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INCIDENCE OF TRAUMATIC SPINAL CORD LESIONS*

JESS F. KRAUS, CHARLES E. FRANTI, RICHARD S. RIGGINS, DANA RICHARDS and NEMAT O. BORHANI

The Departments of Community Health and Orthopaedic Surgery, School of Medicine, University of California, Davis, California 95616,

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INTRODUCTION

INJURY to the spinal cord is devastating and catastrophic. Its unfortunate sequelae have been recognized since early Egyptian times [1]. Since damage to the spinal cord almost always results in permanent loss of sensory and motor functions below the level of the injury, the best solution to the problem of spinal cord injuries is prevention.

There are no published data on the incidence of traumatic spinal cord injuries. Unpublished reports from studies conducted in Hawaii for the years 1965–1970 [2] and in Arizona during 1973 [3] show an annual incidence rate of 25 and 35 per million population, respectively. A 1970 unpublished report by Sharman and Owen [4] for the National Paraplegia Foundation estimates an incidence rate of 12.4 per million population. In all of these unpublished reports, the term incidence refers only to those persons admitted to a hospital with a diagnosis of permanent paralysis. Persons with transient paralysis or paresis and those who died prior to hospitalization were excluded from analysis.

For 1971, U.S. statistics estimate the prevalence of complete or partial paralysis due to injury at 145,000–170,000 persons, a rate of about 0.8 per 1,000 [5]. Descriptions of persons who sustained acute traumatic spinal cord injury† were limited to statistical summaries from records of patients admitted to spinal cord centers or hospitals [6–10].

We conducted an epidemiologic study of acute traumatic episodes of spinal cord injuries which occurred during a 2 yr period (1970 and 1971) in 18 northern California counties. The study was limited to acute traumatic episodes of spinal cord injuries because they represent 60–85 per cent of all persons hospitalized in spinal cord injury centers [1–2, 6–10] and because they share a common, preventable etiologic mechanism.

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†Unless otherwise specified, the term spinal cord injury used in this report refers to acute traumatic lesions and excludes injury due to degenerative or chronic conditions.

The results of our study of the incidence of traumatic spinal cord injury in this 18 county area will be presented in this and subsequent reports. This report focuses only on the methods utilized in case ascertainment, over-all rates of occurrence, and for population subgroups, mortality and case fatality rates, description of external cause of the injury, and description of functional impairment among those admitted to a hospital. Subsequent reports will deal with the clinical and pathologic aspects of spinal cord injury as well as additional epidemiologic features of specific subgroups of patients with various external causes of injury.

METHODS AND MATERIALS

An expert advisory committee was established to assist in the specification of definitions and criteria; pretest of data abstract techniques and forms; establishment of quality control methods in case ascertainment and data recording; review of questionable cases; and classification of injuries and resulting impairments. The members of this advisory committee* included faculty representatives from the University of California, Davis, School of Medicine, Departments of Community Health, Physical Medicine and Rehabilitation, Orthopedic Surgery, Neurosurgery, Pathology, and Internal Medicine.

Definition of spinal cord injury and criteria of incidence

For purposes of this study, a spinal cord† injury was defined as an acute, traumatic lesion of the spinal cord, including trauma to the nerve roots which resulted in varying degrees of motor and/or sensory deficit or paralysis. Spinal cord lesions resulting from chronic degenerative disease were not included in the study. The diagnosis of a spinal cord injury and the resulting deficits were accepted as recorded in the hospital admission or discharge record, autopsy protocol, or other medical record by an attending physician.

The injury must have occurred to a usual resident of the 18 prespecified northern California counties (regardless of place of occurrence or place of treatment of the injury) and in the calendar years of 1970 or 1971 to have been included as an incidence case. No restrictions were placed on the type of traumatic events (external cause) that resulted in the lesion or on the number or extent of other nonspinal cord injuries involved.

Reference population and geographic region

The population at risk of injury was defined as the usual residents of the 18 northern California counties (Fig. 1). This area represents a population (according to the 1970 United States Census) of slightly more than 5.8 million persons or 29.1 per cent of the state's population. The counties involved included Shasta, Tehama, Nevada, Placer, and El Dorado (representing the mountain region of northern California); Butte, Yuba, Sutter, Yolo, Sacramento, San Joaquin, and Solano (representing the central

*Hereafter referred to as the Spinal Cord Injury Committee.

