5228

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Cancer Among Migrant and Seasonal Farmworkers: An Epidemiologic Review and Research Agenda

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There are an estimated three million hired migrant and seasonal farmworkers in the United States. Adults and children may be exposed to mutagenic and potentially carcinogenic pesticides during planting, weeding, thinning, and harvesting crops. Field conditions that provide little opportunity to wash skin or clothing to minimize pesticide absorption may intensify exposure. Little is known, however, about the occurrence of cancer in migrant or seasonal farmworkers. Most cancer epidemiologic research on agricultural populations has focussed on farm owner/operators. The few studies that have evaluated cancer in farmworkers suggest that, like farm owner/operators, they may be experiencing excesses of multiple myeloma and cancers of the stomach, prostate, and testis. A few studies suggest that the farmworkers may differ from farmers by experiencing excesses of cancers of the buccal cavity and pharynx, lung, and liver. Cervical cancer was elevated in female farmworkers in one study. Descriptive data and etiologic research on cancer among farmworkers and family members are urgently needed. Feasibility evaluations, however, should precede etiologic investigations because of possible difficulties in studying this population of workers. Issues that need to be evaluated include assessing where and when farmworkers and family members are diagnosed and/or treated for malignancies, the ability of farmworkers to provide histories of crops, locations, and years worked and living conditions, the ability of agricultural experts to determine likely pesticide exposures based on such farmworkers' histories, the ability to obtain information on potential confounding factors, the ability to recontact or determine vital status of specific farmworkers over time, the suitability of conducting studies in home-base vs. upstream counties, and the ability to study agriculturally related malignancies in persons who have left farm work before the disease occurs.

Key words: agriculture, migrants, cancer, mortality, occupation, pesticides, epidemiologic research, farmwork

INTRODUCTION

There are an estimated three million hired migrant and seasonal farmworkers in the United States [Wilk, 1988]. Adults and children may be exposed to mutagenic and potentially carcinogenic pesticides during planting, cultivation, weeding, and harvesting crops. Field conditions provide little opportunity to wash skin or clothes to

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minimize pesticide absorption. Farmworkers are exposed to other chemical hazards, such as fertilizers which can result in exposure to nitrates and ultimately to nitrosamines, potent carcinogens [Shaver and Tong, 1991]. Little is known, however, about the occurrence of cancer in migrant and seasonal farmworkers. Most cancer epidemiologic research on agricultural populations has focussed on farm owner/operators. In this paper, we review studies evaluating cancer risk in farmworkers and describe the data resources needed to conduct descriptive, cohort, and case-control studies of farmworkers. Recommendations will be made for future research with special emphasis on methodologic and feasibility issues.

CANCER EPIDEMIOLOGIC RESEARCH OF AGRICULTURAL POPULATIONS

There have been numerous epidemiologic studies of cancer in agricultural populations. A recent review cited 26 cohort studies or broad occupational surveys that contained information on agricultural populations and 70 investigations of selected cancers, usually case-control studies, which evaluated risks of cancers commonly associated with farming [Blair and Zahm, 1991]. The overwhelming majority of these studies focussed on farm owner/operators. The review reported only four general occupational studies [Williams et al., 1977; Petersen and Milham, 1980; Milham, 1983; Stubbs et al., 1984] and one case-control study [Mills et al., 1984] that evaluated cancer risks in U.S. farmworkers specifically. The studies of farm owner/operators have consistently shown increases in risks of leukemia, non-Hodgkin's lymphoma, Hodgkin's disease, multiple myeloma, and cancers of the lip, stomach, skin (both melanoma and other skin cancers), prostate, brain, testis, and connective tissue and decreases in overall cancer mortality and cancers of the lung, bladder, colon, and esophagus [Blair and Zahm, 1991].

