Surgeon General's Conference on Agricultural Safety and Health
FarmSafe 2000 • A National Coalition for Local Action
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CHEMICAL HAZARDS

By Linda Rosenstock, M.D.
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Dr. Henry A. Anderson: So, let me introduce Dr. Linda Rosenstock who is Director of Occupational Medicine at the University of Washington. She has done considerable research and has been very active dealing with chemicals—actually all occupational exposures—and today is going to specifically address chemical exposures as they occur in the agricultural setting. Dr. Rosenstock:

There are two things that I would like to highlight during this discussion about pesticide health effects. The first is to consider how surveillance can be used to prompt further investigation and research, particularly looking at the interface between surveillance and research.

The second is to use this opportunity to talk specifically about a class of pesticides—the organophosphate pesticides—because of their significant acute toxicity and because of their potential for chronic toxicity.

As we try to break new ground and broaden our concern for farmers and farmworkers to include community effects of exposures, we will need to investigate the whole spectrum of the dose-response curve. I will provide evidence of long-term neurologic consequences of the highest levels of exposures, which are those that follow serious acute poisoning.

I want to raise for consideration the potential for long-term, chronic neurologic effects from lower levels of exposures to pesticides in the unpoisoned worker. This could happen by directly applying or handling the pesticides and even, perhaps, in the indirect exposures seen in the community setting.

SURVEILLANCE

My colleagues and I at the University of Washington first became involved in pesticide health-effects research in clinical evaluation of patients. Our primary goal at the Occupational Medicine Clinic is to attempt to define a patient's medical condition and then to try to determine whether or not it is work-related.

One such patient was a farmworker who had spent all of his adult life in farm labor. He was living east of the mountains near some of our largest apple orchards. He was referred because of concerns by his physician, who had known him well for a number of years. Following an episode two years before we saw him, he developed a number of new, now chronic, health problems.

At the time we saw him, the patient complained of persistent headache, memory loss, confusion, and generalized fatigue. These symptoms followed soon after a significant pesticide poisoning two years earlier.

He had been involved in a full day of working behind a chemical sprayer, sustaining significant skin absorption of an organophosphate pesticide, and was over-come and soon hospitalized with what was a moderately severe pesticide poisoning. He never successfully returned to work after that episode.

He tried to go to work one week later and just could not. It was at this time that his family and his physician documented a significant change in his general mental status.

The patient had one previous significant pesticide poisoning five years before this latter episode, from which he recovered well except for some continuing complaints of new, mild headaches.

On physical examination, we found evidence of disorientations and problems with memory. Clinically, he looked similar to elderly patients who present with dementing disorders such as Alzheimer's disease. Full neuropsychological tests documented in a more objective fashion significant abnormalities in a wide array of neurologic functions consistent with an organic brain syndrome or chronic encephalopathy.

On the basis of this information, we confirmed that he had a significant dementia-type illness. Important questions still remained. What caused this illness? Was it related to work?

There were certainly several features that made us think it was not traditional Alzheimer's disease. Not only was he a bit young to present this level of abnormality from the disease, but it had come on rather suddenly. Clearly, the temporal relation to the pesticide poisoning was remarkable.

With that in mind, we decided to turn to the medical literature for assistance. Over the last few decades, there have been many suggestions of the potential for chronic neurologic problems to follow acute poisonings. Little formal epidemiologic research has been done.

ORGANOPHOSPHATE PESTICIDES

Our lack of knowledge is perhaps surprising given the extent of pesticide exposures and intoxications. Current estimates from the World Health Organization (WHO) are that around the world there are about three million severe pesticide poisonings a year.

Organophosphate pesticides are the leading cause of intoxications in most areas. Only about one-third of the poisonings are occupational. Two-thirds of these are accidental, including suicide.

It is estimated that the annual poisoning fatality rate on a global basis is about 220,000. People who get occupationally poisoned, as expected, have a lower fatality-to-case ratio than those who sustain intentional and unintentional nonoccupational poisoning.

It is estimated that 99 percent of fatal poisonings occur in the developing world. It has also been estimated that about 5,000 to 10,000 serious poisonings occur each year in the United States.

Much is known about the early effects that will follow acute organophosphate pesticide intoxication. In addition to the acute syndrome there are a few others, which may follow by days or perhaps weeks.

The question, though, that I would like to address and give you some information about is whether or not high-level, acute, single doses of organophosphate exposure can lead to chronic central nervous system neurologic deficits.

In order to look at this question, we had an opportunity to perform a study in Leon, Nicaragua. Leon is the center of an agricultural region in Nicaragua. A very active and reasonably well-validated pesticide registry has been in place there for about 4 years.

Table I. Neuropsychological Performance of Poisoned and Comparison Charts.

	TEST	Mean Test Score (SD)* Poisoned n = 36	Mean Test Score (SD)* Not Poisoned n = 36	Estimate of Difference of Means (95% CI)+	
LANGUAGE					
	WAIS-R Vocabulary	25.2 (12.1)	28.7 (9.4)	3.4	(-1.1,8.0)
ATTENTION					
Verbal	WAIS-R Digit Span[1]++	4.6 (2.1)	6.3 (3.2)	1.7	(0.6,2.9)‡
Visual	Digit Vigilance (seconds)	305 (135)	256 (91)	60.3	(18.9,101.9)‡
MEMORY					
Verbal	REY Auditory Verbal Learning[2]	7.9 (2.9)	8.8 (2.7)	0.9	(-0.2,2.0)
Visual	Benton Visual Retention Test++	4.6 (2.4)	6.1 (2.2)	1.5	(0.6,2.5)‡
VISUO-MOTOR					
Speed	Digital Symbol++	19.2 (12.5)	25.4 (11.9)	6.1	(1.6,10.6)‡
Sequencing	Trail A (seconds)	81.0 (33.0)	63.3 (26.7)	20.6	(7.7,33.5)‡
Problem Solving	Block Design	7.7 (7.3)	14.7 (9.2)	6.9	(3.7,10.2)‡
MOTOR					
Steadiness	Pursuit Aiming II++	75.9 (33.6)	94.4 (29.9)	18.4	(7.3,29.6)‡
Reaction	Simple Reaction Time (milliseconds)++	340 (111)	308 (50)	32	(-2.0,66)
Dexterity	Santa Ana Dexterity Test (dominant hand)++	31.7 (6.5)	35.6 (7.0)	4.2	(1.3, 7.0)‡
Speed	Finger Tapping (dominant hand)	46.3 5.9	47.3 (6.4)	1.1	(-1.9,4.0)
AFFECT/SYMPTOMS					
	Brief Symptom Inventory[3]	20.6 (10.7)	18.8 (9.8)	1.8	(-2.9,6.5)
	Questionnaire 16	7.2 (4.0)	4.7 (3.8)	2.5	(1.0,4.1)‡