†The anatomic definition of spinal cord used in this investigation is that part of the central nervous system which is located in the vertebral canal, extending from the level of the foramen magnum to about the level of the third lumbar vertebra. It also includes the sheaf of roots of the lower spinal nerves (known as the cauda equina) which descend from the inferior aspect of the spinal cord within the vertebral column to the site of their emergence between the vertebrae.

valley region of northern California); and Contra Costa, Alameda, Marin, San Francisco, San Mateo, and Santa Clara (representing the coastal region of northern California).

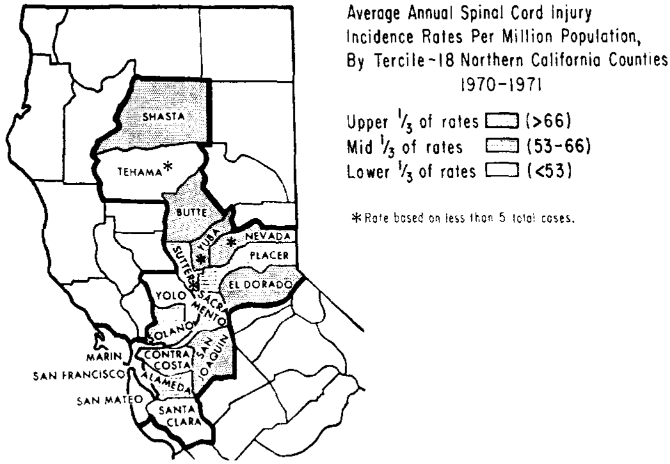

FIG. 1.

The aforementioned counties were selected in an attempt to include in the study area a cross-section of different physical and climatic environments, population subgroups, and human activities. Collectively, the 18 counties include large areas devoted to agricultural, recreational, and industrial activities; it includes many large and medium-sized cities as well as numerous smaller towns inhabited by a mixture of socioeconomic and ethnic population subgroups.

Method of case ascertainment

Case ascertainment included a systematic and exhaustive review of records, files, and reports from all hospitals and coroner's offices in each county and from the records of the State of California Departments of Health (Crippled Children's Service), Rehabilitation, and Industrial Relations (Workmen's Compensation).

Prior to the initiation of the study, each of the aforementioned resources, institutions, and agencies was contacted by letter or in person by a member of the project staff to enlist cooperation and endorsement for the study. In addition, support and endorsement were obtained formally from the following agencies and organizations: California Medical Association, local county medical societies, Regional Medical Programs, California Hospital Association, the Northern California Hospital Association, area Medical Record Librarian Associations, California Coroner's and Public Administrators Association, and the State of California Departments of Health, Rehabilitation, and Industrial Relations.

Case ascertainment within the 18 county area involved three phases. The first phase, which was the principal method of ascertainment involved the review of all hospital admission records. The second phase, which was instituted to identify persons who died suddenly from a spinal cord injury, involved the examination of all autopsy protocols* for evidence of traumatic spinal cord lesions. The third phase involved the review of all records on file with the State of California Departments of Health (Crippled Children's Service), Rehabilitation, and Industrial Relations (Workmen's Compensation) to identify spinal cord injuries possibly missed during the two previous phases. Procedures used for ascertainment of persons with a spinal cord injury who were usual residents of the 18 county region but whose injury occurred outside of the region are discussed later in this report.

Case identification and data recording involved the listing of all pertinent hospitals to be contacted within the geographic region of study, the scheduling of hospital visits for medical record review, the development and testing of case identification criteria, and the design and testing of a multipurpose abstract form which included instructions for data recording.

Once all persons with a confirmed spinal cord injury were identified and relevant medical data were abstracted, supplemental information regarding the circumstances surrounding the injury event was obtained from the California Highway Patrol (for motor vehicle crashes) or city/county police agencies (for other than motor vehicle crashes).

