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DIRECT AND INDIRECT COSTS OF RABIES EXPOSURE: A RETROSPECTIVE STUDY IN SOUTHERN CALIFORNIA (1998–2002)

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ABSTRACT: The direct and indirect costs of suspected human rabies exposure were estimated for San Luis Obispo and Santa Barbara counties, California, USA. Clinic, hospital, and county public health records (1998–2002) were examined to determine direct costs for postexposure prophylaxis (PEP), and 55 (41%) former patients were contacted to voluntarily provide estimates of their indirect costs associated with receiving PEP. Additional costs due to public health and animal control personnel responses to rabid animals were collected, including diagnostic testing and wages. The mean total cost of a suspected human rabies exposure was $3,688, the direct costs per case were $2,564, and the indirect costs were $1,124 of that total. About one third of the total cost for suspected human rabies exposure was attributed to indirect costs (e.g., lost wages, transportation, and day-care fees), most of which were not reimbursable to the patient.

Key words: California, direct costs, economics, indirect costs, postexposure prophylaxis, rabies.

INTRODUCTION

In 2004, 6,292 cases of wildlife rabies were reported for the United States and Puerto Rico (Krebs et al., 2005). Most of these cases involved bats (*Lasionycterus* spp., *Myotis* spp., and *Pipstrellus* spp.), coyotes (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), raccoons (*Procylon lotor*), red fox (*Vulpes vulpes*), and skunks (*Mephitis* spp. and *Spirogola putorius*) (Krebs et al., 2005). Although the number of human deaths due to rabies is low (the median approximates three deaths per year), the increased numbers of wildlife rabies cases have coincided with increased suspected human exposures (Childs, 2002).

The first confirmed case of domestic canine rabies in California occurred in 1898; however, historical writings allude to the disease in both animals and humans more than 60 yr earlier (Humphrey, 1971). During the 1930s, domestic canine rabies reached epidemic proportions (>2,000 cases annually); these cases subsided greatly (<25 cases annually) during the 1950s after implementation of local pet vaccination ordinances and a mandatory statewide dog vaccination program for counties declared "rabies endemic areas" during outbreaks (Humphrey, 1971). Since the reduction of domestic canine rabies during the 1950s, there has been a marked increase in wildlife rabies cases. Today, only bat and skunk variants of the rabies virus are considered enzootic in California (Crawford-Mitsza et al., 1999).

Human exposures to wildlife rabies entail a variety of veterinary, medical, legal, and insurance costs (Meltzer and Rupprecht, 1998a). Human postexposure prophylaxis (PEP) (made up of human rabies immune globulin [HRIG] and human diploid cell vaccine [HDCV]) and pet vaccinations are probably the two greatest factors determining the societal cost of rabies (Meltzer, 1996). Few empirical studies of the direct or indirect costs associated with wildlife rabies have

been reported, and none have quantified the myriad of personal indirect costs related to PEP that are incurred by individuals (Uhaa et al., 1992; Kreindel et al., 1998; Chang et al., 2002). Additionally, most reported studies of the economics of rabies have been criticized for using poorly documented data or inexact methods of defining costs (Meltzer and Rupprecht, 1998b).

In the 1990s, it was reported that between 16,000 and 39,000 persons received PEP annually in the United States (Krebs et al., 1998). Costs of PEP were reported to range between $700 and $5,000 (Uhaa et al., 1992; Kreindel et al., 1998; Chang et al., 2002); however, the price of PEP differs regionally due to the cost of living, and along with other medical services, increases regularly with inflation. Periodic estimates of the monetary costs of PEP are crucial to accurate economic assessments aimed at detailing the financial burden of this disease.

This article presents results of an archival and interview study to determine direct and indirect costs associated with human exposures to suspected rabid wildlife in two southern California counties. The study involved a retrospective approach, with follow-up interviews conducted of patient volunteers that had received PEP in San Luis Obispo (SLO) and Santa Barbara (SB) counties, California, USA.