* = Test results represent raw scores (numbers of incorrect responses) unless other units are specified.
\+ = Positive value for Estimate of Means (and 95% CI) indicates worse performance by poisoned cohort relative to comparison cohort. Estimate is based on paired t-test. Estimate may differ from value obtained by subtracting sample means in instances where full paired data were not available.
++ = Component of WHO Neuropsychological Core Test Battery (11).
‡ = $p<0.01$ by paired t-test.
[1] Digit Span (total recalled: forward and backward).
[2] Rey Auditory Verbal Learning (number correct after distraction, Trial VI).
[3] Brief Symptom Inventory (Positive Symptom Total).

SD = standard deviation
CI = confidence interval

— Adapted from Rosenstock L et al. Chronic Nervous Effects of Acute Organophosphate Intoxication, *The Lancet*. 338: 223-227, 1991.

For example, in one region over a several-month period in 1987, there were close to 300 reported cases. Most were occupational cases of poisoning and two-thirds of these were hospitalized.

Some conditions of pesticide use in Nicaragua are worth noting by a look at some photographs. A common reason for occupational poisonings is malfunction of backpack sprayers. These are made of plastic and there often are not replacement parts available. Skin absorption is hastened in the hot climate. A breakdown of equipment in league with skin absorption can lead rapidly to serious overexposures.

Another photo shows a warning label on a container; the label that gives a warning is in English. This is not very helpful in a Spanish-speaking country where only about half the population in the rural area is even literate.

I will now review briefly how we undertook the study and what our main results have been. We were able to identify 36 men who had been hospitalized in the main hospital in this region with moderate to severe organophosphate pesticide poisoning. We studied them, on average, about two years after the poisoning episode.

A community comparison group was composed by matching to each poisoned individual someone of the same age and sex who was either a close friend or a sibling and who worked in the same community. By doing this kind of design, which is a retrospective, cohort, matched-pair design, we had a comparison group that was significantly exposed to pesticides. What was different was that this group had never been medically treated for a poisoning.

Neuropsychological functioning was assessed by a test battery, which evaluated a wide array of neurological functions including motor testing, visual perception and processing, testing of memory and language abilities, and affect.

Table I shows the characteristics of these populations. There was good matching of our community (never poisoned) and our poisoned group.

Table II. Characteristics of Poisoned and Comparison Cohorts.

	Poisoned (N = 36)	**Not Poisoned** (N = 36)
Mean age in years (±S.D.)	27.6 (±9.5)	27.8 (±9.3)
Number with no formal education	17 (47%)	12 (34%)
Number who consumed any ethanol in past month	13 (36%)	16 (44%)
Number with heavy ethanol consumption past month*	5 (14%)	6 (17%)

* *Defined as drinking more than 10 bottles of beer or 10 one-half bottles (500 cc) of rum in past month.*

— Adapted from Rosenstock L et al. Chronic Nervous Effects of Acute Organophosphate Intoxication, *The Lancet.* 338: 223-227, 1991.

They are almost identical in age. About 70 percent of the comparison cohort has also worked with pesticides. A large number also gave complaints that were consistent with pesticide poisoning, but they had not been hospitalized for these episodes.

The poisoned group performed worse than the non-poisoned comparison group for all outcomes studied (Table II).

In one set of tests, which is a World Health Organization (WHO) standardized, neuropsychological battery, the poisoned group had statistically significant worse performance on five out of six subtests. We also did some additional tests. The same pattern holds.

On the basis of this study and the accumulating evidence in the medical literature, we feel that even episodes of acute organophosphate poisoning can cause permanent neurologic dysfunction.

We cannot in this study tease out as much precision as we would like to compare the contribution of cumulative pesticide exposure to the overall effect. Any analysis we did, looking at why the poisoned group did worse, suggested that it was the actual episode of acute poisoning that contributed as the main factor to these differences in performance rather than other measures of pesticide exposure. On the basis of this study and the accumulating evidence in the medical literature, we feel that even episodes of acute organophosphate poisoning can cause permanent neurologic dysfunction.

Although we concluded that it was likely that the patient first presented in this discussion had sustained a work-related organic brain syndrome, much remains unknown about organophosphates and chronic neurologic sequelae. Further study is needed to try to replicate our findings and explore the effects of specific chemicals within the organophosphate group, the role of other factors interacting with these chemicals, and the clinical significance of the observed neuropsychologic disturbances.□

QUESTIONS

Dr. James A. Dosman: Linda, thanks a lot. I really enjoyed your talk. As scientists we never pay attention to one case, but, as you know, clinical observation is the first step in epidemiology. About two years ago a man came to me who said that he was perfectly healthy until one afternoon when he was spraying with (inaudible); it is a carbamate.

When he went out in the morning, the wind was still. Then the wind came up and it blew over him. When he got in at noon he felt so weak that he could not get to the house. Eventually he did. He lay there for two or three days; he seemed to recover. Since that time, he has been unable to do anything. He has felt depressed. He cannot make decisions. He cannot be effective. I would like to ask you, do you think, on the basis of the work that you have carried out, that this kind of mental reaction is possible following one overdose?

Dr. Linda Rosenstock: I think it is a good question. Using the word "possible" makes it a little easier to answer. If I were asked, again using this legal standard, if there is a greater than 50 percent likelihood, I would have more trouble saying yes.

I think the case reports in the medical literature suggest that there may be significant anxiety and depression following exposures. The question is how much exposure and what the mechanism is. Unfortunately, I think the conventional wisdom has been to say people just get traumatized and we are looking only at a psychological reaction. They are anxious and it has nothing to do with the effects, directly, of the chemicals.

In our study, we were actually surprised. We expected to find differences in psychiatric performance. In other words, there is increased anxiety and depression in the previously poisoned group, which I went over quickly.

In our study, we found no such differences. That made it easier for us to say everything else was real. If we found differences, then a lot of critics would say, "*Well, you are only measuring problems with memory because people are depressed; if you are depressed you do not concentrate as well because you are distracted.*" It made it easier for us to defend our results.