The excesses among farm owner/operators raise concern about cancer among migrant and seasonal farmworkers. Farmers and farmworkers perform many of the same tasks and have many of the same exposures. Studies specifically of farmworkers are needed, however, because there are exposure differences between farmers and farmworkers that may affect cancer risk. Farmers may have exposure to solvents, fuels, welding fumes, fumigants, and exposures related to animal confinement facilities while migrant and seasonal farmworkers are less likely to engage in tasks resulting in these exposures. Farm owner/operators may receive most of their pesticide exposures during mixing and application, while hired farmworkers are more likely to be exposed to pesticide residues during cultivation, weeding, and harvesting of crops [Mentzer and Villalba, 1988]. A study in Washington State reported that 47% of farmworkers had worked in a field within 2 days of its being treated with pesticides and 43% had been exposed from spraying accidents or drift, while only 23% had ever mixed, applied, or helped apply pesticides [Mentzer and Villalba, 1988]. The exposures experienced by farmworkers, however, may result in greater absorption than farmers because of the lack of water for washing in the fields and in the farmworkers' housing. In a 1979 survey of migrant farmworkers in Wisconsin, 63% had no water for washing their hands in the field and 53% had no tub or shower in their housing [Slesinger, 1979]. By 1989, conditions had improved somewhat, but 38% of Wisconsin farmworkers still had no water for washing in the field and 31% lacked a tub or shower in their housing [Slesinger and Ofstead, 1989]. The 1990

National Agricultural Workers Survey [Mines et al., 1991], a nationwide sample, reported that 24% of farmworkers had no access to water for washing at work. Studies of farmworkers are also needed because most of the U.S. studies of farmers have been conducted in areas where grains, cotton, and other field crops are grown, while farmworkers are primarily employed in the fruit, vegetable, and nut sectors of the agricultural industry [Migrant Health Program, 1990]. Farmworkers are also employed in the nursery and greenhouse industry. Because pesticide use and other exposures vary by crop, differences in cancer risks could be expected. In addition, farmers and farmworkers are generally from different ethnic groups. Most of the farmers studied have been white whereas the majority of farmworkers in the United States are Hispanic [Mines et al., 1991]. Smaller numbers of Haitians, African-Americans, Asians, and other groups are also engaged in farmwork [Mines et al., 1991]. These various racial and ethnic groups may have different genetic susceptibilities to cancer, and have different lifestyles with respect to factors such as poverty, diet, tobacco use, alcohol consumption, and access to medical care, which affect cancer risk. For example, Elder et al. [1991] have reported that Hispanics consume more high-fat, high-fiber, and high-calorie foods than Anglos. Hispanic women were less likely to have ever had a mammogram or Pap smear than Anglo women [Elder et al., 1991]. Also, farmworkers include women and children, while the farmers previously studied were adult men. The inclusion of women and children in research is important since cancer risks differ by sex and age.

Our 1991 review [Blair and Zahm] of farmers listed five studies that also evaluated cancer risks in U.S. farmworkers specifically [Williams et al., 1977; Petersen and Milham, 1980; Milham, 1983; Stubbs et al., 1984; Mills et al., 1984]. Subsequently, we identified five additional relevant studies: four general occupational mortality surveys [Brockert et al., 1981; Kan and Brockert, 1982; Schwartz and Grady, 1986; Gallagher et al., 1989] and one case-control study [Stemhagen et al., 1983]. A sixth study [Carlson and Petersen, 1978], which had a cross-sectional mortality design, compared the overall cancer mortality rate among farmworkers with the rate for farmers and farm managers, but did not present rates for individual cancer sites. The referent group of farmers and farm managers would have had many agricultural exposures and practices in common with the farmworkers. The results of these studies of farmworkers are presented in Table I. There are also numerous case reports of cancer among farmworkers and their family members [Moses, 1989]. There are some cancer studies of farmworkers in other countries, but, because their crops, tasks, and nonmigrant lifestyles sometimes vary from those in the United States, they are not included in this review.

There are both similarities and differences in the reported cancer risks experienced by farmers and farmworkers. The farmworkers appeared to experience similar excesses of multiple myeloma [Stubbs et al., 1984] and cancers of the stomach [Stubbs et al., 1984], prostate [Williams et al., 1977; Schwartz and Grady, 1986], and testis [Mills et al., 1984]. The farmworkers differed from farmers, however, by experiencing excesses of cancers of the buccal cavity and pharynx [Brockert et al., 1981; Kan and Brockert, 1982], lung [Brockert et al., 1981; Kan and Brockert, 1982; Schwartz and Grady, 1986], and liver [Petersen and Milham, 1980; Milham, 1983; Stubbs et al., 1984; Stemhagen et al., 1983]. The excess cancers of the lung and buccal cavity and pharynx are particularly interesting given the low mortality for these cancers among Hispanics in comparison to Anglos in Texas [Martin and Suarez,

