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Publisher *Taylor & Francis*

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Journal of Agromedicine

Publication details, including instructions for authors and subscription information:

<http://www.informaworld.com/smpp/title~content=t792303961>

Livestock Handling—Minimizing Worker Injuries

Ricky L. Langley^a; W.E. Morgan Morrow^b

^a North Carolina Department of Health and Human Services, Division of Public Health, Raleigh, North Carolina, USA ^b Department of Animal Sciences, North Carolina State University, Raleigh, North Carolina, USA

Online publication date: 27 July 2010

To cite this Article Langley, Ricky L. and Morrow, W.E. Morgan(2010) 'Livestock Handling—Minimizing Worker Injuries', *Journal of Agromedicine*, 15: 3, 226 — 235

To link to this Article: DOI: 10.1080/1059924X.2010.486327

URL: <http://dx.doi.org/10.1080/1059924X.2010.486327>

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ASHCA/NIOSH CONFERENCE: PANEL PRESENTATION

Livestock Handling—Minimizing Worker Injuries

Ricky L. Langley, MD, MPH
W.E. Morgan Morrow, PhD

ABSTRACT. Numerous hazards may occur on farms raising livestock. Animal contact is often ranked as the first or second leading cause of injuries on the farm. In addition to direct trauma from the animal, other injuries may occur from injection of medications, chemical splashes from cleaning the facility, and repetitive motion injuries. Exposures to toxic gases from decomposition of animal waste such as in manure pits and exposure to animal allergens may cause adverse health effects in humans. One additional consideration is the risk of developing various zoonotic infections. Human injuries happen more often when people are handling animals than during any other activity performed in pork production. The National Pork Board of the United States, in response to a request from pork producers, has developed a program designed to improve worker safety, pig welfare, and pork quality when pigs are moved for whatever reason. The objective of the Transport Quality Assurance™ (TQA) program is to help all those who transport, produce, or handle swine to do so in a way that is optimal for the pigs' well-being, the health of the handler, and to improve the quality of the pork produced. Understanding basic pig behavior, proper handling practices, and using proper handling equipment will help animal handling be a safe activity. This paper was prepared for the Agricultural Safety and Health Council of America/National Institute of Occupational Safety and Health Conference, "Be Safe, Be Profitable: Protecting Workers in Agriculture," January 27–28, 2010, Dallas/Fort Worth, Texas.

KEYWORDS. Animal handling, animal-related injury, farming, livestock, trauma, transportation, zoonoses

INTRODUCTION

The 2007 United States Department of Agriculture (USDA) Census of Agriculture estimated the number of farms in the United States

at approximately 2.2 million.¹ The Census found that the number of cattle operations totaled 956,400, including 757,000 beef cow and 67,000 milk cow operations. The number of hog operations totaled 73,150, sheep operations

Ricky L. Langley is affiliated with the North Carolina Department of Health and Human Services, Division of Public Health, Raleigh, North Carolina, USA.

W.E. Morgan Morrow is affiliated with the Department of Animal Sciences, North Carolina State University, Raleigh, North Carolina, USA.

Address correspondence to: Ricky L. Langley, MD, MPH, North Carolina Department of Health and Human Services, Division of Public Health, 1912 Mail Service Center, Raleigh NC 27699-1912, USA (E-mail: rick.langley@dhhs.nc.gov).

82,330, goat operations 149,800, and farms with any poultry 187,000. There are 575,900 farms with horses and 99,000 farms with mules/donkeys/burros.²

As of July 1, 2009, there were approximately 102 million head of cattle and calves, 67 million hogs and pigs, 7 million sheep and lambs, and 3.7 million goats on farms in the United States.³ In 2007, there were 266 million turkeys and 9 billion broilers produced.² The USDA estimated in 2007 that there were 4,028,000 horses and ponies and 283,000 mules/burrows/donkeys on US farms. The American Horse Council estimated there were 9.2 million horses involved in farming, sports, entertainment, and recreational activities in the United States in 2005.⁴

The weight of farm mammals varies from less than a few pounds in newborns to over 3000 pounds in adult bulls. Animals can cause serious injuries to animal handlers through various mechanisms. Farm animals can bite, kick, gore, trample, fall on, step on, knock down, crush or pin between other animals or farm structures, peck, scratch, throw or buck off, drag, and ram or butt.