But I still think, despite our negative findings in that regard, that the medical literature suggests that results like this can happen. I think they are worthy of further investigation. It is too easy to write off all of these people who have these complaints and say that they, all of a sudden, got a little crazy when they were not crazy before.

Dr. Henry Anderson: I think we all want to keep in mind that we are going to be hearing examples. What we are challenged with is, what data systems or what surveillance currently exists that can assist in the identification of the cases so that it can interface with follow-up research? We have one of the key chemical exposures. I think we are all aware that there are multiple chemical exposures that go on in the agricultural setting. One of the key ones is the organophosphate poisoning. We think in terms of the continuum that Bill presented. We have laboratory testing to measure effect. Whether it is an adverse effect is still being argued. We have exposure assessment techniques. We have disease outcomes ranging from fatality to acute poisonings. The challenge is, "How can surveillance assist in a better understanding of the other parameters that relate to these types of exposures?"

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RESPIRATORY DISEASES

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SUMMARY

The structuring of health surveillance programs for widely dispersed agricultural populations is difficult because of the multiplicity of exposures and health effects. There is also the difficulty with reaching and communicating with widely dispersed populations.

In order to accomplish this objective, a cooperative approach between government, industry, the community, and individuals is necessary. In order to achieve successful "rural family life enhancement," a high degree of local ownership and leadership in the program is essential.

The problems of structuring health surveillance programs for widely dispersed populations that do not fit traditional labor-management structures for industry are numerous. Nonetheless, the significant issues relating to health and well-being—involving high rates of death, disability, and accidents; respiratory difficulties as the result of dust, microbe, and chemical exposure; possible enhanced cancer risks as a result of environmental exposures; hearing loss as a result of unquantified and uncontrolled noise levels; skin problems as a result of exposure to dusts, chemicals, microbes, and other substances; and stress and psychiatric problems as a result of isolation, economic difficulties, and inter-generational family problems—all demand a coordinated occupational health program.

On the organizational level, structuring such programs is difficult as farmers and other agricultural workers are widely dispersed, do not belong to single organizations or companies, and are thus difficult to reach for health surveillance, early identification, and an educational-preventive perspective.

THE TOOLS OF HEALTH SURVEILLANCE

In this model, no one organization may be responsible for, or effectively deal with, occupational health and well-being questions. In order to achieve success, cooperation is required between government, industry, the community, and individuals. This paper describes certain approaches at each of these four levels.

> ...we recommend the establishment of health and safety committees at the local level, organized by target populations, for the purpose of identifying issues, facilitating programming, and achieving results.

GOVERNMENT

Governmental agencies can exercise considerable influence on health surveillance by moral leadership, regulatory approaches, and information retrieval and distribution. In Canada, for example, Labour

Canada, a regulatory agency for workers that is involved in the cereal grain industry, requires that dust levels be maintained at no greater than 10 mg/m³ time-weighted over an 8-hour day, and that workers be given the opportunity for questionnaire assessment and pulmonary function testing every 3 years. As part of this program, Labour Canada requires receipt of dust level and medical information.

The latter requirement has contributed to compliance and interest in the program on the part of industry and labor. It has provided scientific information that is being utilized to estimate longitudinal effects of grain dust exposures on human health. Thus, the regulatory process appears to be accomplishing a number of goals:

1. Reduction and regulation of environmental dust levels.

2. Compliance of industry and workers in providing for, and being involved in, a periodic human health assessment program.

3. The utilization of information from this program in scientific research, that in turn may assist in re-evaluating dust level regulations.

In some ways, this program may be considered a model of the manner by which government may stimulate action at several levels.

INDUSTRY

Where concentrations of agricultural workers exist, as in the grain transport and storage industry, industry may play a leading role in promoting good health amongst its workers. Utilizing the Canadian grain industry as an example, compliance among companies in initiating dust removal equipment in grain facilities has been relatively good. Table I indicates that out of a total of 2,048 dust samples obtained in grain facilities in Canada in the early 1980's, only 19.8 percent of the samples obtained by Labour Canada, and 17.2 percent of the samples obtained by the companies themselves, exceeded the recommended maximum dust exposure limit of 10 mg/m³.

Table I. Number or Dust Samples Obtained in Canadian Grain Elevator Facilities.

	<5 mg/m³		>5 mg/m³		>10 mg/m³	
	n	%	n	%	n	%
Labour Canada*	341	64.8	185	35.2	104	19.8
Companies**	1008	66.2	514	33.8	261	17.2

Samples Collected:

* 1980–1984, n = 526
** 1978–1986, n = 1,552
Total = 2,078

– Reprinted from: McDufie HH, Pahwa P, Dosman JA. Respiratory Health Status of 3,098 Canadian Grain Workers Studied Longitudinally, *American Journal Industrial Hygiene.* (in press) 1991.

An additional dimension to the provision of health surveillance services for these workers is taking place in Canada in the Province of Saskatchewan. In this province, all grain companies have gone beyond the legal requirements of Labour Canada and are providing sufficient resources for a more comprehensive approach to health surveillance that goes beyond the minimum respiratory requirements of the regulatory agency.

Such additional services include, in addition to respiratory testing, one-to-one nurse counselling involving lifestyle management (smoking and other issues), use of personal protective devices, back care, stress, and a variety of other occupational health questions. In our experience, the workers have responded positively to this initiative.

COMMUNITY

The provision of health surveillance to widely dispersed farmers and their families must, by necessity, involve the community. In Saskatchewan, in the model being utilized, a widely dispersed approach is taken to occupational safety and health through the Agricultural Health and Safety Network of the University of Saskatchewan.

In this approach, individual rural municipalities, the local unit of self-government, enroll their resident farm families in the Agricultural Health and Safety Network for the promotion of better health and farming practice. Since its commencement three years ago, 10 percent of the rural municipalities in the province have enrolled their farm families in this network, comprising about 7,000 persons. Once enrolled in the network, individual farm families receive preventive materials on various topics relating to good healthy farm practice annually.

In addition, health surveillance services, such as respiratory testing and seminars on safe dust management, the use of personal protective devices, and other issues, are provided. Recently, as part of this program, seminars on safe chemical management have been offered, and a hearing conservation survey took place in one municipality.

This program is financed by individual subscriptions from the municipalities, amounting to 1/10th of one mill of taxation per year. The relation between the Center for Agricultural Medicine, which promotes the program, and individual farm families is through elected rural Municipal Councils. While it is too early to determine the effectiveness of this approach to health surveillance, it appears to offer potential.

