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Using Routinely Collected Codes to Identify Medical Consultations About Pesticide Health Effects in California

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Abstract

Objectives. This study investigated the accuracy of codes that have been used to estimate the frequency of pesticide poisoning. Coding was evaluated for death certificates, hospital discharge abstracts, and poison control records concerning exposures that occurred in California.
Methods. Stratified random samples of California entries were selected from 1990-96 multiple cause of death tapes, 1994-96 hospital discharge files, and logs of two poison control centers. We reviewed records coded for pesticide toxicity or toxicity of related products. Probabilities of identifying pesticide products were computed for intentional vs. unintentional exposures and by categories of toxicity codes.
Results. Toxicants other than pesticides were identified as solely responsible for 14.5 percent of specifically pesticide-coded death certificates (standard error = 0.048) and for 16.7 percent of specifically pesticide-coded hospital records (standard error = 0.027). Among both hospital records and death certificates, the majority of antimicrobial cases carried codes for caustics/corrosives rather than for disinfectants.
Conclusions. Misinterpretations and differences in definition distort classification of pesticide-related health effects. Estimates of incidence based on statistical summaries of codes should be interpreted with caution.

The frequency and severity of health effects from pesticide exposure has become a subject of public discourse and government regulation in the United States[1-3]. Reliable data, however, remain sparse[4]. Routinely collected data sets such as death certificates and hospital discharge abstracts, which use the International Classification of Diseases (ICD) to describe the causes of mortality and morbidity, remain major sources of information on the epidemiology of pesticide toxicity[5,6]. Hayes and collaborators evaluated death certificate coding for pesticide toxicity for the years1961[7], 1969[8], and 1973 – 1974[9] under the seventh and eighth revisions of the International Classification of Diseases (ICD-7 and ICD-8). Blondell[5] adjusted his estimate of 1981 - 1992 pesticide fatalities by applying a correction factor derived from Hayes's work. Caldwell, Schuman and collaborators[10- 13] periodically review hospital records coded for pesticide toxicity in the State of South Carolina. Another group reviewed North Carolina deaths and hospitalizations from 1990 through 1993[14]. Apart from these limited efforts, we know little about the validity and usefulness of passive surveillance using routinely collected data.

This publication reports review of California death records (1990 through 1996) along with a sample of California inpatient hospital charts and poison control consultations (1994 – 1996). Although the ICD codes have changed substantially since Hayes's work, every effort was made to include all comparable diagnostic categories. This study represents the most comprehensive recent effort to evaluate the use of computerized vital statistics and hospital discharge data sets to ascertain pesticide-related illnesses and injuries.

Materials and Methods

Data sources

All United States death records and all nonfederal licensed California inpatient hospital discharges receive ICD codes. The World Health Organization publishes the ICD coding system, which is now in its ninth revision (ICD-9). The United States Public Health Service publishes an extension for use in American hospitals, ICD-9 CM, that provides additional specificity for some conditions. ICD-9 CM is completely compatible with ICD-9, and is identical to it with respect to all codes used in this work.

Death Certificates: Death records were selected from multiple-cause-of-death files prepared by the National Center for Health Statistics and obtained from the California Department of Health Services. These files provide 41 locations in which to store ICD-9 codes (including external cause of injury codes). One code is designated as the underlying cause of death. All codes were reviewed, and records were retrieved if any code of interest occurred in any location. Deaths without certificate numbers were dropped from the file after verifying that all of them occurred outside of California.

Inpatient Discharges: We selected hospital records from files maintained by the Office of Statewide Health Planning and Development (OSHPD). The State of California requires all nonfederal licensed hospitals to report data on all inpatient discharges semi-annually to OSHPD. The format prescribed for these reports includes locations for up to 25 diagnosis codes of the International Classification of Diseases, ninth revision, clinical modification (ICD-9 CM), and five additional locations for external cause of injury codes. In each category, one code is designated as principal.

Poison Control: Of the six poison control centers that served California during the study period, only the Central Valley Regional Poison Control Center collected narrative information for the full study period from 1994 through 1996. This center serves the most heavily agricultural area of the state. It contributed records for the entire period.

Enhanced data collection was adopted in September, 1995 by the University of California Davis Medical Center Regional Poison Control Center, which served the northeast quadrant of California. Four other poison control centers served other California regions during the period of interest, but their data were considered unusable because, besides lacking narrative, they had not been subject to standard poison control edit and verification procedures.

California Pesticide Illness Surveillance Program (PISP): The PISP maintains electronic files of all cases identified as potentially related to pesticide exposure. All the PISP records had been investigated by the Agricultural Commissioner of the county where exposure occurred. Scientists employed by the California Environmental Protection Agency's Department of Pesticide Regulation evaluated and coded findings from these investigations.