The listing of California Health Care Institutions published by the Journal of the American Hospital Association and the listing of accredited licensed California hospitals on file with the State of California Department of Health were used to identify hospitals located within the geographic region of study. From these lists, certain special purpose hospitals, such as those used exclusively for psychiatric or maternity patients and/or lacking emergency or primary medical/surgical care facilities, were excluded. The final list included a total of 154 hospitals selected for study.

By letter and telephone, contacts were made with the administrator of each hospital to seek cooperation and support for the study. Although approvals were often granted without delay, it was necessary to meet with the administrative and/or medical staff of 24 hospitals to explain the purpose and procedures of the study in detail and to answer questions which had been raised. The questions most frequently asked concerned methods to be employed to maintain confidentiality of the information collected. There were no refusals to review the medical records by any of the 154 hospitals.

Case ascertainment began in each county once approvals for access to medical records had been obtained from all hospitals in that county. As the approvals of the hospitals were being sought, specific procedures for case ascertainment were developed. This latter activity involved the selection of hospital admission indexing rubrics which could identify best all persons with a potential spinal cord injury who had been admitted to the hospital. The rubrics selected for each hospital varied depending on the system of indexing employed by that hospital. All hospitals utilized the International Classification of Diseases, Adapted (ICDA) [11], the hospital adaptation of the ICDA [12], or, to a lesser extent, the Standard Nomenclature of Diseases and Operations [13].

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*California law requires that all persons who sustain an unexpected, sudden, violent, or unattended death shall have a postmortem examination and a coroner's investigation. (Section 27491, California Government Code.)

After testing in several different hospitals, a final list of nine rubrics (Table 1) was adopted. The inclusion of ICDA 805 (fracture and fracture dislocation of vertebral column *without* mention of spinal cord lesion) in the list was necessitated because of the fact that during the pretrial phase of case ascertainment, patients with spinal cord injuries occasionally were found to have been classified according to this rubric. The medical record of each potential case was first examined to determine conformance with the definition of spinal cord injury adopted for the study. After careful review, each case was included in the study group if criteria of incidence were met.

TABLE 1

HOSPITAL ADMISSION INDEXING CODE NUMBERS AND RUBRICS USED FOR SPINAL CORD INJURY CASE ASCERTAINMENT*

Rubric No.*	Rubric
349	Other diseases of spinal cord (mono, hemi, para, quadriplegia)
725	Displacement of intervertebral disc
772.1	Birth injury without mention of cause: To spinal cord
805	Fracture and fracture dislocation of vertebral column without mention of spinal cord lesion
806	Fracture and fracture dislocation of vertebral column with spinal cord lesion
839	Other dislocation:Spine
958	Spinal cord lesion without evidence of spinal bone injury
959	Other nerve injury
03	Surgical operations: Operations on spinal cord structures

*International Classification of Diseases, Adapted (8th revision)

As the list of hospital admission indexing rubrics was being developed and pretested, a multipurpose data abstract form was also constructed and tested. The final abstract form contained space for recording information on the sociodemographic features of the person injured, a description of the injury event, results of autopsy (when appropriate), medical data on the anatomic and physiologic description of the lesion (including type of impairment), emergency and primary treatment procedures, orthopedic and neurologic evaluation, medical complications, and rehabilitation status and needs. Because of the confidentiality restriction imposed on us by every source of information utilized in this study, the survivor of the injury *was not* contacted. Thus, all information used in this study was obtained only from existing records and not by personal interviews.

A system of quality control to reduce ascertainment bias or data abstraction errors was instituted. This system included: (1) independent (blind) duplicate case ascertainment in a sample of hospitals by members of the Spinal Cord Injury Committee, (2) duplicate data abstraction by either the field supervisor or a member of the Spinal Cord Injury Committee on a 20 per cent random sample of cases identified, (3) random allocation of field staff to counties for purposes of case ascertainment and record abstraction, (4) contacting of attending physicians for clarification of any question on the medical record from our staff of medical record librarians, and (5) the restriction of case ascertainment and data abstraction staff to four full-time employees in order to minimize interobserver variation.