THE INDIVIDUAL

The most successful approach to good work, health, and lifestyle practice is through an educated and motivated individual. Farm families are scattered widely geographically. With farm work practices being ingrained over many years, the process of education remains the most important and useful means of making gains.

The basis of the approach through the Agricultural Health and Safety Network is to achieve an educated and motivated individual. Yearly provision of materials, the provision of stickers for farm implements identifying individuals as members of the Agricultural Health and Safety Network, and tailored educational sessions are important in this process. In addition, information and material developed within the geographic area in question that is useful to, and identified with, the type of farm practice, social issues, and family life of the region, are important.

RURAL FAMILY LIFE ENHANCEMENT

The goal of health surveillance in the agricultural industry should be a broadly based approach to a multiplicity of issues that go beyond the workplace *per se* and result in an enhanced quality of life for persons who live in rural areas, the majority of whom are involved in agriculture and its related industries. In order to accomplish these goals, a combined, coordinated approach between government, industry, community organizations, and individuals is essential.

Underlying this cooperative approach is the necessity of local ownership of and leadership for programs that are undertaken. Specifically, we recommend the establishment of health and safety committees at the local level, organized by target populations, for the purpose of identifying issues, facilitating programming, and achieving results.□

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SURVEILLANCE OF INJURIES IN AGRICULTURE

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ABSTRACT

There has been no comprehensive data system to identify the magnitude of the injury problem in the rural farming community or the potential risk factors that may be associated with this problem. Serious discrepancies among the existing data sources, pertinent to occupational morbidity and mortality, limit identification of the true magnitude of the problem. Based on a recent National Academy of Sciences report, it has been documented that fatal as well as non-fatal occupationally related injuries have been greatly undercounted. In part, these discrepancies in mortality and morbidity data are due to variations in definitions, the worker populations included, methods of case ascertainment, and the data sources utilized.

Fatality rates identified for agriculture have ranked among the highest for many years. However, given the overall discrepancies among the data systems and the reporting limitations for agriculture, these would appear to be extremely conservative estimates. A major barrier to progress in the prevention of agricultural injuries has not only been a lack of knowledge about the magnitude of the problem but also a lack of knowledge about specific causes or risk factors

due to the lack of analytical studies. This paper includes an historical perspective of surveillance and its importance to the problem of injuries in the agricultural community. Special emphasis is placed upon the data sources and methodological approaches that have been used in agricultural surveillance, including advantages and limitations.

Among the agricultural injury surveillance efforts that will be discussed are two major population-based efforts, conducted by a multi-disciplinary team, using a methodology that can also serve as a model for long-term surveillance efforts at the state, regional and national levels. These efforts are the Olmsted Agricultural Trauma Study (OATS) and the Regional Rural Injury Study (RRIS):

1. The overall purpose of OATS was to identify the magnitude and characteristics of the injury problem among all farms in Olmsted County, Minnesota, using a telephone interview methodology, validated through medical records. Data pertinent to the household members, characteristics of the farm operation, and injury events (farming and non-farming related; intentional and unintentional) were collected. In concert with this effort, a case-control study to facilitate identification of risk factors, an inter- and intra-rater reliability study of E-coding, and a follow-up pilot investigation of machinery-related injury events were also conducted. Specific findings, including injury rates, characteristics of the injuries and injury events, and risk factors, are presented with regard to implications for surveillance.

2. OATS provided the basis for the Regional Rural Injury Study (RRIS), currently being conducted in a five-state region: Minnesota, Wisconsin, North Dakota, South Dakota, and Nebraska. Data collection covers a twelve-month period of time for over 4000 rural households, utilizing computer-assisted telephone interviews (CATI). This effort will enable the identification of injury rates for each state and the region as well as multiple analytic substudies, including tractor-rollovers and animal-human injuries. The project also includes application of the results to the development of intervention strategies, to be achieved by convening nationally recognized experts and the regional participants in the Agricultural Injury Intervention Stratepy Workshop.

INTRODUCTION

There has been no comprehensive data system to identify the magnitude of the injury problem in the rural farming community or the potential risk factors that may be associated with this problem that can enable progress in the prevention of agricultural injuries. Serious discrepancies among existing data sources limit identification of the true magnitude of occupational morbidity and mortality. For example, the fatality rates identified for agriculture have ranked among the highest for many years, but a recent National Academy of Sciences report,[1] documented that fatal as well as non-fatal occupationally-related injuries have been greatly undercounted.

Another major barrier to progress in the prevention of agricultural injuries has been a deficiency in knowledge about specific causes or risk factors due to the lack of analytical studies. This paper includes an historical perspective of surveillance and its importance to the problem of injuries in the agricultural community. Special emphasis is placed upon the data sources and methodological approaches that have been used in agricultural surveillance, including advantages and limitations.

SURVEILLANCE: AN HISTORICAL PERSPECTIVE

Surveillance is a French word originally meaning, "keeping a close watch over an individual or group of individuals in order to detect any subversive *tendencies*."[2] Current dictionary definitions, e.g., "vigilant supervision," "spylike watching," or "watch or observation kept over a person, especially one under suspicion or a prisoner,"[3] continue this negative connotation. This historical perspective provides a basis for the negative perception of "surveillance" in the general population that can seriously affect data collection efforts.

Surveillance of disease evolved in the 17th century when fear of plague epidemics resulted in efforts to document the impact of morbidity and mortality. Subsequently, surveillance efforts have been utilized to monitor acute disease outbreaks and to ascertain potential relationships between working environments and certain health conditions in Europe.[2] However, it was not until the 19th century that surveillance had evolved as a "means of collection and interpretation of data related to environmental and health monitoring processes for the definition of appropriate action, for prevention and health care."[2]

A surveillance effort comparable to those that were developed in Europe and focused on disease entities did not emerge in the United States until 1900; full national mortality coverage was not attained until 1933.