Criteria for record selection

Death Certificates and Inpatient Discharges: Death certificates and hospital records were selected based on diagnostic coding, ICD-9 for death certificates and ICD-9 CM for hospital discharge records. Records were selected if any of their diagnosis fields held ICD-9 CM codes 989.1 through 989.4 or E861.4, E863.0 through E863.9, E950.6, or E980.7. These seventeen codes constitute the "specific codes". Code E861.4, "accidental poisoning by disinfectants", was included as a specific code, since disinfectant products are regulated as pesticides. For regulatory purposes, this class of pesticides is referred to as "antimicrobial", and described as including sanitizers and disinfectants. The three terms are used interchangeably.

We also investigated hospital records that carried any of a broader group of "general codes," to maintain comparability to previous work and to collect as many pesticide-related cases as possible. We selected records that carried any of 42 diagnostic codes or 42 external cause of injury codes that indicate toxicity or chemical injury by unclassified substances or by classes of substances that include pesticides among other products (see Appendix A). Codes for metals and caustic materials were included based partially on Hayes's procedures. Inclusion of codes for irritant effects and for burns of internal organs was suggested by a 1985 study of hospitals in central Nebraska[15]. The ninth revision of ICD provides no code for fluorides, so it was not possible to replicate that aspect of Hayes's work.

For convenience of analysis, the codes were further subdivided into ten groups (identified in Appendix A). Among specific codes, antimicrobials and strychnine products were separated from other pesticide codes. Subcategories of general codes included metal toxicity, toxic effects of cleaning agents, caustics and corrosives, toxic effects of alcohols, miscellaneous toxicants, other or unspecified toxicants, and irritant effects (without reference to specific toxicants).

Poison Control: We selected poison control records for review if they carried a generic toxicant code likely to indicate pesticide exposure, indicated involvement of a medical professional, and included narrative fields to provide details of exposure, symptomatology, and clinical course. A poison control analyst assisted us in identifying generic toxicant codes likely to represent pesticides. We considered that medical professionals had been involved in calls recorded as having come from health care facilities, in those regarding patients in or en route to health care facilities, and in those in which the patient had been referred to a health care facility.

We made no attempt to ascertain pesticide toxicity that did not result in medical consultation. Because the legal requirement to report such cases is imposed on physicians, the PISP accepts medical consultation as a legislatively imposed threshold. Any inquiry into health effects not evaluated medically faces a serious challenge in validating the relevance of reported events.

PISP: All PISP records were considered eligible for inclusion in this study. The database records only cases in which pesticide exposure is suspected of causing or contributing to adverse health effects.

Sample selection

Death Certificates: For the period 1994 – 1996, all of the identified death certificates were purchased and reviewed, with the exception of those selected based on presence of seven very common ICD codes (identified with an asterisk in Appendix A). Those seven codes all represent alcohol toxicity, toxicity of unspecified substances, or toxicity of substances for which ICD provides no specific code. A simple random sample of somewhat more than ten percent of these was purchased and reviewed.

Only 17 pesticide fatalities were identified from death certificates within the 1994 – 1996 time period, so the sample was supplemented with the 38 death certificates identified from 1990 – 1993 that carried pesticide-specific codes. We took the opportunity to evaluate 98 additional 1990 – 1993 death certificates that carried uncommon general codes. Investigation reports were requested from county coroners for all deaths for which the printed death certificate did not clearly document a cause unrelated to pesticides.

Inpatient Discharges: The California Office of Statewide Health Planning and Development provided a file that contained all 12,830 hospital discharge records from 1994 through 1996 that carried codes of interest in any of 25 locations. We selected a two-stage stratified probability sample of discharges from this file for detailed review. In the first stage, we selected a sample of 100 hospitals stratified on the number of cases with specific codes identified per hospital. Twenty-five hospitals were selected randomly from each of four strata, including one composed of hospitals that reported no discharges with specific codes, but only general codes. Hospitals were not eligible for sampling if they reported no cases with either specific or general codes suggestive of pesticide-related illness or injury.

After the sample was selected, we contacted each hospital to ascertain the appropriate executives from whom to request participation. Letters explaining the project were sent to the Chief Executive Officer and the Director of Medical Records (or equivalent positions) at each hospital. After three weeks, hospitals that had not responded were contacted by telephone. We made a minimum of eight attempts to contact each nonresponding hospital, using telephone, facsimile, and electronic and conventional mail. Several medical records directors deferred decisions regarding hospital participation to the hospital's Risk Management or Quality Improvement departments. We followed up with certified letters to address specific concerns from these sources, and to facilitate local Institutional Review Board (IRB) approval, as appropriate.