TABLE I. Summary of Descriptive and Analytical Epidemiologic Studies of Cancer Among US and Canadian Migrant and Seasonal Farmworkers

Reference	Location	Study design[a]	Number[b]	Findings	Comments
Petersen and Milham [1980]	California	PMR	6,567	Liver[c]	
Brockert et al. [1981]	Utah	PMR	Unknown	Lung[c]	Utah referent population includes many Mormons who generally abstain from tobacco
Kan and Brockert [1982]	Utah	PMR	444	Lung, buccal cavity and pharynx[c], bone, soft tissue, sarcoma, skin	Utah referent population includes many Mormons who generally abstain from tobacco and alcohol
Milham [1983]	Washington	PMR	4,438	Liver, larynx	
Stubbs et al. [1984]	California	PMR	7,504	Multiple myeloma[c], stomach[c], liver, cervix[c]	
Schwartz and Grady [1986]	New Hampshire	PMR	90	Prostate, lung	
Gallagher et al. [1989][d]	British Columbia	PMR	2,634	No cancer excess; accidents, tuberculosis, pneumonia	Large proportion of accidental and infectious deaths may have influenced cancer PMR
Carlson and Petersen [1978]	California	Cross-sectional	2,936	Overall cancer excess, farmworkers vs. farmers	Farmer referent population would have shared many similar exposures as farmworkers, minimizing differences; no individual cancer site data presented
Williams et al. [1977]	U.S.	Case-control	Unknown	Prostate[c], esophagus, oral cavity, colon	Personal interviews, "main lifetime occupation"
Stemhagen et al. [1983]	New Jersey	Case-control	41	Liver[c]	Personal interviews, ever employed 6 months or more
Mills et al. [1984]	Texas	Case-control	18	Testis[c]	Present occupation, abstracted from hospital medical records

[a]PMR Studies: Farmworkers are often no longer actively employed in farmwork at older ages, when cancer generally occurs. So, PMR studies based on death certificate occupational data may not detect all associations between farmwork and cancer.
[b]Number represents the number of deaths from PMR and cross-sectional studies and the number of exposed cases for case-control studies.
[c]$p < 0.05$.
[d]Gallagher et al. [1989] who report on deaths during 1950–1984, subsumes data in Gallagher et al. [1984], who report on deaths during 1950–1978.

1987]. Two of the three studies [Brockert et al., 1981; Kan and Brockert, 1982] with these excesses of lung, buccal cavity, and pharyngeal cancer, however, were conducted in Utah, where the local population includes many members of the Church of the Latter Day Saints of Jesus Christ (Mormons), which proscribes the use of tobacco and alcohol by its members. Nonsignificant excesses of cancers of the bone, connective tissue, and skin [Stubbs et al., 1984; Kan and Brockert, 1982], larynx [Milham, 1983; Stubbs et al., 1984], esophagus [Williams et al., 1977], and rectum [Stubbs et al., 1984] have also been observed in farmworkers. It should be noted that the proportional mortality ratio (PMR) studies that showed no or few elevated cancer risks among farmworkers may have been strongly influenced by the large proportion of accidental and infectious disease deaths [Petersen and Milham, 1980; Milham, 1983; Stubbs et al., 1984; Kan and Brockert, 1982; Carlson and Petersen, 1978; Gallagher et al., 1989]. The PMR studies are also affected by the fact that cancer usually occurs at elderly ages when people are typically no longer actively engaged in farmwork. Other occupations would appear on the death certificates. Cervical cancer was elevated among female farmworkers in one study [Stubbs et al., 1984].

RESEARCH NEEDS

Research is needed to further assess the cancer risks among farmworkers that have been suggested by the few available studies and to identify the agricultural exposures and other factors that might be responsible. Research needs include descriptive, analytic, and exposure assessment investigations. None of the available studies collected information from the farmworkers on agricultural activities or exposures.