INJURY SURVEILLANCE

Of great importance is the fact that, although injuries have been identified as a persistent problem over time, there have been no adequate comprehensive surveillance systems established.[4] In particular, occupational injuries, which constitute an important part of the injury problem in the United States, have not received attention commensurate with the magnitude of the problem. Agriculturally related injuries have received even less attention since about 95 percent of all farming operations, by virtue of their size, do not fall under the jurisdiction of the Occupational Safety and Health Administration's, or other agencies' recording and reporting requirements.[5,6]

Occupational Injury Surveillance

Serious discrepancies among the existing data sources pertinent to occupational morbidity and mortality limit identification of the true magnitude of the problem. In 1989, the National Safety Council estimated that there were 10,400 occupationally related fatalities.[7] The Bureau of Labor Statistics: (BLS) reported 3,300 for the same year.[8] A third source of occupational fatality data is the National Traumatic Occupational Fatality (NTOF) data base at NIOSH, based on death certificates specifically coded with the "injury-at-work" designation. Through this source, it was estimated that approximately 7,000 work-related fatalities occurred each year during the period between 1980 and 1985.[9]

Similar discrepancies are identified for non-fatal occupational injuries. In 1989, the National Safety Council estimated that there were 1.7 million disabling injuries.[7] During the same year, the Bureau of Labor Statistics estimated that approximately 6.2 million work-related injuries occurred, with 2.9 million of those involving lost work days.[8] Another source of data is based on a sample of approximately 66 emergency rooms from the

United States Consumer Products Safety Commission's (CPSC) National Electronic Injury Surveillance System (NEISS). From an unpublished NIOSH report based on these data, it was estimated that over 3.8 million occupational injuries of varying severity and outcome are treated every year in all U.S. emergency departments. In part, these discrepancies in morbidity as well as mortality data are due to variations in definitions, the worker populations that have been included, different methods of case ascertainment, and the various data sources that have been utilized.[10]

Agricultural Injury Surveillance

Fatality rates identified for agriculture have ranked among the highest across all occupations for many years. Based on National Safety Council data for 1989,[7] agriculture accounted for a rate of 40 deaths per 100,000 workers, compared with 9 deaths per 100,000 workers for all occupations. National morbidity rates in agriculture have been elusive due to the lack of adequate population-based data for non-fatal events.

However, the data suggest a major problem among farm residents.[5,11-15] In 1989, an estimated 120,000 disabling injuries occurred in agricultural work, with 70,000 of these involving farm residents.[7] Given the discrepancies among the various data systems and the reporting limitations for agriculture, the estimates identified would appear to be extremely conservative.

A major barrier to progress in the prevention of agricultural injuries has been not only a lack of knowledge about the magnitude of the problem but also a deficiency in knowledge about the specific causes or risk factors due to the lack of analytical studies.[15,16] Through ongoing, systematic data collection, with consequent analysis and interpretation, epidemiologic surveillance (Figure 1) enables the identification of the magnitude of the morbidity and mortality problem, injury epidemics, new injury problems, and potential risk factors.

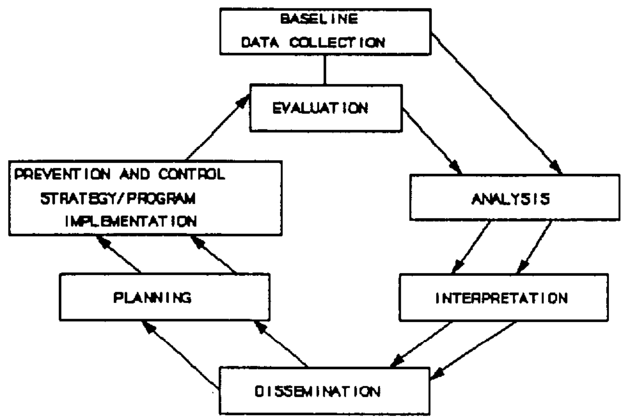

Figure 1. Surveillance of Injuries in Agriculture.

Of particular importance is that it can provide a scientific basis for analytic research to identify specific risk factors that are critical to the development of intervention strategies for the prevention and control of agricultural injuries. The integrity of a surveillance system is reliant upon regular evaluation and modification, as appropriate, with specific attention to validity and reliability measures. Finally, the surveillance system provides for ongoing evaluation of specific prevention and control activities so that alterations can be implemented, if necessary, along the way.

ELEMENTS OF SURVEILLANCE

Meaningful injury surveillance requires data that will allow the calculation of population-based morbidity and mortality rates. This requires complete numerator and denominator data for the population from which the data are drawn.

A serious deficiency in many of the surveillance efforts that have been initiated is the inability to identify adequate denominator data.[6,15,17-19] Not only is it essential to identify the total numbers of people at risk but also the various demographic characteristics of that population (e.g., age, gender, education, socioeconomic status, length and types of exposures, experience, and behavioral characteristics).

Of further importance is the collection of exposure data that address the farming operation, including the sizes and types of operations, the animals involved, and the machinery, equipment, and chemicals that are in use. Basic to the numerator is a clearly established definition of injury that may be very broad or may focus on specific types and severity of injuries, sources and locations of injuries that occur to the entire population or, perhaps, to certain subpopulations, and whether the injuries are intentional or unintentional.[19]

These elements are all integral to an injury definition. Utilization of an active versus passive system of reporting will enhance the likelihood of identifying complete numerator data.[20,21] Of further importance is consideration of the specific time period for which the data are to be collected, the relevant data analysis to be conducted, and dissemination and utilization of the results.[15,22]

Based on recommendations published from a National Academy of Sciences Committee,[4,23] there are essential data elements for injury surveillance (Table I). These include time of the event; place of occurrence; demographic characteristics of the injured person; characteristics of the injury, including the body part affected, type and severity; the agent causing the event, as well as the source and mechanism of the event, and the circumstances surrounding the injury event; medical care provided;

Table I. Essential Data Elements for Injury Surveillance.

INJURY CASE ELEMENTS

- TIME OF EVENT
- PLACE OF OCCURRENCE
- DEMOGRAPHIC CHARACTERISTICS OF THE INJURED PERSON (e.g., age, gender, education, socioeconomic status, occupation)
- CHARACTERISTIC OF THE INJURY (including body location affected, type of injury, severity)
- * AGENT CAUSING THE EVENT (e.g., mechanical, chemical, electrical energy)
- * SOURCE OF THE EVENT (e.g., machinery, tractor, gun, animal)
- * MECHANISM OF THE EVENT (e.g., fall, struck by/against)
- * CIRCUMSTANCES SURROUNDING THE INJURY EVENT (actively involved, equipment failure, weather, surface, or other environmental conditions)
- MEDICAL/HEALTH CARE PROVIDED TO THE INJURED PERSON
- HEALTH OUTCOME OF THE EVENT (e.g., complete recovery, persistent disability involving limitation of activities)

* Necessary to facilitate International Classification of Diseases (ICD) External Cause Coding (E-coding).