MATERIALS AND METHODS

Selection of cases

Five years (from January 1998 to December 2002) of clinic, hospital, and public health agency records in SLO and SB counties were searched for cases of suspected human exposure to rabid animals. All cases involving administration of PEP were identified. Follow-up telephone interviews were then conducted with a sample of patient volunteers. The study was approved by The Committee for the Protection of Human Subjects, California Department of Health Services (Sacramento, California, USA).

Data forms

Three forms were prepared and used for records retrieval and telephone interviews (see Table 1 for a list of variables; the complete forms are available in an online-only appendix at United States Department of Agriculture (2005).

Form A (Local Public Health Costs) was a 12-item list of Animal Rabies Case History and a 20-item list of Costs to Local Government. These data were recorded by research staff by using clinic, hospital, and public health records from the two counties. Rabies case history data included incident information, laboratory test results for the animal, numbers of animals/humans exposed, circumstances surrounding the human-animal contact, etc.

Form B (Direct Medical Costs for Rabies PEP Treatment) was a seven-item list about billing costs for PEP. This form was filled out by researchers using records provided by the clinics, medical facilities, and public health offices. Form B was used to collect the direct medical costs associated with each human rabies exposure. These data included information about the location and start of treatment; method of payment; and direct costs required to perform PEP, such as charges for HRIG, HDCV, physician, and other charges.

Form C (Patient Interview) was a 53-item questionnaire that provided uniformity for the telephone interviews with each patient volunteer. These questions referred to the PEP and other treatment-related costs borne by the patient (e.g., lost wages, medicines for adverse effects of treatment, travel time, day care, and miscellaneous costs). Questions also attempted to identify insurance copay or deductible charges incurred by the patient (Table 1).

Procedures

Data collections occurred between April and July 2003. Initially, clinics, hospitals, and public health offices were visited by a researcher who completed data entry for Forms A and B on site. Each former patient was then sent a postcard requesting participation in a future interview. These individuals were told that they would be contacted for a response after 10 days. Patients that agreed to be interviewed (patient volunteers) then scheduled a convenient date and time and participated in a "structured" telephone interview; the interviewer sequentially read the questions contained in Form C to the patient and recorded the patient's answers.

Data from Forms A, B, and C were summarized using descriptive statistics; these data characterized sample demographics and rabies incidents. Cost estimates were comput-

TABLE 1. List of data entry categories and representative data items that made up records retrieval (Forms A and B) and telephone interviews (Form C).

Form A: local public health costs	Form B: direct medical costs for rabies PEP	Form C: patient interview[a]
Public health laboratory (e.g., relevant species, dates, case facts about animal incident)	Type/location of medical facility	Animal rabies exposure costs (e.g., specie, owner, exposure, injury, residency, agency assistance)
Municipal costs (e.g., animal control personnel, time, capture, euthanasia, quarantine, other)	Gender/age of patient	Clinic or hospital visit costs (e.g., referral, physician visits, PEP location, PEP regimen)
Laboratory costs (e.g., rabies test, personnel exposure, other)	Method of payments (e.g., self-pay, insurance, worker's compensation, MediCare, other)	Treatment costs and lost wages (e.g., payments, occupation, income, missed work, lost wages)
Public health costs (e.g., employees and activities, time, personnel exposure)	Direct medical costs (total)	Adverse effects of PEP costs (e.g., reactions, visits for reactions, out-of-pocket costs, missed work)
Veterinary costs (e.g., potential veterinary involvement, time, personnel exposure, other)	Details of PEP regimen and costs (e.g., HRIG, vaccination series-partials recorded, vaccination date)	Travel time and other costs (e.g., travel and mileage, babysitting fees, other costs)
Other miscellaneous costs	Other direct costs	

[a] Interviews with patient volunteers (or parents/guardians) were "structured" (i.e., questions were posed in the same way to all respondents).

ed based on verified values among forms. We converted all direct medical (PEP) cost and computed all net present values for cited PEP costs by using the medical component of the Consumer Price Indexes (CPIs; United States Department of Labor, 2005); all indirect cost values were converted to 2004 US dollars based on CPIs for urban consumers (Economic Research, 2005).