Livestock handlers are involved in a variety of activities such as feeding, moving animals to different locations, loading animals on trucks/trailers, artificial insemination, shearing, grooming, basic animal care such as hoof care, dehorning, and cleaning animals, roping animals, applying topical insecticides, giving vaccinations, applying topical or administering oral medications, castrating, pulling teeth, ear tagging, milking, branding, shoeing, assisting with delivery of newborns, and assisting veterinarians with treatment or handling of injured animals. Other activities involving animals may include work tasks such as plowing fields; pulling equipment such as wagons to transport farm goods; riding animals, primarily horses, for farm or ranch activities such as corralling cattle; teaching others to ride; butchering animals for food; and, rarely, euthanizing or destroying sick or aggressive animals.

Unfortunately, the number of animal handlers is not exactly known, but tens of thousands of people are exposed daily to farm animals. A recent survey estimated that there

were at least 54,000 workers on swine and poultry establishments in the United States.⁵

Numerous hazards exist on poultry and livestock farms. However, most of the information in the recent medical literature has primarily focused on respiratory symptoms in pork production facilities, and injuries primarily involving cattle and horses, especially recreational activities with horses. There is very little published on injuries associated with handling swine or sheep/goats or other farm animals.

TRENDS AMONG EXPOSED POPULATIONS

Several studies have been published on livestock/poultry farms evaluating exposures to indoor air in animal facilities and identifying tasks that increase the risks of animal-related injuries to farm workers. Although there have been a few national surveys of injuries to farm workers, most studies that have evaluated particular tasks that may put the worker at risk when handling an animal have been limited to local or regional surveys.

In a survey of US farm operations 1993–1995, the National Institute for Occupational Safety and Health (NIOSH) found that livestock was the number two cause of nonfatal injuries (99,310 injuries), almost the same as machinery, which was the number one cause of injuries (99,402 injuries).^{6,7} The rate of nonfatal occupational injuries from 1993 to 1995 was 7 per 100 workers on livestock farms, and cattle/hog/sheep operations had the highest number of injuries by type of farm operation.^{6,7} Of the injuries, 37% were due to horses and 31% due to cattle.

NIOSH also conducted another national survey of farms in 1995 and estimated that there were 195,825 lost work-time injuries.⁸ The major source of injuries on US farming operations were machinery excluding tractor (21.3%), livestock (20%), and slips, trips, and falls on working surfaces (8.5%). Beef, hog, or sheep operations were found to have the highest number of lost work-time injuries (84,736) and restricted workdays (1,869,561). When looking at activities in which workers were injured,

45.7% involved livestock handling. When looking at restricted workdays by source of injury, livestock were responsible for the largest percent (34.9%), followed by machinery.

Austin studied nonvenomous animal related fatalities in the workplace 1992–1994.⁹ She found that about 40 deaths per year occur, and 27 of these occur in farmers. Of 144 deaths obtained using the US Department of Labor (US DOL) Census of Fatal Occupational Injuries (CFOI), there were 22 transportation fatalities involving animals. Of the 122 nontransportation deaths, 68 were due to cattle and 41 from horses, and 13 from other animals. Bulls caused 54% of the cattle related deaths. Of workers that were farmers, cattle caused 54 deaths and horses caused 27 deaths. Of the deaths from cattle, 40% were due to multiorgan trauma, 35% trauma to trunk and chest, and 18% from head trauma. Of the horse-related deaths, 46% were due to head trauma.