Adapted from Ing, 1985; Committee on Trauma Research, Commission on Life Sciences, Natural Research Council and the National Institute of Medicine, 1985.

and overall health outcome. Inclusion of appropriately coded severity levels is particularly important in determining the overall magnitude.[24,25]

> A major barrier to progress in the prevention of agricultural injuries has not only been a lack of knowledge about the magnitude of the problem but also a lack of knowledge about specific causes or risk factors due to the lack of analytical studies.

Identification of the agent, source and mechanism of the injury event, together with the circumstances surrounding the event, is crucial to External Cause Coding, or E-coding, using the International Classification of Diseases (ICD) codes and modifications specific to agricultural injuries.[15,26] The use of E-codes provides the critical link between the source and the nature of an injury, which enables targeting for more comprehensive analytic studies to identify specific risk factors and, subsequently, to develop relevant prevention and control programs; it also facilitates comparisons across data sets. The fact that intervention at the source of the injury event has been the most successful in the prevention and control of injuries highlights this element as integral.[24]

The items that have been identified provide only the very basic elements of a surveillance system. More comprehensive systems can be implemented with the recognition that as more items are included, the system becomes more expensive and it is more difficult to ensure consistency and quality of the data.[19]

SURVEILLANCE OF AGRICULTURALLY RELATED INJURIES

Advantages and Limitations of Surveillance Efforts

A *variety* of efforts in the surveillance of agriculturally related injuries have been undertaken to ascertain the magnitude of the problem, with varying degrees of success. The data sources for these efforts are presented in Table II (at the end of this paper), with elaboration on the advantages and limitations of each of these sources. For example, death certificates, which are utilized in agricultural fatality surveillance, are easily accessible. Yet there are many limitations, including the persistent lack of attention by those who complete these certificates to indicating that the event occurred at work. As a single source for surveillance, fatalities account for an extremely small proportion of the total problem.[15]

The Occupational Safety and Health Administration (OSHA) is extremely limited as a data source, given that about 95 percent of farms are not covered by this system; Federal appropriations do not enable enforcement of OSHA regulations among farms employing ten people or less. For a variety of reasons, there has also been underreporting of both morbidity and mortality data through the BLS.[1] Workers' Compensation data also are limited by virtue of a small proportion of farmers covered by this system.

Another very large national system, the Fatal Accident Reporting System (FARS), which is operated by the National Highway Traffic Safety Administration (NHTSA), enables identification of non-truck farm vehicle fatalities that occur on roadways.[27] However, it is not possible to identify the specific type of vehicles involved through this system.

Newspaper clipping services have been used by several investigators[5,12] in various efforts and, while this source has serious limitations, it can facilitate recognition of emerging as well as persistent injury problems. To a limited degree, it can also detect fatal events that are not readily accessed through death certificate data.

While hospital records may enable identification of specific diagnoses and treatments, there are also many limitations in using these records for surveillance. These include the problem of confidentiality, as well as inadequate information on the circumstances surrounding the event and the long-term consequences, together with a bias toward the more severe injuries.[19] Of particular importance is the fact that only a small proportion of injuries related to farm operations result in hospitalizations and, with extremely rare exceptions, the hospital record sources are not population-based[15].

The records from emergency departments, outpatient facilities, and from primary care practitioners have even greater limitations, including accessibility, unless they are linked into a major data base. Operation of such data bases is extremely difficult and, consequently, very rare. The denominator is a major problem for these data sources, as well. While there are a few success stories, linking multiple data sources is extremely complex and not recommended.[19]

Data from a combination of some of the above sources have also been used with varying success.[19,28-30] In Minnesota, a feasibility effort in establishing injury surveillance was initiated to link multiple existing data sets, ranging from hospital-based data to agency-based data, including highway crash events.[19] Many limitations were identified. These included:

1. Issues of confidentiality, which prevented access to personal identifiers in some cases, preventing detection of duplication of cases.

2. Quality and quantity of data elements, affected by varying injury definitions, data elements included, methodologies and a combination of active and passive reporting.

3. The inability to calculate rates other than for mortality, which accounted for only 0.3 percent of the total injury problem.

Finally, there is the potential for ongoing surveillance using in-person and telephone-based interviews or mailed questionnaires, each with advantages and limitations. In general, the quality of data do not vary greatly between in-person and telephone interviews, given the same interview content.[31] However, the in-person interview is much more expensive. While mailed questionnaires can provide ease of contact, the quantity and quality of information and the potential for lower response rates can be a problem.

POPULATION-BASED SURVEILLANCE OF AGRICULTURAL INJURIES IN THE UPPER MIDWEST

Olmsted Agricultural Trauma Study (OATS): Given the limitations that have been identified and that there has been no comprehensive data system to identify the true magnitude of the injury problem in the agricultural community or the variables that might be associated with this problem, a major project was undertaken in Minnesota in 1986 by a multidisciplinary team of investigators. The purpose of this population-based effort, known as the OATS,[15] was to determine the magnitude of the injury problem, using a methodology that could serve as the basis for long-term surveillance efforts at the state, regional, and national levels.

OATS, which served as the basis for the current regional five-state effort, was implemented in Olmsted County, Minnesota due to the ability to validate telephone interview-based injury data using the Mayo Clinic's comprehensive Rochester Epidemiology Project.[15,32] This internationally recognized unique data base contains health care records for virtually all residents in the county.

Definition of Terms

Two basic issues our research team dealt with, initially, were the elusive definition of a farm and the definition of an injury. The definition of a farm was based on the USDA's Master Sampling Frame; their definition is "an operation with annual sales of $1,000 or more of agricultural products."

An injury event was defined as one, which restricted normal activities for at least four hours, involved a loss of consciousness, loss of awareness, or amnesia for any length of time, or required professional health care, or any combination of these three.

This included both farming and non-farming activity-related injuries classified either as intentional or unintentional. The injury definition was based on experience in previous research endeavors and is compatible with definitions used by the NCHS.[15]

Data Sources

The sources of data included both telephone interviews and medical record review. Demographic and exposure data were collected from both male and female heads of household by trained telephone interviewers, using specially designed, pretested data collection instruments. The female head of household was the preferred respondent for demographic information on the family and whether or not any family members, workers, or visitors had been injured during the designated one-year time frame.

The male head of household was the preferred respondent for the farming operation exposure information. Injured persons were interviewed, directly, to obtain information concerning the injury events, with the exception of children under the age of 18, in which case the female head of household was asked to respond pertaining to their injuries.