Descriptive and Proportionate Mortality Studies

There have been many surveys that have described the age, sex, marital status, average number of children, education level, ethnicity, and other characteristics of subgroups of farmworkers in selected locations. Some provide information on the occurrence of acute illnesses, but there are no studies of cancer morbidity or mortality according to these characteristics. Garnering descriptive and general mortality data on any occupational group can be challenging, but is particularly problematic for migrant and seasonal farmworkers. First, there is no universally accepted definition of a migrant or seasonal farmworker. The federal, state, and local government agencies and private organizations concerned with migrant and seasonal farmworkers often use different definitions and so produce varying estimates of the number of farmworkers. The U.S. Census, which can produce reliable statistics on the number of persons in some occupations, is generally thought to seriously underestimate the number of migrant and seasonal farmworkers [Migrant Health Program, 1985; Slesinger and Pfeffer, 1990]. Lack of reliable estimates of the number of workers "at risk" can make calculations of disease rates difficult.

Second, cancer most commonly occurs at older ages, but farmworkers often leave agricultural work before reaching the high risk ages. Less than 7% of migrant and seasonal farmworkers were aged 55–64 years and only 1% over age 64 years in the 1990 National Agricultural Workers Survey [Mines et al., 1991]. In Wisconsin [Slesinger, 1979], 16.6% of the farmworkers were aged 50–64 years and 2.2% were aged 65–67 years. Only 1.5% of all visits to migrant health centers are made by

persons over age 64 years [Dever, 1991]. Consequently, very few active farmworkers in Tulare County, California (0.5%) [Mines, 1981], or in Washington State (0.4%) [Mentzer and Villalba, 1988] reported a previous diagnosis of cancer. By the time cancer develops, the former farmworker may have retired or found employment in some other industry, which then appears on the medical record or death certificate.

Third, the death certificate coding for farmworkers may be especially prone to inaccuracies. Farmworkers may be inadvertently assigned the occupational code for farmer or some other erroneous code. In 1956, Buechley et al. found that 70% of the men who identified themselves as having been farmworkers in an interview were later classified as farmers (20%) or in nonfarming occupations (50%) on their death certificates. It is not known if these error rates persist today. Race and ethnicity data may also be inaccurate. In a Bureau of Census study of race and ethnicity in 27 states, approximately 33% of the estimated Mexican-American population, the most common ethnic group among farmworkers, was misclassified with respect to race [Hahn, 1992]. In an infant mortality study which compared race and ethnicity on birth and death certificates, race information was inconsistent for 30.3% of the Hispanics, 3.5% of the non-Hispanic whites, and 3.3% of non-Hispanic blacks [Hahn et al., 1992]. We could find no information on the accuracy of cause of death coding for farmworkers or Hispanics relative to the rest of the population. Poverty and lack of access to medical care may affect reporting of cause of death, especially for rare cancer events. Percy (unpublished results), however, found no differences in agreement between death certificates and hospital diagnoses for cancer by race.

Research needs for descriptive and proportionate mortality studies. Several methodologic investigations of the relative accuracy of cause of death coding would contribute to the interpretation of past and future mortality studies of farmworkers. A methodologic study that could clarify the value of death certificate-based farmworker studies would be to ask a sample of current farmworkers to identify family members who were also farmworkers who died in this country. The age, race, ethnicity, and occupation at the time of death supplied by the relative could be compared to the information on the death certificate. The percent of older generation members who had been farmworkers in the United States, but who died outside the country would also be valuable to know.

Up-to-date information on the accuracy of the death certificate occupational data is needed. The 70% error rate from Buechley et al. [1956] may grossly overestimate the current situation. We need to assess the accuracy for persons actively employed as farmworkers at the time of death, for persons who have left agriculture but whose "usual occupation" was farmwork, and for persons who are classified as "farmers" on their death certificates. Buechley et al. [1956] found that 20% of farmworkers were classified as farmers on their death certificates. To evaluate the current magnitude of this last type of error, next-of-kin of persons whose death certificate occupation is "farmer" could be contacted to verify the occupation. This type of study would be most feasible in an area where the population of seasonal farmworkers was large relative to the estimated number of farm owner/operators. Focussing on seasonal rather than migrant farmworkers would enhance the possibility of locating the next-of-kin. A large number of farmworkers relative to farmers would maximize the statistical power of the study.