Drudi studied occupational injuries due to animals from 1992 to 1997 using the US DOL Census of Fatal Occupational Injuries and the Surveillance of Occupational Injuries and Illnesses (SOII) databases.¹⁰ He found there were 4600 bovine-related, 5100 equine-related, and 1900 porcine-related nonfatal occupational injuries reported over this time period. For these nonfatal injuries, it should be noted that self-employed and farms with less than 11 employees were excluded from the SOII. From CFOI information, of the 375 occupational deaths from animals, cattle caused 141 deaths and equine 104. Fewer than 5 deaths were reported from sheep and swine. On average about 30 deaths per year were from cattle and equine. Bulls, which account for only 2% of cattle, were responsible for 48% of the deaths from cattle. Five deaths were reported to farmers that were related to birthing or maternal defensiveness, such as cows attacking farmers trying to midwife them. Cattle attacks accounted for four fifths of the cattle-related deaths and about three fifths of cattle-related nonfatal injuries involved the worker being attacked by cattle. Likewise about half of the deaths from equine were due to attacks and more than half of the cases of nonfatal injuries from equine involved an attack.

In a follow-up study using CFOI data, Meyer evaluated fatal occupational injuries to farmers 55 years and older for the period 1995–2002.¹¹ He found of 190 farm fatalities due to assaults from animals, 113 occurred in older workers (5% of the work-related deaths in older farmers). The median age of workers assaulted by an animal was 62 years, 4 to 6 years older than the average farmer age of 56 to 58 years. Fifty-nine percent of the deaths were from cattle.

A national study of youth on farms (younger than 20 years of age) was conducted in 1998. Approximately 1,260,000 youth under age 20 lived on farms. An estimated 32,808 injuries occurred with about 20% being due to animals. Of the animal-related injuries, 41% occurred in youth <10 years old, 29% in those 10–15 years old, and 30% in those 16–19 year olds.¹² Seventy percent of the animal-related injuries occurred to farm residents and 69% were work related. In a survey of youth on racial minority farms and Hispanic farms, horses accounted for the second highest number and rate of nonfatal injuries, followed by all terrain vehicles (ATVs) and tractors.¹³

NIOSH also conducted a national survey of injuries in farmers age 20 and older in 2001 and 2004. From the information collected, Myers et al. looked at injuries in a subgroup of farmers 55 years and older.¹⁴ Workers 20 to 54 years old had an injury rate of 5.8 per 100 compared to 5.3 per 100 in workers 55 and older, but the older farmers had more severe injuries and a fatality rate 2.6 times greater than farm workers <55 years old. They found that 10% of nonfatal injuries in older farmers were due to animals. Animals were the third leading mechanism of death in older farmers behind tractors (46%) and trucks (7%), with 5% of fatalities due to animals.

The most comprehensive evaluation of bull-related injuries on persons or property was recently completed, finding 287 cases using different databases.¹⁵ The majority of reports were from 1980 to 2008. Of the 261 cases involving attacks on people, 57% resulted in a fatality. Of the fatal injuries, 94% were males. The average age of the victim was 56 years with a range from 3 to 91 years. The nature of the injury was classified as follows: unspecified attack (110

cases); charged (49 cases); gored (21 cases); trampled (15 cases); mauled (11 cases); and other (56 cases). The type of injuries reported appeared to be related to the nature of the attack. When a person was charged by a bull, the injury usually involved broken ribs, puncture wounds due to goring, or blunt force chest trauma. When the victim was trampled, the injuries usually involved broken bones, crushing-type injuries, internal injuries, or head injuries. The authors concluded that a bull that shows aggressive behavior should be culled from the herd and sent to slaughter and not sold at a general livestock auction in order to prevent it from posing a risk to a new owner.

Although few national surveys of farm-related injuries have been conducted, there have been many local or regional surveys that have looked at risk to farm animal handlers.^{16–28} Most of the studies show that livestock handling activities are the second or third leading cause of injuries on the farm, causing from 12% to 24% of farm injuries. It is estimated that about 30 farmers are killed each year from contact with farm animals, primarily horses and cattle.⁹ Dairy bulls may be more likely to injure humans than beef bulls. Dairy bulls generally have more frequent contact with humans than do beef cattle, and are known to be possessive of their herd and occasionally disrupt routine feeding, cleaning, and milking operations.²⁶