Estimated case costs

Total cost (TC) per case of suspected human exposure to rabies was estimated as the sum of the direct costs (DC) and indirect costs (IC) paid by patients, public heath agencies, and county animal control units for rabies-related charges (Fig. 1).

Estimates of TC and IC were derived using the following formula where *pep* is cost of PEP, *med* is other medical costs, *ph* is entailed public health costs, *ac* is animal control costs, *o* is other indirect costs, *tt* is travel time costs, *lw* is lost wages, and *alt* is alternative medicines for adverse reactions.

$$TC = \overbrace{(pep + med)}^{DC} + \overbrace{(ph + ac + o + tt + lw + alt)}^{IC}$$

This equation was used to calculate average DC and IC estimates as well as minimum and maximum values. We used all DC and IC mean charges to determine mean TC; minimum and maximum values of specific charges were then reported to provide estimates of dispersion. The DC values were obtained from Forms B and C, whereas IC values were obtained exclusively from Form C responses. All costs reported and verified for the patient volunteers answering Form C were used in the final IC cost computations. Therefore, IC fiscal records for 32 of the 55 PEP patient volunteers were verified and used; disparities, missing data, or unknown costs for 23 patient volunteers resulted in exclusion of their fiscal data from only the IC portion of analysis.

Direct costs consisted of those costs associated with the provision and administration of PEP and associated PEP charges. Because rabies is monitored by public health agencies, nonpatient costs referred to the initial physician's diagnosis, subsequent administrations of PEP, and the cost of the vaccines (HRIG plus the five doses of HDCV). Direct patient costs included insurance copayments or deductibles plus any other specific medical charges directly paid by the patient for PEP.

Indirect costs were incurred by patient and nonpatient (government) entities. Patient IC referred to any lost wages, travel costs, alternative medicine costs, or other outlays related to the patient volunteer receiving PEP, such as babysitter fees, day-care charges, long-distance telephone costs, and psychological

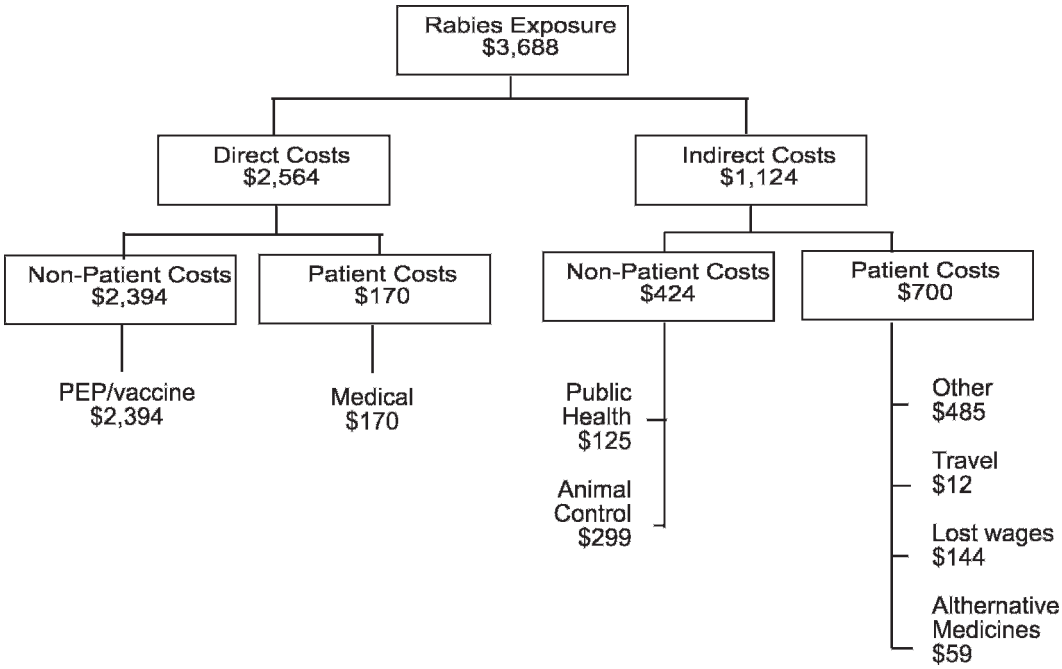

FIGURE 1. Average costs associated with rabies exposure. Estimates derived from 55 patients from San Luis Obispo and Santa Barbara counties, California (1998–2002).

fees for counseling or anxiety treatment. Nonpatient IC included public health and animal control costs borne by county governments to contain the public health risk of the disease. The average salary of public health and animal control workers plus average transportation and investigational costs (e.g., diagnostic laboratory test to identify the rabies virus in animals) was used to value activities based upon the mean hours worked/traveled per case.