Within selected hospitals, all records with specific pesticide codes were requested. Records with only general codes were grouped into three strata: Records coded for cyanide or metal toxicity held special interest for historical reasons, and constituted one stratum. Another stratum segregated records selected based on two especially common codes: toxicity of ethyl alcohol (980.0), which is an active ingredient in more than 100 registered pesticide products, and self-inflicted poisoning by other and unspecified solid and liquid substances (E950.9). All other general codes were grouped in the third stratum. Up to five records were requested from each stratum. From strata containing more than five records, a sample of five was selected randomly.

Poison Control: Poison control review began with the earliest records, those concerning consultations at the Fresno center early in 1994. Review of the first 100 records demonstrated the impracticality of reviewing all 2,756 records received. The file was then divided into two strata, one consisting of the most severe cases, and one of all others. Severe cases included fatalities, outcomes coded as "major", and all inpatient admissions (both medical and psychiatric). We reviewed all records in the severe stratum and a randomly selected 20 percent sample of the others. On statistical advice, we included the initial 100 records reviewed as a third stratum.

For the final six months of the study period, the PISP contracted with the Central Valley Regional Poison Control Center to explore the feasibility of poison control assistance in reporting pesticide cases to the PISP. During 1996, this center mediated transmission of 57 cases under this contract. Data received from poison control did not identify these cases. Those reviewed in this investigation were recognized after merging with PISP data and segregated in analysis.

PISP: Data on all PISP cases identified between 1994 and 1996 were converted electronically to the format used for recording hospital and poison control reviews. Because case reports sometimes arrive late, we also converted records received during 1997 that referenced exposures that occurred earlier. To maintain consistency with the standards applied to hospital and poison control records, all PISP records were included in analysis. Some of them had been evaluated after investigation as involving no pesticide. Their presence in the database, however, documented some consideration that exposure to a pesticide product had contributed to development of health problems.

Review and Coding

We reviewed hospital and poison control records individually to identify the toxicants involved and to determine the source of exposure. When case reports could be identified as derived from a common event, such as pesticide drift onto a group of people, we used the case identifier of the earliest case encountered as an event identifier, and entered it as a reference number in each associated record. Episodes involving 5 or more people receive particular attention from the PISP, so were identified as an analytic category.

Records were classified as pesticide-related if the responsible health professional(s) documented any consideration that exposure to a pesticide product (as defined by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA))[16] had contributed to the health problems about which medical professionals were consulted. The FIFRA definition states that pesticides include "any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest. …". This definition explicitly includes microbes as pests and the products that control them as pesticides, except when regulated as therapeutic agents by the Food and Drug Administration. Ingestions of household bleach were not classified as pesticide cases, since the product was unlikely to have been registered as a pesticide, and since there was clearly no intent to use the product as a pesticide.

Pesticide exposures were classified as intentional if the record indicated that the person intended toxic exposure to occur. The following exposures were classified as unintentional: exposures incidental to using a pesticide for its intended purpose, exposures that arose from misunderstanding about the nature of the product, self exposures of children up to 12 years old, and older individuals who exposed themselves while compromised by dementia, intoxication, or an acute psychotic episode. Exposure in attempting to treat delusional parasitosis, however, was classified as intentional.

Pesticides were identified as agricultural if their use was intended to contribute to production of an agricultural commodity. Exposures were classified as occupational if they occurred while the affected people were at work. Specific work tasks did not figure in determining occupational exposure.

One investigator reviewed and coded all poison control records. Two specially trained nurse-abstractors reviewed charts provided by cooperating hospitals and recorded the substances to which patients had been exposed, the mechanism and situation of their exposure, and the documentation available to substantiate exposure. They also abstracted signs and symptoms from the medical record, the results of significant diagnostic tests and therapeutic efforts, and indicated whether the case included consultation with specialists such as poison control centers, academic toxicologists, or government health and safety agencies. For records that contained no reference to pesticides, abstraction was limited to a brief narrative and list of toxicants identified. All of this information was entered directly into a computerized database with built-in error checks and detailed guidelines, based on the National Institute for Occupational Safety and Health's definitions of standardized variables for state surveillance programs. The first author independently abstracted a randomly selected sample of hospital charts. All identified discrepancies were resolved through group meetings and guideline revisions.

After coding, all cases that documented any consideration of pesticide involvement were merged into a file containing records collected during the study period by the PISP. A program extracted from the existing file all entries that occurred within two weeks of the event under consideration, and all that involved a victim of comparable age (within two years) to the current case. For each entry extracted, a similarity score was constructed by summing one half of any difference in age (in years), one third of any difference in date of exposure (in days), and one for each discrepancy in sex, occurrence of hospitalization, fatal outcome, occupational exposure, intent (self-inflicted vs. accidental), or exposure in the course of using the pesticide.

The investigator then reviewed a display of the event under consideration juxtaposed with an ordered list of potential matches, including names. Before a case could be entered as matched, the program displayed a complete list of variables, including identity of the pesticides involved, for the case under consideration and the proposed match. The investigator then made a final decision either to add the case as a separate event or to register it as another identification of an event already recorded. This produced a file in which one record represented each known event of medical consultation concerning possible health effects of pesticide exposure. When data sources differed regarding details of an event, information from the source indicating the greater level of certainty was maintained in the merged file.