Cancer mortality rates in counties with a large number of farmworkers and with farmworkers representing a large percent of the total county population could be

compared to county rates in the rest of the United States. This approach has been a valuable hypothesis-generating tool for cancer risks in other occupational settings [Blot and Fraumeni, 1975, 1977; Blot et al., 1977]. For migrant farmworkers, downstream home-base counties should be evaluated, while, for seasonal farmworkers, any counties with large numbers of seasonal farmworkers could be evaluated. Some geographic locations have extremely high proportions of farmworkers. For example, over 75% of the workforce of Crystal City, Zavala County, Texas are migrant and seasonal farmworkers [National Water Project, 1988]. The counties with the most farmworkers are, in general, located in the South. However, some migrant farmworkers settle permanently in other regions, particularly in areas with food processing industries. Sources of information on the estimated number of farmworkers by county include: "An Atlas of State Profiles which Estimate Number of Migrant and Seasonal Farmworkers and Members of Their Family" [Migrant Health Program, 1990] (persons are counted at each location where they live or work); "Method for Designating High Impact Migrant and Seasonal Agricultural Areas" [Migrant Health Program, 1985]; the 1982 U.S. Census of Agriculture [US Department of Agriculture, 1982]; and "Estimate of Migrant and Seasonal Agricultural Workers in Iowa, Kansas, Missouri, and Nebraska" [Slesinger and Cautley, 1988]. Other sources, described and evaluated in Slesinger and Cautley [1988], might also be useful.

Although death certificate occupational data are limited, more proportionate mortality studies of farmworkers could be conducted. The United States does not code occupation on death certificates nationwide, but a number of individual states do so. Studies could be conducted in the states with counties with a large number of migrant or seasonal farmworkers. Risks among the subgroups of decedents with Hispanic surnames, identified by the method used by Martin and Suarez [1987], or from other ethnic groups likely to be farmworkers could be evaluated. Caution, however, should be taken in comparing farmworkers to other occupations likely to be held by members of the same ethnic group, such as the service industry, in attempts to control for nonoccupational factors, because those industries are also the most common type of employment for farmworkers leaving agriculture [Mines, 1981].

Many population-based cancer registries exist in the United States but only a few routinely collect and computerize information on occupation. Researchers could perform more proportionate morbidity analyses or series of case-control studies, as done by Brownson et al. [1989], but should take care to distinguish farmworkers and farmers.

Cohort Studies

Cohort studies are those in which subjects are identified on the basis of their exposure status, before the occurrence of disease, then traced over time until disease develops or death occurs. Disease rates in the exposed cohort are compared to rates experienced by a referent, presumably nonexposed, population. Cohort studies can be either prospective or retrospective. In a prospective study, the exposed cohort is identified at the present time and followed into the future for a time period sufficiently long enough to account for the disease of interest to develop, commonly called the latency period. Although a prospective study offers the opportunity for repeated exposure assessment, no health outcome information is available for many years, which may be unappealing for farmworkers and researchers.

Although a prospective cohort study of migrant and seasonal farmworkers

should be considered, opportunities for retrospective cohort studies should also be investigated further. In a retrospective cohort study, the exposed cohort is identified from preexisting records as of some time in the past and traced to the present time. Tracing to determine vital status requires personal identifiers for cohort members, such as name, date of birth, and Social Security numbers.

Research needs for cohort studies. Identification of a cohort of farmworkers may be more difficult than for other occupational groups. There may be fewer large employers than elsewhere and the seasonal nature of the work indicates that fewer records may be kept. Farmworker unions may have suitable records, but whether the records date back far enough to allow for the relatively long latency for cancer needs to be investigated. Record systems, such as the centralized national computerized Migrant Student Record Transfer System of the Migrant Educational Program, might be useful to identify parent farmworkers, but would miss workers without accompanying children [Slesinger and Cautley, 1988]. Widespread searches for other sources which might identify farmworkers at some point in the past are needed.