Zoonotic Infections from Livestock and Poultry

Zoonoses are defined as diseases that can be naturally transmitted from animals to humans and from humans to animals. Zoonotic diseases may be acquired or spread in a variety of ways: through the air (aerosol), by direct contact, by contact with an inanimate object that harbors the disease (fomite transmission), by oral ingestion, and by vector transmission. A study of known infections in humans found that there were 1415 different species of microorganisms reported to have caused disease in man.²⁹ Of this number, 868 (61%) are known to be zoonotic. Of the 175 recently described emerging infections, 75% are zoonotic. Fortunately,

the number of zoonotic infections in livestock, especially in the United States, is much less. But we must remain vigilant, especially for imported agents. Table 1 shows many zoonotic infections that have been reported in livestock and poultry.^{30–34} Examples of recently emerging infections in poultry and livestock include avian influenza, hendra virus, nipah virus, menangle virus, hepatitis E, methicillin-resistant *Staphylococcus aureus* (MRSA), and West Nile virus. Recently an Ebola virus has been found to infect swine in the Philippines and workers have seroconverted, but fortunately none became ill from this strain of Ebola.

Several methods to prevent zoonotic infections have been recommended by the National Association of State Public Health Veterinarians Veterinary Infection Control Committee (NASPHV).³⁵ These include the following: vaccinate animals against zoonotic diseases, vaccinate farmers who work with livestock, wear personal protective equipment such as gloves and outer garments when treating ill animals, properly dispose of infectious tissues and dead animals, clean contaminated surfaces and equipment, control vectors through proper use of pesticides, practice good hand hygiene, use physical restraints on animals to prevent bites and other injuries, use insect repellents when working outdoors, and never drink raw milk.

NEEDLE STICKS IN FARM WORKERS

Needle stick injuries are not uncommon in animal handlers.^{36–38} Very little research has been done on needle sticks in farmers, but there are several studies that have looked at needle sticks in veterinarians. Some vaccines contain live bacteria and infection has occurred in the person who was accidentally injected. Some cases of sterile abscess formation and even tissue necrosis have developed after unintentional vaccine injections, especially ones with oil-based adjuvants. Deaths have even occurred from accidental injections of medications such as Milcotil 300 (tilmicosin phosphate).²⁷

Injuries from needles sticks can be prevented by following the recommendations of the NASPHV and others.^{35,36}

TABLE 1. Zoonotic Diseases Associated With Livestock and Poultry

Disease	Cattle	Sheep/goats	Swine	Poultry	Transmission ^a	Target organs ^b
Bacteria						
<i>Actinobacillus</i> infection	+	+	+		C	C
Brucellosis	+	+		+	C, I, R	S, N, Re
Campylobacteriosis			+	+	I	G
Dermatophilus	+	+	+		C	D
Erysipeloid	+		+	+	C	D, C
<i>E. colibacillosis</i>	+				I	G, U
Glanders	+				R, C, I	D, R
Leptospirosis	+		+		C, I	U, S
Listeriosis	+	+		+	I	S, N
Melioidosis	+				C, R, I	D, R, S
Mycobacteria	+		+	+	R, I	R, D
Ornithosis/Psittacosis	+	+		+	R	R
Pasteurellosis	+	+	+	+	C, R	D, R
Q fever	+	+			R, A	R, C, F, G, Re
Salmonellosis	+	+	+	+	I	G
Streptococcal infection	+		+		C	D
Tetanus	+				C	N
Tularemia		+	+		C, I, A, R	R, G, D, O, S
Yersiniosis	+	+	+		I	G
Parasite						
Amebiasis			+		I	G
Babesiosis	+				A	H
Cryptosporidiosis	+				I	G
Cysticercosis	+		+		I	N, D
Echinococcosis	+	+	+		I	G
Giardiasis	+				I	G
Mange	+	+			A	D
Sarcocystiasis	+	+	+		I	M, G
Strongyloidiasis		+	+		C	G, D
Trichinosis			+		I	M, D, O
Trypanosomiasis, African	+	+			A	N
Virus						
Contagious ecthyma		+			C	D
Cowpox	+				C	D
Ebola			+		C	Sc ^c
Exotic Newcastle disease				+	C	O
Foot and mouth disease	+	+	+		C, I	D
Influenza			+	+	R, C	R, G
Louping ill	+	+			A	N
Menangle			+		C	F, D
Nipah encephalitis			+		C	N, R
Orf		+			C	D
Psuedocowpox	+				C	D
Rabies	+	+	+		C	N
Rift Valley fever	+	+			A	N
Vesicular stomatitis	+		+		C	D, F
Viral encephalitis WEE, EEE				+	A	N