Analyses were performed using Stata for Windows® statistical software, version 6.0, Stata Corporation, College Station, Texas. Case weights were computed as the inverse of the sampling probability, that is, as the ratio of the total number of entries in a stratum to the number of entries reviewed from that stratum. For hospital cases, this procedure was applied separately to hospital strata and to case strata within hospitals. The final case weight for hospital cases was computed as the product of the weights for the hospital and for the case within the hospital, and the hospital was identified as the primary sampling unit. Survey commands applied these weights to generate unbiased estimates of probabilities, total frequencies, and associated standard errors.

Results

All 501 death certificates requested were available for purchase and review. Investigations were requested from county coroners for the 110 that did not document a non-pesticide toxicant as the cause of death and were received for 106. Two had not been investigated, one was unavailable for technical reasons, and the coroner of one county did not respond to inquiries by letter and by telephone.

Among the 100 hospitals sampled, 72 ultimately agreed to participate in the study. Six additional hospitals were still awaiting approval from local IRBs when recruitment ended, and were excluded for that reason. Of the remaining 22 nonparticipants, six had closed and efforts to locate their records were unsuccessful. Six psychiatric hospitals declined to participate because of confidentiality concerns. The 72 participating hospitals provided 944 of the 1035 records

(91.2%) requested from those hospitals, although some hospitals only provided partial records because of confidentiality or cost concerns. Hospital records reviewed were found to resemble the full dataset closely with respect to distributions by age, sex, severity, disposition following hospitalization, and length of hospital stay. All regions of the state were represented in proportion to their contributions to the dataset with the exception of the San Francisco Bay area, where only eight hospitals agreed to participate of the 14 from which we requested participation.

Coding of Death Certificates:
Although neither specific nor general codes perfectly identified pesticide deaths, the predictive value of specific codes was much higher than that of general codes (Table 1). Intentional exposures did not differ significantly from unintentional exposures with respect to the predictive value of pesticide-related codes. When present in record locations other than the underlying cause of death, both specific and general codes were less likely to identify pesticide-related events. Of the 12 cases in which a pesticide-specific code was present but not the underlying cause of death, pesticide involvement was documented in only three. One of the three carried a general code of interest as its underlying cause of death.

Cyanide and strychnine were the most frequently encountered toxicants that occur both as pesticides and as other products. Among 34 deaths attributed to cyanide, a pesticide was identified as the toxicant source in one, which carried a pesticide-specific code. Non-pesticide products were identified in four fatal cases of cyanide poisoning. The remaining 29 provided no indication that pesticides were involved, but the possibility could not be ruled out.

A pesticide source was identified for five of 13 deaths from strychnine ingestion. The other eight provided no information on the source of the strychnine, although one of them described a form in which pesticidal strychnine is not distributed. Finally, we were unable to resolve pesticide involvement in eight other deaths that referenced poorly characterized toxicants or, in one case, no toxicant.

Misinterpretations resulted in assignment of pesticide-specific codes to death certificates that recorded toxicity from carbamates, phosphine, nicotine, and hydrofluoric acid. The ICD-9 CM table of drugs and chemicals provides both pesticide and non-pesticide interpretations of the first three, and does not designate hydrofluoric acid as a pesticide. The death certificates for these cases did not provide any indication whether the substances involved were pesticides, but the coroners' investigations clarified the absence of pesticide involvement.

Some categories of ICD-9 codes failed to yield any true cases of pesticide-related fatal illness or injury. No pesticide-related illnesses or injuries were located among cases retrieved by coding for alcohols, or among the small numbers of deaths attributed to cleaners or chemical burns (Table 2). Alcohols were correctly identified as the toxicants in several disinfectant ingestions, but all of those cases received the code for disinfectant toxicity. Among metals, only the codes for arsenic retrieved any pesticide cases. The predictive value of using nonspecific codes for other or unspecified toxicants to ascertain pesticide-related illnesses or injuries was less than 1%.

Coding of Inpatient Discharges:
We confirmed pesticide involvement in most exposures coded with a principal diagnosis specific for pesticides (Table 3). The predictive value of specific codes in the principal diagnosis field was significantly higher for intentional exposures (93%) than for unintentional exposures (78%). The predictive value of general codes in the principal diagnosis field (8.9% intentional; 5.8% unintentional) was substantially lower that that of pesticide-specific codes. Most of the pesticide cases that received only general codes (16 of 22) were antimicrobial exposures, and had received appropriate codes for exposure to caustics (12 cases), to chlorine, or for irritant effects (Table 4). Of the 29 cases reviewed in which a pesticide-specific code was present but not the principal diagnosis, pesticide involvement was documented in 15. Seven of the 15 carried general codes of interest as their principal diagnoses, as did one of the 14 that did not indicate pesticide involvement.