Case ascertainment was initiated in October 1972 and completed in January 1974—a period of about 15 months. The latter few months of this period were devoted to case ascertainment outside the 18 county region. For this purpose, additional case ascertainment procedures were implemented. One procedure involved the review of admission records of major hospitals located in counties on the periphery of the 18 county study region (i.e. California, Western Nevada, and Southern Oregon). The selection of peripheral area hospitals for case ascertainment was designed to be coincidental with a possible place of occurrence of an injury 250–300 miles from the person's usual residence in the 18 county region. Thirty additional hospitals were contacted, admission indexing files were searched, and, when appropriate, data on probable cases were abstracted. Case ascertainment in hospitals beyond this peripheral region was not practical. Another procedure involved a complete search of the files of the State of California, Crippled Children's Service, Department of Rehabilitation, and Workmen's Compensation to identify *all* possible cases which met criteria of incidence. Also, autopsy protocols from an additional thirty of the most populous counties in California, western Nevada, and southern Oregon were reviewed for potential cases.

The selection of 1970 and 1971 as the study years was made to utilize the 1970 United States Census data as a denominator for the derivation of incidence rates according to sociodemographic and other factors.

RESULTS

Incidence

Utilizing hospital medical records, Crippled Children's Service and Workmen's Compensation files, coroner's reports, and records of the California State Department of Rehabilitation, 760 persons with a confirmed acute traumatic spinal cord lesion were identified. One hundred and forty-one persons (18.6 per cent) did not meet incidence criteria of residency and year of injury occurrence, leaving a total of 619 persons with a spinal cord injury among the 5.8 million residents of the 18 county geographic area during 1970–1971, producing an average annual incidence rate of

53.4 per million. The percentage occurrence of incidence cases was about the same for each of the 2 yr under study (1970=49.3, 1971=50.7 per cent). Incidence by age, sex, race/ethnic group, external cause of the injury, or living status was not associated with year of occurrence of the injury (1970 or 1971). Hence, no further analysis will be included in this report in regard to incidence of spinal cord injury by year of occurrence.

For 430 of the 619 incidence cases (69.5 per cent), the county of injury occurrence was the same as county of residence. For slightly more than 17 per cent, the place of injury was within the geographic area of study but not in the county of residence. For slightly more than 13 per cent, injury was outside of the 18 county area.

Mortality and case fatality rates

There were 299 deaths* among the 619 cases, a mortality rate of 25.8 per million population and a case fatality rate of 48.3 per cent. Almost 79 per cent of the persons were dead-on-arrival at the hospital emergency room or taken directly to the county morgue. Sixty-four (21.4 per cent) expired during hospitalization. In all the autopsy protocols, 187 (62.5 per cent) listed spinal cord injury as the primary cause of death (Table 2). Spinal cord injury was listed as a 'significant' autopsy finding for 37 (11 per cent). For 75 persons (26 per cent) the autopsy protocol described damage to the spinal cord as part of massive multiple injuries (e.g. whole body crushing, decapitation, etc.).

TABLE 2

CONCORDANCE OF CLASSIFICATION OF DEATH CERTIFICATES WITH AUTOPSY PROTOCOLS ACCORDING TO DEGREE OF INVOLVEMENT OF SPINAL CORD AS THE CAUSE OF DEATH: 18 NORTHERN CALIFORNIA COUNTIES, 1970-71

Autopsy Protocol Classification-Spinal Cord Listed as:	Death Certificate Classification-Spinal Cord Listed As:				
	Immediate or Death as a Consequence of	A Significant Finding or Condition	Part of Massive Multiple Trauma	No Mention on Death Certificate	All Cases
Immediate or Major Cause of Death	163	0	14	10	187
Significant Finding on Autopsy	1	16	8	12	37
Listed as Part of Massive Multiple Trauma	1	2	69	3	75
All Cases	165	18	91	25	299

*In the context of this report, deaths included only those that occurred during the period from the injury event to hospital discharge. It is possible that persons hospitalized due to a spinal cord injury could have died as a result of their injuries but after discharge from the hospital. There was no practical way to determine deaths-to-date for each survivor after hospital discharge.