(Continued)

TABLE 1. (Continued)

Disease	Cattle	Sheep/goats	Swine	Poultry	Transmission ^a	Target organs ^b
Fungi						
Histoplasmosis				+	R	R, S
Rhinosporidiosis	+				C	D, R
Ringworm	+	+	+		C	D
Prion						
Bovine spongiform encephalopathy	+				I	N

^aTransmission: I = ingestion; C = contact; R = inhalation; A = arthropod.

^bOrgans affected: C = cardiovascular; D = dermal; F = flu-like illness; G = gastrointestinal; H = hematological; M = musculoskeletal; N = neurological; O = ocular; Re = reproductive; R = respiratory; S = septicemia; Sc = seroconversion; U = urologic.

^cThe strain of Ebola virus that causes severe illness and high mortality in primates and humans is different than the strain reported to cause illness in pigs.

- Read the package insert, label, and material safety data sheet (MSDS) for any medications administered, and use the product only as directed on the package or as directed by your veterinarian.
- Never remove needle caps by using your mouth.
- Do not recap needles except in rare instances when required as part of a medical procedure or protocol.
- Dispose of all sharps in designated puncture-proof sharps containers.
- Dispose of the used syringe with attached needle in the sharps container when injecting live vaccines or aspirating body fluids. For most other veterinary procedures, use the needle removal device on the sharps container and dispose of the syringe in the regular trash.
- Sharps containers should be located in every area of the workplace where sharps are used.
- Do not transfer sharps from one container to another.
- Devices that cut needles prior to disposal should not be used because they increase the potential for aerosolization of the contents.
- Never dispose of sharps in the regular trash.
- Work with your veterinarian to determine how often you should change needles.
- Don't place your hands between the animal and the side of the stall when injecting drugs.
- Don't carry a syringe and needle in your pocket.

- Don't use damaged or bent needles.
- Develop, communicate, and enforce standard operating procedures for safe sharps handling.
- Make sure employees are trained on hazards of handling drugs, hormones, and vaccines.
- Develop a policy for reporting, medical evaluation, and documentation of each needle stick injury.

OTHER HEALTH AND SAFETY HAZARDS ON LIVESTOCK AND POULTRY OPERATIONS

There are numerous hazards besides animal contact that present a risk to livestock handlers on the farm or ranch. As previously noted, most fatal injuries are due to machinery and equipment. Tractors, augers, and other feeding equipment are frequent sources of injuries. Trucks and trailers used to move livestock may be involved in traffic accidents. Injuries from corral gates, either from the animal kicking the gate that strikes the worker or from other contact with gates, caused 4% of compensation claims in livestock handlers in Colorado.²⁸ Injuries were also associated with contact with milking units, milking rail, walls, squeeze chute, and even a hose.

Falls and slips on farms and ranches from slippery surfaces or stepping in holes or uneven surfaces are often recorded as being in the top

three leading causes of farm injuries. Strains from heavy lifting caused 13% to 21% of the claims among dairy farm workers, cattle raisers and dealers in Colorado.²⁸

Waller evaluated dairy farmers and the various sources/activities that led to their injuries.¹⁹ Of 147 injuries, 29% were due to cattle but other causes included equipment repair/use 7.5%, chemicals/biologics 7%, hay/haying 6%, tractors 6%, slip/trip/fall same level 5%, foreign body in eye 5%, bumped fixed object 4%, pitchfork 3%, fall from height 3%, and miscellaneous 5%.

Asphyxiation from oxygen deficient environments may occur when farmers enter manure pits or silos. Meyer found 73 fatalities among farm workers due to oxygen-deficient exposures from 1995 to 2002.¹¹ He also detected 157 electrocutions among farm workers.