RESULTS

Patient demographics and rabies incidents

During the study period, 134 individuals in the two counties were involved in suspected human exposures to rabies virus and received PEP. Fifty-five (41%) of the individuals contacted agreed to be study volunteers and were interviewed. Several reasons were cited for nonparticipation, including individuals were not interested or did not have the time to participate, contact information was out dated and individuals had changed their phone number and mailing address, individuals did not return phone calls (three messages were left before giving up), and two individuals had died. These patient volunteers consisted of 27 male (49%) and 28 female (51%) patients with a reported mean age of 38 yr (range 0.6–77). Patient volunteers reported a mean income category of $30,001–$40,000 (range $20,001 to >$70,001); two patients declined to provide income information.

The animals involved in suspected exposures of the 55 patient volunteers consisted of 12 (22%) dogs, eight (15%) cats (*Felis catus*), 19 (35%) bats, four (7%) skunks, three (5%) foxes, and nine (16%) other species. Thirty-three (60%) and 14 (25%) incidents occurred within SLO and SB counties, respectively. Interestingly, eight (15%) rabies exposures occurred outside these counties (respondents returned to SLO and SB counties after exposure, with PEP administered in the respective county). Two suspected exposures occurred in other counties of California (Humbolt and Monterey), one

exposure occurred in Texas, and five exposures occurred in foreign countries (two exposures in Mexico, two exposures in Romania, and one exposure in the Philippines). Thirty-nine (71%) patient volunteers listed their residence as SLO County and 15 (27%) listed their residence as SB County; one respondent gave Washington state as the site of residency at the time of the incident.

During the study period, 1,765 animals were tested for rabies in SLO and SB counties; they were predominantly domestic pet and wildlife specimens with a few livestock specimens. Skunk specimens totaled 249 and 209 for SLO and SB counties, with an average of 49.8 and 41.8 suspected rabid skunks tested each year, respectively. Positive rabies tests were obtained for 56 (22%) and 71 (34%) of the skunks tested in SLO and SB counties, respectively.

Case cost estimates

Mean TC of a suspected human rabies exposure was $3,688 (range $721–$9,197) (Fig. 1). Mean DC equaled $2,564 (range $303–$6,455; 70% of TC) and IC equaled $1,124 (range $418–$2,742; 30% of TC). The mean nonpatient DC was $2,394 (range $293–$5,772), with one very low-cost value possibly reflecting a partial PEP. The patient DC mean was $170 (range $11–$682). Only 12% of those interviewed stated that they paid the full amount of the HRIG and HDCV treatments; the remaining patients paid a small portion through a copay or deductible.

Nonpatient IC (county public health and animal control departments) had a mean cost of $424 (range $259–$581) per case; the mean cost of animal control activities equaled $299 and accounted for roughly two thirds of this cost. Mean patient IC was $700 (range $161–$2,161). The largest portion (69%) of these costs was under the "other" category (mean $485; range $16–$1,854), which included day-care and babysitter costs associated with parent respondents' medical appointments for treatments or examinations. Mean values for patients' IC were travel ($12), lost wages ($144), and alternative medicines ($59) paid by the patient made up only 2, 21, and 8%, respectively. The single highest reported cost was by one patient who experienced severe adverse reactions to the PEP and visited a psychotherapist due to mental anguish from rabies exposure and treatment.

DISCUSSION

We conclude that indirect costs of suspected human rabies exposures can add one third to the direct costs commonly associated with these cases. Our findings also confirm that suspected rabies exposures exert sizable economic burdens on local municipalities and county governments in rabies endemic areas.