Tracing farmworkers for vital status determination presents unusual challenges. Feasibility studies of tracing a sample of farmworkers over extended periods of time are needed. In most cohort studies, the Social Security number is a crucial component for tracing. It may be of less value for studies of farmworkers because of inaccuracies in reported numbers and missing numbers. In most occupational cohort studies, successful tracing and determination of vital status are only possible if the subjects have remained in the United States. For farmworkers, the magnitude of loss due to subjects leaving the United States could be substantial and would have to be evaluated.

The value of cohort studies increases with the quality of the exposure data. A retrospective study of farmworkers would be more informative if it incorporated qualitative or quantitative exposure data for study subjects. In epidemiologic studies of industrial workers, considerable information can often be obtained from records of the employer, including production processes, use of protective equipment, and monitoring data. Such information is unlikely to be recorded for farmworkers. Assessing exposures to farmworkers is further complicated because they have many employers. Evaluation of farmworkers' exposures is discussed further in conjunction with exposure assessment for case-control studies.

Case-Control Studies

In case-control studies, subjects are identified on the basis of their disease status, then the past exposures of the cases and controls are compared. For a farmworker study, the proportion of cases and controls who were farmworkers or farmworkers with particular exposures would be compared. Information on past exposures in case-control studies can come from employment records, but typically is obtained from the study subjects themselves or, if deceased, incapacitated, or otherwise unable to provide information, from surrogates such as their next-of-kin. The tumors that are good candidates for case-control studies of farmworkers are those found to be excessive in farmers, e.g., leukemia, lymphoma, multiple myeloma, brain, prostate, and stomach cancer.

Studies of farmworker women, who constitute about one-third of the hired farm labor force, would be valuable. Cervical cancer was excessive in farm women in one report [Stubbs et al., 1984]. Hormonally mediated tumors, such as breast, ovary, and

endometrium, may be affected by exposure to pesticides such as atrazine, which acts on the hypothalamus-pituitary-gonadal axis [International Agency for Research on Cancer, 1991]. Other aspects of farmwork may also increase the risk of cancer among women. For example, because of the lack of toilets in the field, farmworker women are at increased risk for urinary tract infections, which have been linked to risk of bladder cancer [Kantor et al., 1984; Braver et al., 1987].

Cancer among farmworker children should also be investigated. Children can be exposed to pesticides and other hazards in utero as the mother works, and in early childhood by spending days in the fields with their families, either because of a lack of alternative day care or because they are working, assisting the family. Migrant farm housing may also be a source of exposure if located close to spray areas. A study in Wayne County, New York, found most migrant camps were within orchard spray areas, with 68% within 20 feet of trees [Morse et al., 1982]. There have been several reports of cancer clusters of children who were in farmworker families or residents of agricultural areas [Holzman, 1989; Weisskopf, 1988]. Childhood cancers, in particular, leukemia, brain cancer, and Ewing's sarcoma, are also of interest because these cancers have been associated with pesticides in case reports and epidemiologic studies [Moses, 1989; Blair and Zahm, 1991; Holly et al., 1992].

Case identification. The geographic location for a case-control study should be in an area likely to have many farmworkers, or former farmworkers, in its population in order to maximize the study's statistical power. Several factors might be considered in selection of the locations. First, cancer is a rare disease in young people. Because of the young average age of farmworkers, cancer is rarely diagnosed in actively employed farmworkers. Consequently, migrant health centers would not be good sources of subjects for a cancer case-control study. By the time farmworkers reach the peak age groups for cancer diagnosis, many farmworkers are no longer employed in agriculture. Consequently, it does not seem wise to conduct cancer case-control studies in upstream locations unless there is a large local seasonal farmworker population or there is some evidence that migrant farmworkers settle there and remain after leaving farmwork. Cancer case-control studies probably need to be conducted downstream in states such as California, Florida, and Texas, which have large numbers of farmworkers and population-based cancer registries.

There is a need for more information on where current and former farmworkers, especially migrant farmworkers, who develop cancer are diagnosed and treated, to design a successful study. It might be useful to survey a sample of current farmworkers concerning members of older generations who were farmworkers and who developed cancer to determine information such as the type of medical care provider who diagnosed their cancers, their residence at the time, where they were treated, type of treatment (orthodox vs. folk remedies), whether they left the United States after diagnosis, and how soon they left. It would be important to determine if cases appear in the existing population-based cancer registries and if subjects could be located for interviews. Quantitative data on these items would be far more useful in planning case-control studies than the current predominantly anecdotal information.