Exposure to noise on farms is common. Noise levels may be especially high when feeding animals in confinement facilities or working around older equipment. In a study of dairy farmers, Marvel et al. found that 65% had hearing loss in the higher frequencies and 37% had loss in the mid-frequency range as compared to 37% and 12% of nonfarmers respectively.⁴⁰ An inability to hear warning noises indicating changes in animal activity may lead to an increase in injury risk.²¹

Musculoskeletal complaints, especially of the neck, shoulders, wrist and hand, and elbows are common in animal handlers. Nonnenmann et al. found that 75% of dairy farmers had musculoskeletal symptoms during a 12 month period.⁴⁰ Activities highly associated with development of symptoms included manually feeding animals, tractor use, manually cleaning animal stalls, and milking animals. Langley has reviewed other environmental hazards involved in various aspects of animal handling, including weather extremes and driving hazards.⁴¹

Although injuries from chemical use on farms are not uncommonly reported, thousands of tons of various chemicals and fertilizers are used on farms, creating risk not only to the handler but also to farm family members, farm animals, and the environment. In recent surveys on use of insecticides on dairy cattle, swine,

and sheep reported by the USDA, 174,000 pounds of insecticides was applied to cattle (59% for fly control, 23% for lice, 9% for mange/mites, and 9% other). An additional 149,100 pounds was applied to the dairy cattle facility. For swine, 22,856 pounds of insecticide was applied (53% for mange/mites, 27% for lice, and 10% for fly control). An additional 13,000 pounds was applied to the swine facility. For sheep, 14,191 pounds of insecticides was applied to the animals and about 5000 pounds to animal facilities. These surveys did not include all states but did account for the majority of animals raised.⁴² There are thousands of pounds of herbicides also used on farms that may potentially cause adverse effects if not handled properly.

RESEARCH ANALYSIS

The majority of studies find that activities involved in livestock handling are a leading cause of injury on the farm and that contact with animals causes 12% to 25% of injuries. Various researchers have found factors that may increase the risk of incurring an injury in livestock handlers. Among the risk factors found are presence of hearing loss or joint problems,^{16,21} working more hours per day or week,^{16,20} younger age,^{16,18,21} older age,^{22,23} alcohol consumption,¹⁸ male sex,^{22,23} and prescription drug use.²²

CURRENT INITIATIVES

Education is a key component to prevent injuries and illnesses in the livestock industry. Frequent staff turnover means that training new employees may be needed several times a year. Employees in livestock operations need to be trained on such issues as proper animal handling, including animal welfare concerns, correct methods to employ during animal loading and transportation, proper use of personal protective equipment, and proper use of antibiotics, pesticides, and other chemicals. Employees also need to be trained on hazards of confined spaces, weather extremes, and proper cleaning

and first-aid of any injury that occurs. Workers should be instructed to report to their supervisor any on-the-job injury or illness that may affect their health or the health of the animal herd. Use of vaccines, such as influenza vaccine, to prevent spread of disease to coworkers or to animals should also be a component of a worker health and safety program. Organizations such as the National Pork Board have developed Web sites with information on worker health and safety.⁴³

Proper design of animal facilities may relieve animal stress and make movement of animals easier. Properly designed facilities should also reduce injuries from slippery uneven surfaces. Dr. Temple Grandin has developed plans for animal facility construction that incorporates basic animal behavior issues.⁴⁴

The National Ag Safety Database (NASD) maintained by NIOSH has collected a vast number of resources on safety while working with animals.⁴⁵ The majority of the information has been supplied by various state Cooperative Extension Services.

INDUSTRY RESPONSE TO THE ISSUE

There is widespread awareness in the swine industry of injuries resulting from a range of agents, including accidental injection with a variety of drugs, cuts, bruises, partial deafness from exposure to loud noises, and being hit, crushed, stepped on, or otherwise impacted by pigs. In the field, handlers learn to avoid these hazards through bitter experience, common sense or occupational safety training. Most large swine farms have training programs for the safety of their workers and insurance purposes.