Only three empirical studies have sought to quantify rabies-related costs in the United States (Uhaa et al., 1992; Kreindel et al., 1998; Chang et al., 2002). These studies dealt with economic data from three eastern states where raccoon-variant rabies epizootics occurred during the 1980s and 1990s; the studies attempted to quantify pre-epizootic and epizootic shifts in rabies-related costs.

A study in New Jersey quantified raccoon rabies-related costs in Hunterdon and Warren counties by comparing 1988 costs (prerabies epizootic) with 1990 costs (year of rabies epizootic) (Uhaa et al., 1992). The study attempted to assess the benefits of oral rabies vaccination and incorporated some secondary costs associated with animal control (e.g., pet vaccinations, bite investigations, public health advertisements, and animal quarantines), laboratory diagnosis (e.g., specimen preparation and testing), and miscellaneous other costs (e.g., education, training, consultation, epidemiology, research, clerical, and administrative). Total two-county, municipal costs were estimated in 2004 US dollars at $1,743,351 versus $3,868,291 for 1988 and 1990, respectively. Exposures

where PEP was administered increased from two to 131 during these same years. Interestingly, these authors assumed that the indirect charges of lost time and earnings of patients due to suspected rabies exposures or to adverse reactions from PEP were "minimal."

A study in Massachusetts examined statewide reports of raccoon rabies between 1991 (pre-epizootic) and 1995 (soon after start of the epizootic) to assess trends in numbers of rabid raccoons; suspected human exposures; and PEPs before, during, and after the epizootic (Kreindel et al., 1998). The incidence of PEPs increased 26-fold between 1991 and 1995; this increase represented a jump from approximately 1.7 to 45 PEPs per 100,000 residents. No estimates of the indirect costs associated with this epizootic were reported.

More recently, Chang et al. (2002) reported extensive data on public health impacts related to mainly raccoon-variant rabies in New York state during the 1990s. In total, 56,947 animal and 61 human diagnostic tests for rabies were performed between 1993 and 1998; these tests led to 18,238 PEP administrations during the period. Roughly 16% of the animal specimens tested positive for rabies throughout the period, with positives peaking at 2,688 (23% of tests) in 1993 and declining to 1,097 (11% of tests) in 1998. Interestingly, no decline in PEPs occurred, because raccoons testing positive for rabies declined during the period; PEPS remained relatively high and stable. The average PEP cost/patient ranged between $769 and $1,136 and increased in a transitive manner across years of the study.

Our findings both agree and disagree with certain aspects of studies by Uhaa et al. (1992), Kreindel et al. (1998), and Chang et al. (2002). Differences are largely attributed to how specific cost components were isolated in this and previous studies for suspected rabies exposures. Converting PEP-only direct costs in the earlier studies to 2004 US dollars yields a mean estimate of $2,292, a cost relatively close to our $2,564 value, and readily explained by our inclusion of some ($170) patient DC (mean medical costs borne directly by the patient). Although the Kreindel et al. (1998) study focused strictly on direct PEP costs, it did not include indirect cost components; thus, our total case charges differ. The Uhaa et al. (1992) findings included both direct and indirect estimates of patient costs as well as the 1990 two-county costs of $18,810 for bite investigations, $34,724 animal confinements, $248,378 general rabies control salaries, and $36,035 animal specimen preparation for rabies diagnostics (17,572 specimens).

Economic uncertainty is associated with determinations of disease-related costs in assessing the potential savings from rabies intervention activities. Uncertainty refers to the variance of potential benefits and costs likely to be derived from a myriad of factors associated with these interventions (e.g., animal population size, vaccination efficacy, PEP costs, animal and control costs). Reducing uncertainty by empirical determinations of precise components of the benefit-cost structure will allow public health officials and other government representatives to make more rational fiscal policy decisions regarding control of wildlife rabies. Our costs of human rabies exposures did not capture all of the potential costs associated with rabies; and to date, such a study remains elusive. We did not sample the money spent by individuals who were not suspected of being exposed to rabies but may have dealt with possibly rabid animals, nor did we include estimates of indirect expenses needed to educate the public and public health workers about the disease.

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