A single misunderstanding appeared to underlie the majority of the false positive codes specific for pesticide exposure: The acronym “PCP”, which can represent the pesticide pentachlorophenol, appeared in 46 hospital charts coded as pesticide-related, none of which mentioned the pesticide. In most cases, it abbreviated phencyclidine, an illicit drug. Some charts that referenced *Pneumocystis carinii* pneumonia and pancytopenia also used the abbreviation PCP. No common source was apparent for the charts miscoded in this way; they came from 16 hospitals in six counties.

Another group of hospital cases had been coded appropriately from a clinical perspective, but did not involve products classified as pesticides for regulatory purposes. Cases coded as pesticide toxicity included 11 related to pharmaceutical products for treating scabies. Such products contain the same active ingredients as insecticides, but are regulated by the Food and Drug Administration rather than the Environmental Protection Agency. For regulatory purposes, they are not pesticides. Similarly, 12 hospitalizations for exposures to ammonia received the code for disinfectant exposure, in accordance with ICD-9-CM instructions. No registered disinfectant, however, lists ammonia as an active ingredient.

Pesticide-specific codes varied in accuracy of application. Codes 989.2 (toxicity of chlorinated hydrocarbons) and E863.0 (accidental poisoning by organochlorine insecticides) both were assigned to various chlorinated substances, including herbicides, organophosphates, and chlorine gas. Code 989.3 (toxicity of organophosphates and carbamates) was assigned to 51 of the 60 organophosphate cases identified, but to only two of six carbamate cases.

We found no pesticide products among 255 charts coded for toxicity of various sorts of alcohols. As among the fatalities, isopropyl alcohol was correctly identified as a toxicant in some cases of disinfectant exposure, but retrieval did not depend upon that code. Codes for caustics and corrosives had a predictive value of 0.39 (standard error = 0.08) for identification of antimicrobials. All other general codes had predictive value of less than 0.1 for any sort of pesticide, and standard errors similar in magnitude to the estimate of predictive value.

Hospital charts generally were more informative than coroners' investigation reports, as they recorded the perspectives of several different professionals. Although they seldom recorded chemical verification of the reported exposures, they more frequently mentioned product names and descriptions, leaving a smaller percentage of toxicants unresolved. In most of those that remain unresolved, we could identify no source for toxicity coding. None of them provided any indication that a pesticide had been involved.

Coding of Poison Control Consultations:
All poison control log narratives were consistent with the codes assigned to them. They followed the clinical standard for coding, assigning the same codes to pediculocide exposures as to exposures to insecticides with the same active ingredients. This definition discrepancy resulted in finding pediculocides rather than pesticides involved in 24 of the 30 organochlorine entries reviewed and 12 of the 28 pyrethroid entries.

We found that certain poison control policies and procedures also led to difficulty in interpreting their data. Poison control centers offer consultation to practitioners and to the public; they do not attempt to verify the information presented to them. Among 78 poison control entries identified as related to events present in files of the PISP, 8 proved on investigation not to have involved pesticide exposure. Similarly, poison control centers do not require callers to identify themselves, and their records do not include any reliable event identifier. In some cases, multiple entries appeared to relate to the same event, but this could not be confirmed, so all entries were retained.

Summary:
We reviewed a total of 501 death certificates, 943 hospital chart abstractions, and 741 poison control records. We found explicit reference to pesticide exposure as a potential cause of health effects in 46 of the deaths, 246 of the hospital admissions, and 551 poison control contacts. We found that misinterpretations and variations in definition resulted in assignment of pesticide-specific codes to a significant number of intoxications that did not involve pesticides. We confirmed pesticide involvement more frequently in cases of intentional exposure and when specific codes were identified as principal than in accidental cases or those that listed pesticide codes in subsidiary positions.

Codes other than those specific for pesticides were effective only in locating cases related to antimicrobials. Weighted results indicated that antimicrobial cases are more likely to carry codes for caustic or corrosive substances than for disinfectants. Review of 446 death certificates and 630 hospital charts without pesticide-specific codes located only three deaths and six hospitalizations involving pesticides other than antimicrobials. These numbers were inadequate to derive a reliable estimate of the total number of such cases.

Discussion

This study was designed to assess the validity of using existing vital statistics and hospital discharge data sets to ascertain pesticide-related illnesses and injuries in a large, diverse state with substantial pesticide use. Review of original documents identified toxicants other than pesticides as responsible for 8 of 55 deaths that carried pesticide-specific codes, and for 78 of the 314 reviewed hospitalizations that carried pesticide-specific codes. These false positive rates were higher (33 to 86%) when pesticide exposure was listed only as a secondary or contributing diagnosis, although these estimates are unreliable due to small numbers. Most of the false positives resulted from misinterpretation of diagnostic terminology. The most frequent example was assignment of the code for fungicides to hospital charts that used the abbreviation "PCP".