A major component of a swine handler's normal daily routine is to walk through or by the pigs' pens, and, when indicated, tend to a pig's individual needs. On these occasions handlers may sometimes be injured by the pigs or from the equipment in the facility. However, many injuries occur during swine movement and handling when pigs are moved from one location to another and ultimately to market/slaughter.

In an effort to reduce handler injuries and improve pork quality and animal welfare, the National Pork Board developed a Transport Quality Assurance program.⁴⁶ The Transport Quality Assurance™ (TQA) discusses all aspects of movement and loading of pigs. Emphasis is placed on proper handling to decrease animal stress, understanding animal behavior such as fight or flight responses, and the proper environmental conditions such as surfaces, lighting, foot traction, temperature, and noises that may affect animal movement. In addition, the proper use of handling tools and equipment to help sort and move pigs in a safe manner is described. Also discussed in the TQA program is the use of personal protective equipment and information on proper design of loading ramps. Unfortunately, the success of this program in reducing handlers' injuries has not been documented but anecdotally farm managers have noted a reduction in injuries after handlers have been trained in the program.

GAPS IN KNOWLEDGE AND PRACTICE

There are many studies evaluating the respiratory health of livestock confinement workers but studies on other illnesses in confinement workers are needed. The frequency and type of zoonotic infections in farmers has not been thoroughly investigated. Most cases of zoonotic infections are from case reports. With increased terrorism concerns, farmers also need to be educated on things to look for and biosecurity measures they can take to prevent disease introduction and transmission in their facilities. Many industries have or are developing plans to educate their contract growers.

Other areas needing further investigation are the frequency of needle stick injuries in farmers, and subsequent adverse effects from accidental injection of chemical or biological agents. How are farmers disposing of their needles? Do any companies offer a needle disposal plan for their producers? As the Occupational Safety and Health Administration (OSHA) has little jurisdiction on small farm operations,

underreporting of needle stick injuries likely occurs.

Anecdotally, “near miss” injuries frequently are reported on farms but they are poorly documented. More documentation and investigation of these events are needed. For example, although deaths are rare from confined spaces, how often has a person been rescued by a co-worker but the event was never been reported? NIOSH and OSHA are involved in fatality investigations on farms but “near misses” and nonfatal events on farms with less than 11 employees are rarely investigated.

Thousands of pounds of pesticides are used on animals or applied in animal facilities. Unless serious, most overexposures are unreported. More information of frequency and types of overexposures are needed. New application methods may need to be developed to prevent these exposures from occurring.

RECOMMENDATIONS FOR THE FUTURE

Animals are a major source of injuries to livestock handlers. Injuries usually occur from direct contact with the animal and uncommonly the handler may develop a zoonotic infection. From the literature reviewed, in the United States, approximately 30 farmers and farm workers are killed each year from animal-related injuries and tens of thousands are injured, up to 5% permanently. More research is needed to develop programs that lead to a decrease in injuries, that is acceptable and easy to use, and that maintains animal welfare. The following are some suggestions for future research. We recommend that NIOSH update national surveys of injuries in livestock handlers to look at the types of injuries that occur and the circumstances behind the injuries. Studies should be conducted to determine if there is a decrease in animal handler injuries following species-specific training programs for the handlers. These studies should include pig, sheep, and goat farms as well as the traditional cattle and horse farms. Studies should be conducted to determine the incidence of needle stick injuries by species and agent injected and if

redesign of equipment is needed. An evaluation of needleless injection systems should be included to see if they can be successfully used on animals. Studies to determine the incidence of all-cause/all-species injuries and death on small farms compared to larger farms are needed to see if there are different risk factors that may play a role. Insurance industries’ databases for all deaths/injuries on livestock and poultry farms should be evaluated to look for trends in types of injuries. We are seeing more cases methicillin-resistant *Staphylococcus aureus* (MRSA) infections in the general population. More studies are needed to determine the role of farm animals in transmitting MRSA and *Clostridium difficile* to farm workers and the general population. Evaluations of the effectiveness of programs such as TQA should be performed and if effective determine best methods to incorporate such programs into other commodities.

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