the Center room and not exposed to the electrical discharge, had an 85.7% farrowing rate with an average of 11.2 pigs born alive. The structure of the groups and location within the facility allowed some comparison among groups for fertility, since the replacement gilts for Group 2b were housed in the Center room, which was unaffected by the electrical surge. Group 2b gilts were mated at the same time, at same location, and with the same semen as the Group 2a females, but were relocated in the next week due to the need for space in the breeding row. For the same reason, three Group 1 sows were moved into the center row. There were no effects of electric shock, group, or parity on any measure of reproductive performance ($P > .10$). Data from 23 groups that farrowed during January through November 2012 were not included in the analysis but were obtained for use in qualitative comparison. The overall farrowing rate during the 11 months before the incident was 80.1%, with 11.7 born alive for sows, and 78.6%, with 11.9 born alive for the replacement gilts.

Investigation into the incident

Inspection of the electrical cords by a farm staff member revealed a 1.3-cm section of exposed wire on the 100-foot cord where it had been looped around the steel post, and investigation into the incident identified this as the cause of the electrocution incident. An image of the cord (Figure 2) revealed that the damage likely resulted when a rodent chewed on the extension cord at that single location. There were no other areas of damage. The surge of electricity occurred when the damaged cord was re-adjusted to allow movement of the ultrasound machine, and the exposed wires directly contacted the steel corner post. The flow of current appeared to have followed the path of the conducting metal in the room. The behavior of the sows suggested that most of those in the stalls were affected and perhaps many of those in the pens as well. It is possible that the more severely affected sows had been drinking or in contact with water on the concrete floor at the time of the incident. This would have resulted in electrocution for some and painful shocks for the others. None of the trainees in contact with the stalls or concrete noted any shock, which was likely due to grounding by rubber boots and rubber-soled shoes.

A subsequent investigation was initiated by the Institutional Animal Care and Use Committee of the University of Illinois, and reports were submitted to the committee. Committee review identified the incident

Figure 2: An electrocution incident and layout of the breeding and gestation barn where the incident occurred are described in Figure 1. The damaged area of the 100-foot extension cord is shown. This type of damage suggested that rodents had chewed the cord's outer insulation, allowing the flow of current through the metal of the pens and stalls.

as an accident. However, from this incident, concerns arose about the safety issues involving electricity in the livestock facilities and within the departmental laboratories.

A mandatory educational session was held for all departmental employees to inform faculty, staff, and students who worked at the farms or within the departmental laboratories about the incident and electrical safety. The education session relayed the sequence of events that resulted in the deaths and euthanasia of the sows at the farm. It also identified the risks posed by extension-cord damage when cords are stored unprotected on the floor. For safety reasons, all extension cords were required to be protected from potential rodent damage and inspected before use. In the initial period after the incident, the Department of Animal Sciences required that all extension cords at the farms be 12-gauge and attached to a plug-in ground fault interrupter (GFI) adapter until the electrical systems could be evaluated. In the interim period before the mandatory training session, the training staff visited farm facilities and laboratories in the department and documented various potentially dangerous electrical conditions using digital pictures that were shared during the training session. In several cases, entire electrical cords or just sections of electrical cords were found lying unprotected on the ground, whether in or out of use. There were also several instances where excessive numbers of plugs were used per outlet, and electrical outlets and plugs were too close to a water supply. In the subsequent month, wired-in GFI units were installed in all receptacles at the farms.

Discussion

The results of this incident, although limited in observations, indicated that electrical shock at the time of breeding and at the time of implantation had no discernable effects on pregnancy establishment, farrowing rate, or litter size. This may not be surprising, since other studies have also shown that exposure of pigs to short-term stressors appears to have limited effects on reproduction,[7] even when induced by mild electric shock during estrus.[8] Although, to the knowledge of the authors, there are no published reports of the effects of electrical shock to swine at the time of implantation, most studies have failed to show any obvious negative effects of stress on fertility in response to mixing sows or gilts in groups.[10]

Much of what is known about electric shock and electrocution comes from human forensic and emergency-medicine reports, as well as veterinary reports involving postmortem examination of animals that were dead or euthanized due to paralysis. In humans, currents greater than 10 mA are capable of causing painful to severe shock, while those between 100 and 200 mA are lethal. With currents in the 10-mA to 20-mA range, muscular contractions can be strong enough to make breathing difficult. If the electrical current approaches 100 mA, ventricular fibrillation of the heart occurs, resulting in death. The resistance of the body may vary depending upon the points of electrical contact and whether the skin is wet or dry and may be $\leq$ 1000 Ω for wet skin to > 500,000 Ω for dry skin.[11] Neither the current the animals in the present report were exposed to nor their electrical resistance is known. It is likely that both the current and resistance varied from animal to animal, depending upon their location and contact with water. However, we do know that the outlet voltage was 120 V and it is likely the total duration of electrical shock was 15 to 20 seconds. If we estimate the conditions for exposure to the electrical current on the basis of animal electrical resistance to a fixed voltage using the equation $I = 120\ V \div R$ (where I is current in amps, V is voltage in volts, and R is resistance in ohms [Ω]), then animals with dry skin (250,000 Ω) would have been exposed to a current of < 1 mA. However, exposure of sows in contact with some moisture (10,000 Ω) may have been 12 mA or more, resulting in painful shocks as they touched metal surfaces on the sides, front, and back of the crates and pens. For animals that were wet or in contact with water, electrical resistance was lower (1000 Ω). Their exposure may have been $\geq$ 120 mA for 20 seconds and would have been severe enough to cause electrocution. The conditions that resulted in severe electric shock in four sows with posterior paralysis are uncertain, but may have resulted from a current flow at or just below that identified as lethal for a shorter period of time than in the sows that were electrocuted. Similar to the causes of death by electrocution noted for humans, previous reports in cases of electrocution in swine have indicated that death occurs primarily from cardiac or respiratory disruption. In cases where electric shock results in immobility and hind-leg paralysis, lesions were identified with fractures of the lumbosacral vertebrae, pelvis, and neck of the femur.[5,6]

The use of electrical cords and extension cords is common in livestock facilities, and with the risk of cord damage by any number of causes, it may be prudent to limit the length of the cord used when possible, to evaluate the cords often, and to protect the cords as much as possible. The use of heavier gauge extension cords may help to reduce the risk of damage in some cases, but damage to extension cords of any size can occur. The issue of a working GFI is important, and while re-wiring entire facilities can be expensive, plug-in GFI adapters can be used in line with extension cords. It should be noted that in this case, the personnel in the barn were also likely susceptible to shock, but were protected because all were wearing rubber-soled shoes or boots.

Implications

- Electrical cords are subject to damage and should be protected and inspected regularly.
- GFI systems should be checked for operation periodically.
- Personnel in barns should wear rubber-soled boots or shoes to aid in prevention of electrical shock and electrocution.
- Recognizing exposure to a dangerous electrical discharge in a swine facility can be characterized by unexpected loud vocalization of sows with frantic movement in stalls.

Conflict of interest

None reported.

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