Among hospital and poison control records, false positives also occurred among cases with specific pesticide-related diagnoses because of differences between the clinically based assignment of diagnostic codes and the regulatory designation of products as pesticides. In particular, the Food and Drug Administration regulates products for treatment of human scabies as pharmaceuticals, rather than placing them under the jurisdiction of the Environmental Protection Agency as pesticides. Scabicides may contain the same chemical toxicants as pesticide products, but a different agency has responsibility for assuring their safety. If researchers aim to identify circumstances in which regulatory intervention could improve safety, they must report results in terms relevant to the agencies that have jurisdiction.

The recent California legislative mandate to replace lindane with malathion as the fallback treatment for scabies undoubtedly will change the codes subject to this sort of misinterpretation. Future reviews will be needed to determine whether the frequency changes[16].

This study was also designed to determine whether passive surveillance systems using these data sources should capture only codes specific for pesticide exposure, or also codes for other or unspecified toxicants that might represent pesticides. We found that these general codes had less than a 4 percent probability of identifying pesticide-related deaths and less than a 9 percent probability of identifying pesticide-related hospitalizations, even when they were listed as the principal or underlying diagnosis. These predictive values dropped to less than 0.5% and 4%, respectively, when toxic exposure was listed only as a secondary or contributing diagnosis. Because these general codes are assigned more frequently than specific codes, however, even a small percentage of pesticide cases may represent a substantial fraction of the health burden from pesticides.

We designed the sampling scheme for the study with the intention of locating as many pesticide cases as possible, while still investigating other categories into which pesticide cases might fall. This produced small sample sizes for most general codes, and makes estimates of predictive values unstable.

The sampling scheme also proved to have biased the sample towards false positive pesticide-specific codes. All of the charts with specific codes for which we identified non-pesticide products came from hospitals that assigned specific codes to relatively large numbers of cases. These hospitals had been sampled with higher probability than those that reported fewer pesticide cases. Because this bias derived from the sampling scheme, weighted results are free of bias.

The identification of substantial numbers of false positives differs from the findings of the only previously published reviews of United States death certificates coded for pesticide toxicity [8,9], which reported only five percent false positives. That work differed from this in that records were then coded using the eighth revision of ICD, which provided only one code for pesticide toxicity. It also differed in reviewing only unintentional cases and cases in which intention was not recorded, and in that it did not include deaths related to disinfectant exposure. However, these differences cannot account for the higher rate of false positives detected in our work, since false positives occurred more frequently among unintentional than among intentional cases, and the six deaths attributed to disinfectants were coded correctly. The authors of these previous studies did not specify whether they reviewed codes for contributing factors in addition to the underlying cause of death.

Previous reviews of hospital records also reported low rates of miscoding. The earliest of the ICD-9 based South Carolina studies [11] noted that 20 of 334 charts were found to be miscoded, but did not specify standards for the determination. Subsequent publications [12, 13] did not address miscoding. The North Carolina study [14] mentioned that in 14 of 292 hospitalizations "poisoning was found not to be due to pesticides." We infer use of similar standards to those applied in this work from the fact that the North Carolina investigators separately evaluated the clinical evidence for intoxication. Applying standards intended to exclude effects of solvents and other inert ingredients, they reported that "46% of cases described as being hospitalized for pesticide poisoning had a relatively low likelihood of true poisoning"

These hospitalization studies reviewed only cases that received ICD-9 codes 989.2, 989.3, and 989.4, and did not describe how many diagnosis fields were available for review. In our sample, 251 records carried one of those three codes, of which 67 were found not to involve products legally defined as pesticides. Restricting analysis to those 251 records resulted in a weighted probability of 0.82 (0.76 – 0.88) of pesticide involvement. Among 197 hospitalizations that listed one of the three specific pesticide codes as the principal diagnosis, 48 were found not to describe pesticide exposure, for a weighted probability of 0.84 (0.78 – 0.90).

Of the 55 fatalities with specific pesticide codes, ten did not provide enough information to confirm or exclude pesticide involvement, so the results are heavily influenced by assumptions about these cases. Tables 1 and 2 present results in terms of confirmed pesticide involvement in fatalities, which effectively makes the assumption that none of the unresolved cases involved a pesticide. This convention is highly conservative, and probably inaccurate at least with respect to strychnine toxicity. If we assume instead that all of the unresolved strychnine exposures actually involved a pesticide, then the predictive value of a specific pesticide-related code would increase to 0.82, with a standard error of 0.05. This may well overstate the number of genuine pesticide cases. In his review of death certificates for pesticide toxicity [9], Hayes considered strychnine to be only potentially derived from a pesticide, and commented that "strychnine is used about as much as a drug as for pest control." Internet postings confirm that strychnine continues to be administered for therapeutic purposes, although it is not approved by the Food and Drug Administration for any indication.