The injury data collected included type, severity, source, mechanism, and contributing factors. Injury events reported through the telephone interviews were validated by review of the health care records in the Mayo Clinic medical records linkage system.[15,32]

Selected Results and Discussion

Among the total eligible farms in the county (n=892), there was an overall participation rate of 82 percent, with 75 percent completing all components of the interview. The distribution of the farm household members by age and gender revealed nearly identical mean ages for males and females (34.7 and 34.6, respectively).

Examples of the exposure data that were collected included the types of farming operations, which enabled calculation of specific injury rates. For example, the rates for farming and non-farming activity-related injury events per 100 farms per year were 16.0 and 21.6, respectively. Similarly, the injury event rates per 100 farm residents for farming and non-farming related activities were 4.6 and 6.2, respectively.

The fact that non-farming injury rates exceeded the farming-related rates is of particular interest. Consideration of the total injury picture is essential to address the overall impact of injuries on the farming operation and potential intervention strategies that might ultimately be implemented.

The age- and gender-specific rates provided further information. It is important to note that the conclusions drawn from any such data can vary with the use of different denominators. For non-farmwork related injuries, among males (whose overall rate was 6.3 injury events/100 persons), those less than 14 years of age (8.8/100) and 14-24 years of age (11.9/100) had the highest rates; among females (whose overall rate was 5.1 injury events/100 persons), the highest rates occurred in those age groups less than 14 years (5.2/100), 14-24 years (7.0/100), and 25-44 years (5.6/100).

In contrast, when considering the farmwork-related injury events per 100 farm residents, the older age groups emerged as being primarily involved. Among males (whose overall rate was 6.5/100), the highest rates were shown in the 25-44 (12.3/100) and 45-64 (7.6/100) year age groups; among females (whose overall rate was 1.5/100), the highest rate was in the 45-64 year age group (2.6/100).

In order to target groups for potential intervention efforts, it is also critical to consider the total exposure time with regard to farming-related injuries. Given this information, a very different pattern was demonstrated, whereby the children and younger adults were shown to be at greatest risk.

Among the males, the highest injury rate per 100,000 hours worked per year was in the age group involving those less than 14 years of age (8.3); the next highest rate was among those 25-44 years of age (4.7). Among females, the highest rate was found in the 15-24 year age group (6.0), followed by the 45-64 year age group (2.8).

To identify potential risk factors, the sources of the injury events were documented for both the farming and non-farming related injuries. The primary sources of the farming operation-related injuries were machinery (23 percent), animals (18 percent), general farm sources (16 percent), and tractors (12 percent), while sports and recreational sources (38 percent), vehicles other than farm machinery (12 percent), and home activity sources (12 percent) were primarily involved in the non-farming related injury events. These data, together with other comprehensive data that have been collected, provide a basis for identifying potential risk factors that might be investigated through specifically designed analytic efforts and serve as a springboard for development of prevention and control strategies.

Descriptive information pertinent to the injury can also be generated from this type of effort. The three major types of farmwork-related injuries were sprains and strains (27 percent), contusions (17 percent), and fractures (14 percent). Similar types of non-farmwork related injuries were also identified: sprains and strains (28 percent), lacerations (18 percent), and fractures (17 percent).

Of particular relevance are the proportions of injury cases that required hospitalization—8 percent of the farmwork-related injuries and 10 percent of the non-farmwork related injuries. As indicated previously, this finding has implications pertinent to the limitations imposed when only hospital-based surveillance is used.

Consideration of restricted activity must also be taken into account when assessing the total impact on the farming operation. The fact that a large proportion of injured individuals were actually restricted for a week or more as a result of either a farming-related injury (21 percent) or a non-farming related injury (24 percent) is very important when looking at the overall impact. Moreover, a large proportion, when interviewed, still had some type of persistent problem, including some permanent disabilities (farming and non-farming related injuries, 27 percent and 25 percent, respectively).

These findings constitute only a very small proportion of the total analyses, but give an indication of the possibility of identifying the extent of the problem in a comprehensive manner. OATS data were also used as a basis for conducting sub-studies, including analytic efforts, to further address the agricultural injury problem. These efforts included a case control study to identify human and environmental risk factors for farming-related injuries.[33]

In addition, a pilot on-site investigation of machinery-related injury events was conducted by a team of engineers and epidemiologists to identify factors for consideration in subsequent engineering studies.[34] A sub-study of inter- and intra-rater reliability in the assignment of ICD E-codes provided a further contribution to the use of this system for classifying farming and non-farming-related injuries.[26]

Regional Rural Injury Study

The research design that was evaluated in OATS served as a basis for the current Regional Rural Injury Study (RRIS),[35] involving Minnesota, Wisconsin, North Dakota, South Dakota, and Nebraska. This new project has been designed to serve as a national model for conducting surveillance in agricultural populations. In addition to its value as a comprehensive surveillance system, the five-state RRIS also provides a basis for specific analytic studies, as well as the potential for ongoing surveillance that can facilitate evaluation of specific intervention efforts.

In the RRIS, data were collected from 4,201 households, identified through a stratified random sampling process, using the USDA Master Sampling Frame. These data were collected in two phases to cover a 12 month period (January 01-June 30, and July 01—December 31, 1990) To accomplish this, the data collection instruments designed for OATS were converted to a computer-assisted telephone interview (CATI) system, which facilitates the interviewing and the data management and analyses.

The interviewing has been completed and initial analyses have been implemented. The final analyses will include age- and gender-specific rates for farmwork and non-farmwork related injuries in the region and for each state. Rates adjusted according to hours worked on the farm will also be calculated.

Analyses, including types of injuries, body parts affected, and relevant sources and mechanisms, are integral to this effort. Other more comprehensive and analytical analyses will be conducted on a variety of substudies, including case-control studies focused on animal-human injuries and tractor rollovers.

This effort will also result in a workshop in July 1992, at which time the regional participants as well as other experts and the investigators involved will meet to develop state action plans for the prevention of agricultural injuries. Data generated from the RRIS will be used as the basis for development of prevention and control strategies in the five-state region that may also be applied at the national level.

SUMMARY

This presentation has provided a background on the surveillance of injuries and specifically with regard to agricultural injuries. The need for ongoing, systematic data collection, not only to identify the magnitude of the problem but also to provide a basis for analytic studies, is clear.