The feasibility of using alternative mechanisms of case identification and surveillance, such as treatment data from Medicaid records, should also be investigated.

Logistics of case-control studies. Logistical issues of case-control studies that need to be considered include: the ability to locate a cancer case some time after diagnosis, especially if the case is still actively employed in farmwork; the best design

for data collection instruments; and whether incentives should be used to increase participation. Even with rapid ascertainment, researchers usually are not able to contact cancer cases for weeks or months after diagnosis. For settled-out migrant farmworkers still employed in agriculture, former migrant farmworkers no longer employed in agriculture, and seasonal farmworkers, locating the subject may be relatively easy, but recontacting currently migrating farmworkers may pose problems. Contact during the off-season in downstream home-base locations seems most feasible. Over 80% of Wisconsin migrant farmworkers are in their home state during the months of December through March [Slesinger and Ofstead, 1989]. Locating subjects would be much more difficult for migrants who leave the country permanently or temporarily. The 1990 National Agricultural Workers Survey reported that 40% of migrant farmworkers spent part of the previous year abroad visiting relatives, on vacation, or working [Mines et al., 1991].

Case-control studies of U.S. farmers have used telephone interviews, in-person interviews, and self-administered mail questionnaires. In-person interviews, in the native language of the subjects, are necessary for research on migrant farmworkers. Telephone interviews would not be feasible for subjects still actively involved with migrant farm work, but, because of cost considerations, opportunities for telephone interviews with seasonal, settled-out migrants, or former farmworkers should be evaluated. Researchers will likely need to work with community leaders and organizations such as churches and civic groups to reach the farmworkers more effectively. The involvement of individuals and groups that the farmworkers trust will enhance cooperation, particularly if the farmworkers or family members are undocumented.

Incentives are sometimes used to increase participation in research studies. Certain questions, however, need to be answered before using incentives in studies of farmworkers. First, we need to resolve whether incentives are needed or would be viewed suspiciously and be counterproductive. If deemed to be useful, cash or a health-related incentive might be appropriate, such as an infant thermometer, a medical record protector, work gloves, a first aid kit, first aid training, or nutritional information. The last two were among the 10 most needed health services identified by migrant farmworkers not currently using that health service [Slesinger, 1979].

Exposure Assessment

The informativeness of cohort and case-control studies depends on the ability to assess the exposures of the study subjects. We need to go beyond merely determining if a subject was a farmworker to determining the characteristics of that employment, i.e., to assessing the exposures sustained through farm labor. Historically, the main focus in agricultural studies has been on pesticide exposures. This will probably continue, but should not exclude evaluation of other agricultural exposures, such as fertilizers, dusts, fuels, and solvents.

Questionnaires. In most case-control studies, the primary source of job histories and exposure information is subject interviews or questionnaires, with preexisting records a distant second. The reverse is true for cohort studies. In past case-control studies of farm owner/operators, the subjects have supplied detailed histories of their pesticide use and other agricultural practices. It may not be possible, however, to ascertain detailed information regarding pesticide exposure directly from

farmworkers. In Washington State, 89% of farmworkers did not know the name of any pesticides with which or near which they had worked [Mentzer and Villalba, 1988]. Assumptions about specific pesticides might be based on histories of geographic location (e.g., state) of employment, crops, and activities by month and year. Although many cross-sectional and case-control questionnaires have been developed and used successfully to ascertain farmworkers' current activities and information for the recent past, feasibility research is needed to evaluate the ability of current and former farmworkers to provide lifetime occupational histories. For example, how accurately can farmworkers recall their work locations and how does accuracy change over time? The ability of agricultural experts to determine possible and probable exposures to pesticides and other substances based on such histories should also be investigated. Reliability could be assessed by comparing the exposure determinations of multiple experts. The validity of the experts' exposure determinations might be evaluated, in part, by comparisons with farmer pesticide application records that are required by a small number of states and some large food processing companies [Mentzer and Villalba, 1988]. These pesticide records should become increasingly valuable in the future for the identification and validation of histories of farmworker exposures as the years covered and the geographic extent of their use increase. An amendment to the 1990 Farm Bill requires recordkeeping for all applications of restricted use agricultural pesticides. The regulations to implement this provision have not been issued, however.