It seems unlikely that unresolved cyanide cases involved pesticide exposure, since the victims' occupations in science and technology suggested other sources more readily accessible. Lack of documentation, however, prevented this study from determining the likelihood of pesticide products providing access to cyanide.

The key strength of this study is that we comprehensively and carefully evaluated the validity of ascertaining pesticide-related illnesses and injuries in a large and diverse state that consumes substantial quantities of pesticide. We used probability sampling to maximize the generalizability of our results. Furthermore, we applied a very broad set of ICD-9-CM codes and reviewed all available diagnosis and external-cause-of-injury fields to capture any death or hospitalization that might be attributable to pesticide exposure.

Records of fatalities were readily available, and the responsiveness of county coroners compared favorably with Hayes's experience in eliciting information from the physicians who certified deaths. Hospital participation was poorer. The most strenuous efforts elicited cooperation from only 72 of 100 hospitals, compared with rates in excess of 90% in South Carolina[10-13] and 100% participation in a Nebraska study[15]. This probably results in under-representation of intentional poisonings, since six of the 28 hospitals that did not participate declined because of confidentiality considerations related to their function as psychiatric institutions. Weighting does not correct for the limited participation by psychiatric facilities, because this characteristic of hospitals was not used for stratification.

These results support the practice of using only the principal ICD-9-CM discharge diagnosis, or the underlying cause of death, to identify cases of pesticide poisoning[5,6]. Pesticide-specific codes are listed as principal diagnoses more often than they appear in other positions, and have a higher predictive value when they are entered as principal diagnoses. Some general toxicant codes appear to be useful for locating antimicrobial cases. This work cannot provide a good estimate of the predictive value of non-specific toxicity codes for pesticides other than sanitizers, as review of 630 such charts located only six pesticide cases, one of which had been sampled with very low probability. More extensive reviews would be needed to justify adjusting estimates of pesticide morbidity or mortality based on the fraction of false positive or false negative results.

Review of original documents identified misinterpretations of diagnostic terminology in a significant number of hospitalizations and fatalities coded for pesticide toxicity. Definitions developed for clinical purposes were found to differ from those adopted by regulatory agencies, which may then be misled by case counts. Pesticide safety programs may use hospital discharge and death certificate data to estimate incidence, but should monitor the coding standards that apply and the frequency of misapplication of codes. Statistical summaries are vulnerable to over-estimation as well as under-estimation.

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16) Title 7 United States Code, Federal Insecticide, Fungicide, and Rodenticide Act Sec. 2 (u)

17) California Health & Safety Code (HSC) Section 111246

Table 1: Summary of investigation of California death certificates, 1990 – 1996, that received ICD-9 codes suggestive of potential pesticide involvement				
	Specific Codes[a]		General Codes[b]	
	Underlying Cause of Death	Other Death Certificate Entry	Underlying Cause of Death	Other Death Certificate Entry
Intentional Exposures[c]				
Antimicrobials Identified	0	0	3	0
Other Pesticides Identified	23	3	2	0
Non-Pesticide	1	1	46	19
Unresolved	5	1	29	0
Weighted Probability of Antimicrobial Identification (standard error)[d]	0 (0)	0 (0)	0.02 (0.014)	0 (0)
Weighted Probability of Other Pesticide Identification (standard error)[d]	0.79 (0.075)	0.60 (0.22)	0.16 (0.011)	0 (0)
Exposure Not Documented as Intentional				
Antimicrobials Identified	5	1	2	1
Other Pesticides Identified	5	0	0	1
Non-Pesticide	3	3	94	243
Unresolved	1	3	3	3
Weighted Probability of Antimicrobial Identification (standard error)[d]	0.36 (0.13)	0.14 (0.13)	0.028 (0.022)	0.00076 (0.00077)
Weighted Probability of Other Pesticide Identification (standard error)[d]	0.36 (0.13)	0 (0)	0 (0)	0.00076 (0.00077)
Total Death Certificates Reviewed	43	12	179	267
Total Death Certificates Available for Review	43	12	498	3170

a: Specific codes include nature of injury codes 989.1 through 989.4 and external cause of injury codes E861.4, E863.0 through E863.9, E950.6, and E980.7.

b: General codes include 84 codes thought to have potential to include pesticide exposures. They were selected from codes for burns or irritant effects, metal toxicity, toxicity of cleaners, caustics, alcohols, various individual toxicants, and toxicity of other/unspecified substances (see Appendix A).

c: Intentional exposures are those for which the record documents intention for toxic exposure to occur. They are represented by external cause of injury codes in the range E950 – E979.

d: Weighted results for stratified samples were generated by Stata for Windows® statistical software