Identification of specific risk factors will facilitate more appropriate planning and implementation of strategies. Finally, application of surveillance to monitor the effects of prevention and control programs that have been implemented will enable evaluation of their efficacy and identify necessary modifications to ensure optimal reduction of agricultural injuries.□

TABLE II. Data Sources Utilized in Agricultural Injury Surveillance: Advantages and Limitations

DATA SOURCES	AGENCIES/ AUTHORS	ADVANTAGES	LIMITATIONS
Occupational Safety and Health Administration	• Bureau of Labor Statistics		• Approximately 95% of all farms are not covered under OSHA, i.e., those with 10 or less employees.
Workers' Compensation			• Limited proportion of farms included.
Fatal Accident Reporting System (FARS)	• National Highway Traffic Safety Administration • Gerberich, Robertson, Gibson et al, 1991[27]	• Detects roadway farm vehicle-related fatalities.	• Off-roadway vehicle events not included. • No identification of specific type of vehicle.

DATA SOURCES	AGENCIES/ AUTHORS	ADVANTAGES	LIMITATIONS
Death Certificates	• Welsch et al., 1989[12] • Gunderson, et al., 1990[5]	• Easily accessible. • Includes intentional and unintentional events.	• Fatality rate less that 1/100 of 1% assuming no more than one farmer per farm. • Extremely difficult to assess accurate count—occupation. frequently misclassified. • Information inadequate on death certificate relevant to primary/secondary causes of death. • "at work" box infrequently checked. • Source/mechanism of injury information limited and/or missing.
	• National Institute for Occupational Safety and Health—National Traumatic Occupational Fatalities (NTOF), Myers, 1990[38]		• Excludes individuals under 16 years of age. • All limitations, identified above, apply.
Newspaper Clipping Services-National/State Newspaper Clipping Services	• Welsch et al., 1989[12] • Gunderson et al., 1990[5]	• May facilitate recognition of emerging as well as persistent injury problems. • Authors included death certificates for verification. •Detects fatal events not readily accessed through death certificate data	• Identifies agricultural-related fatalities and catastrophic injuries. • 50% of fatalities may be missed as well as a large proportion of non-fatal injuries. • Reporting is biased according to gender/other variables.

DATA SOURCES	AGENCIES/ AUTHORS	ADVANTAGES	LIMITATIONS
Hospital Records	• Gerberich et al., 1989, 1990, 1991 (Used to validate telephone interview)[15, 18]	• Identification of specific diagnosis and treatment.	• Confidentiality makes records difficult to access. • Bias—only most severe injury cases included. • Inadequate data on circumstances of event. • Non population-based. • Oriented toward diagnosis, treatment and, possibly, rehabilitation. • Long-term consequences not identifiable. • very few persons are hospitalized; only 8% of all farming-related injury cases. • Miss those who die before reaching hospital or are transferred elsewhere. • Biased due to type of insurance, if any.
Hospital Records— All hospitals (n=25) in 15 county sample	• Fuortes et al., 1990[37]	• Active system employed.	• Selection of sample not identified. • Occupation-related injuries only. • Procedures regarding confidentiality not identified—cases were followed up by investigators with no apparent consent procedures. • No indication of participation rate of either hospitals or patients.
Emergency Room Cases U.S. Consumer Product Safety Commission (CPSC), National Electronic Injury Surveillance System (NEISS)	• McKnight, 1984[38]	• Provides national estimates.	• Product-related injuries only . • Sample of emergency rooms is not representative of those in the United States. •Identification of manufacturer not released.
Emergency Room Cases Part of project to develop systems for continuous and periodic injury surveillance	• Jansson, 1987[39] • Jansson and Svanstrom, 1989[40]	• May facilitate recognition of emerging as well as persistent problems.	• Descriptive data on injured cases only • No exposure data collected.

DATA SOURCES	AGENCIES/ AUTHORS	ADVANTAGES	LIMITATIONS
Emergency Room and Urgent Care Cases	• Stueland et al., 1991[41]	• May facilitate recognition of emerging as well as persistent injury problems	• Descriptive data on injured cases only • No exposure data collected.
Outpatient Facilities		• Potential to detect greater range of severity.	• Diagnosis may not be ascertained initially. • No denominator information.
Primary Care Practitioners		• Potential to detect greater range of severity.	• No denominator information (age/gender composition is overestimated, Eylenbosch and Noah, 1988).[2] • Typically a passive system. • Quality of classification underestimated.
In-Person Interviews	• National Safety Council	• Contact reportedly every three months—minimized recall bias.	• Sample selection unclear • Use of local volunteer interviewers.
Telephone-Based Interviews-Olmsted Agricultural Trauma Study (OATS); Provided basis for Regional Rural Injury Study adn Subsequent Surveillance (validation with medical records)	• Gerberich et al., 1991[15]	• Population-based, enabling. • Utilized U.S. Department of Agriculture's (USDA) Master Sampling Frame to identify all farms in Olmsted County. • Ensured qualification as an operating farm during period of study. • Collected demographic and farm exposure injury data on all participating farms in the county. • Overall participation rate = 82%, full interview participation = 75%. • Provided a basis for the following multiple sub-studies, including: 1) Case-Control Study of Farmwork-Related Injuries. 2) E-Coding Study. 3) Follow-up site visit, machinery-related studies.	• Confidentiality of records necessitates access through USDA office resources only.

DATA SOURCES	AGENCIES/ AUTHORS	ADVANTAGES	LIMITATIONS
Telephone-Based Interviews-Regional Rural Injury Study (RRIS) Provides a basis for national surveillance	• Gerberich et al., 1989-1992[35]	• Population-based, enabling identification of specific rates. • Utilized USDA Master Sampling Frame to select stratified random sample of farms in five states. • Ensured qualification as an operating farm during period of study. • Collected demographic and farm exposure injury data on participating farms in five states. • Participation Rate-78%. • Data are entered directed into the Computer Assisted Telephone Interview (CATI) system, enabling efficient monitoring, data management, and analysis. • Provides a basis for multiple studies, including the following: 1) Case-control study of tractor rollovers. 2) Case-control study of animal related injuries.	• Confidentiality of records necessitates access through USDA office resources only.
Mailed Questionnaires 545 dairy farms in Otsego County	• Stallones, 1986[42]	• Ease of contact.	• Response rate 45% • Self-selected sample.
Mailed Questionnaires	• Fuortes et al., 1990[37]	• Ease of contact.	• Response rate 41%. • Biased populations of hospitalized individuals. • Identification of occupation relatedness and event characteristics in medical records are notoriously poor. • No control for days of hospitalization. • High potential for misclassification.