Since it is often necessary to use surrogate respondents for deceased or incapacitated subjects, the validity of data supplied by surrogates should be evaluated by interviewing the next-of-kin for some living current and former farmworkers. Comparisons of responses from subjects and from their surrogates have been done for farmers in Iowa and Minnesota [Brown et al., 1991; Blair and Zahm, in press]. Similar information is needed for farmworkers.

In contrast to studies of most other occupations, questionnaires covering lifetime occupational histories of farmworkers must also inquire about early childhood years. Children perform a substantial amount of the farm labor in the United States. According to current law, they may work at age 12 years in any crop and as young as 10 years to harvest potatoes and strawberries. Historically and even today, child farm labor has begun much younger [Meister, 1991].

Exposure monitoring. Case-control studies need lifetime duration, intensity, frequency, and cumulative exposure data or relative rankings to explore associations with cancer. There is a wealth of monitoring data on agricultural pesticide exposures, although studies of applicators outnumber studies of farmworkers. The challenge is to use the monitoring data on current exposures to help reconstruct historical exposures. The results of current exposure monitoring also can be used to help develop the most sensitive questionnaires possible and to confirm the relative exposure rankings suggested by the responses to the questionnaire. Development and validation of questionnaire exposure indices for use in epidemiologic studies are underway for farmers [Blair et al., 1990; Mandel et al., 1989; Stallones and Reif, 1991], but more research is needed for farmworkers.

Biological monitoring studies that compare seasonal and migrant farmworkers would be useful. The two types of farmworkers may perform similar tasks and have the same exposures, but their housing, access to tubs or showers, and laundry facilities vary, which could affect the received dose. A study of migrant and seasonal

farmworkers with similar tasks and exposures, comparing the absorbed doses of the two groups, would indicate whether the disease risks of the two groups are likely to be similar. This information would help us to evaluate whether epidemiologic research of seasonal farmworkers, which may be logistically easier, would be applicable to migrant farmworkers. In some areas of the country, however, seasonal and migrant farmworkers perform different tasks and need to be evaluated separately.

Nonoccupational exposures. To evaluate cancer risk, nonoccupational exposures must also be assessed. These exposures include nonoccupational exposures to pesticides and other farming hazards through mechanisms such as contaminated drinking or bathing water, contaminated living areas, contact with contaminated work clothing, spraying operations drift, and spraying accidents. Other critical nonoccupational factors that must be assessed include diet, tobacco use, alcohol consumption, family history of cancer, medical history, and use of herbal folk remedies. The epidemiologic methods for collection on some of these other factors are well developed in comparison to assessment of historical agricultural exposures. Many surveys of farmworkers have included some of these factors [Mines, 1981; Rust, 1990; Watson et al., 1985; Kaufman et al., 1975], but the methods to study other factors, such as nonoccupational exposure to pesticides, may need further evaluation for use in farmworker populations.

Molecular epidemiology. Molecular epidemiology utilizes biomonitoring for exposures and biomarkers of susceptibility, early disease, and disease. Use of molecular techniques can enhance a "traditional" epidemiologic study. Application of these techniques to cancer epidemiologic research of migrant and seasonal farmworkers should be considered. The distribution of some biomarkers vary by race, ethnic group, and age, however, and therefore it would be important to have information on the "normal" values and distributions in unexposed members of the Hispanic, African-American, Haitian, Asian, or other populations under investigation.

CONCLUSION

There have been few studies that have examined cancer risk in hired migrant and seasonal farmworkers. Such investigations are needed because of farmworkers' widespread opportunity for exposure to potential carcinogens, which often starts at an early age. This dearth of research is probably the result of concern over anticipated feasibility difficulties. This paper described some of the feasibility issues that need to be resolved and suggested a number of methodologic investigations which would help researchers plan successful etiologic studies. The results of such feasibility investigations and subsequent etiologic research may not pertain to locations, populations, or farming practices beyond those studied, but, even so, the information would contribute to assessing cancer in farmworkers.

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