Table 2: Summary of California Death Certificates, 1990 Through 1996, by Category of ICD-9 CM[a] Code					
ICD Code Category	Number Reviewed	Antimicrobials Identified	Weighted Probability of Antimicrobial Identification (standard error)	Other Pesticide Products Identified	Weighted Probability of Other Pesticide Identification (standard error)
Sanitizers	6	6	1 (0)	0	0 (0)
Strychnine	13	0	0 (0)	5	0.38 (0.14)
Other Pesticides	36	0	0 (0)	26	0.72 (0.075)
Metals	30	0	0 (0)	1	0.03 (0.03)
Cleaners	4	0	0 (0)	0	0 (0)
Caustics	22	3	0.22 (0.12)	1	0.04 (0.04)
Alcohols	112	0	0 (0)	0	0 (0)
Miscellaneous	53	2	0.024 (0.017)	0	0 (0)
Burns/Irritant Effects	12	0	0 (0)	0	0 (0)
Other/Unspecified Toxicant	213	1	0.001 (0.001)	1	0.001 (0.001)
Total	501	12	0.008 (0.003)	34	0.02 (0.004)

a. Results cover 101 codes of the International Classification of Diseases assigned to death certificates by the National Center for Health Statistics. See Appendix A for the individual codes assigned to each category.

Table 3: Summary of investigation of California inpatient hospitalization records, 1994 – 1996, that received ICD-9 codes suggestive of potential pesticide involvement				
	Specific Codes[a]		General Codes[b]	
	Principal Diagnosis	Other Diagnostic Entry	Principal Diagnosis	Other Diagnostic Entry
Intentional Exposures[c]				
Antimicrobials Identified	0	0	5	0
Other Pesticides Identified	85	6	2	0
Non-Pesticide	9	5	90	96
Unresolved	1	0	6	1
Weighted Probability of Antimicrobial Identification (standard error)[d]	0 (0)	0 (0)	0.041 (0.020)	0 (0)
Weighted Probability of Other Pesticide Identification (standard error)[d]	0.93 (0.019)	0.64 (0.19)	0.0093 (0.0074)	0 (0)
Exposure Not Documented as Intentional				
Antimicrobials Identified	19	4	11	0
Other Pesticides Identified	105	5	3	1
Non-Pesticide	56	8	205	132
Unresolved	9	1	38	40
Weighted Probability of Antimicrobial Identification (standard error)[d]	0.11 (0.03)	0.42 (0.14)	0.062 (0.023)	0 (0)
Weighted Probability of Other Pesticide Identification (standard error)[d]	0.67 (0.045)	0.21 (0.10)	0.010 (0.0064)	0.038 (0.038)
Total Hospital Charts Reviewed	284	29	360	270
Total Hospital Charts Potentially Available for Review	883	128	5458	6361

a: Specific codes include nature of injury codes 989.1 through 989.4 and external cause of injury codes E861.4, E863.0 through E863.9, E950.6, and E980.7.

b: General codes include 84 codes thought to have potential to include pesticide exposures. They were selected from codes for burns or irritant effects, metal toxicity, toxicity of cleaners, caustics, alcohols, various individual toxicants, and toxicity of other/unspecified substances (see Appendix A).

c: Intentional exposures are those for which the record documents intention for toxic exposure to occur. They are represented by external cause of injury codes in the range E950 – E979.

d: Weighted results for stratified samples were generated by Stata for Windows® statistical software.

Table 4: Summary of California Inpatient Hospitalizations, 1994 Through 1996, by Category of ICD-9 CM[a] Code					
ICD Code Category	Number Reviewed	Antimicrobials Identified	Weighted Probability of Antimicrobial Identification (standard error)	Other Pesticide Products Identified	Weighted Probability of Other Pesticide Identification (standard error)
Sanitizers	37	22	0.72 (0.1)	0	0 (0)
Strychnine	4	0	0 (0)	4	1.0 (0)
Other Pesticides	272	1	0.002 (0.001)	197	0.82 (0.03)
Metals	71	0	0.0 (0)	1	0.01 (0.01)
Cleaners	15	1	0.056 (0.056)	1	0.052 (0.052)
Caustics	39	12	0.39 (0.08)	1	0.03 (0.03)
Alcohols	255	0	0 (0)	0	0 (0)
Miscellaneous	16	2	0.14 (0.10)	0	0 (0)
Burns/Irritant Effects	80	1	0.015 (0.014)	1	0.07 (0.07)
Other/Unspecified Toxicant	154	0	0 (0)	2	0.007 (0.005)
Total	943	39	0.03 (0.009)	207	0.07 (0.01)

a. Results cover 101 codes of the International Classification of Diseases Clinical Modification assigned to inpatient discharge records by the hospitals where the patients were admitted. See Appendix A for the individual codes assigned to each category.