The relationship of spinal cord injury to cause of death as entered on the official death certificate was compared with the notation listed on the matching autopsy protocol for the group of 299 fatalities. Death certificates for 165 (55 per cent) of the fatalities showed the spinal cord injury as the immediate or consequential cause of death. Eighteen certificates (6 per cent) mentioned spinal cord injury as an 'other significant finding'. Twenty-five (8 per cent) of the death certificates failed to mention spinal cord injury, and for 91 (30 per cent), spinal cord injury was included with 'massive multiple fatal injuries'. The distribution of autopsy protocols according to similar classifications as death certificates are given in Table 2. Concordance between death certificate and autopsy protocol classifications was 90.5 per cent.

External cause of injury

Causes of spinal cord injuries were classified according to the 8th Revision of the International Classification of Diseases, Adapted. For ease of description and analysis, five general groups of causes were established. The basic ICDA external cause rubrics and code numbers which make up each group and their percentage distributions are given in Fig. 2. Almost 56 per cent of the spinal cord injuries were attributed to motor vehicle collisions. Of this group, one-third were single vehicle and one-third were multiple vehicle collisions.* About 10 per cent resulted from a collision involving a motorcycle. Almost 20 per cent were pedestrians struck by motor vehicles.

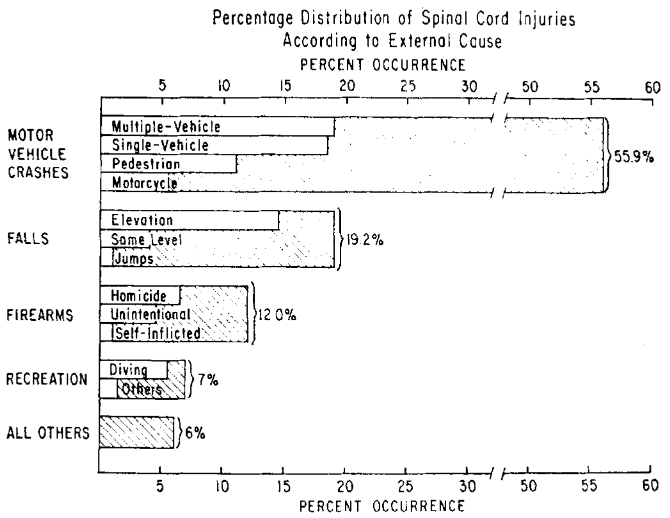

FIG. 2.

Falls accounted for about 20 per cent of all cases; 75 per cent of this number were due to falls from an elevated place, such as stairs and roofs.

Firearms accounted for 12 per cent of all cases. Homicide or attempted homicide due to firearms represented half of the persons injured in this group.

Seven per cent of all spinal cord injuries resulted from recreational or sporting activities. Injuries sustained while diving into swimming pools, rivers, and lakes accounted for 75 per cent of this group.

*Excluding motorcycles.

Six per cent of spinal cord injuries were due to 'other' causes which included non-firearm self- or criminally-inflicted injuries, being struck or caught by an object, airplane crashes, military injuries, and others.

TABLE 3

CONCORDANCE OF TYPE OF FUNCTIONAL IMPAIRMENTS DUE TO A SPINAL CORD INJURY AT TIME OF HOSPITAL ADMISSION TO THAT AT HOSPITAL DISCHARGE: 18 NORTHERN CALIFORNIA COUNTIES, 1970-1971

Type of Impairment at Hospital Admission	TYPE OF IMPAIRMENT AT HOSPITAL DISCHARGE							Total at Hospital Admission	DOA
	Quadriplegia	Quadriparesis	Paraplegia	Paraparesis	Other Paralysis[a]	Other Deficit[b]	Died in Hospital		
Quadriplegia	8 / 22[c] / 100[d]	2 / 5 / 3	- / - / -	- / - / -	- / - / -	2 / 5 / 4	25 / 68 / 39	37 / 100 / 10	-
Quadriparesis	- / - / -	66 / 62 / 93	2 / 2 / 3	6 / 6 / 9	4 / 4 / 7	7 / 6 / 13	22 / 21 / 34	107 / 100 / 28	-
Paraplegia	- / - / -	2 / 2 / 3	61 / 67 / 97	14 / 15 / 22	- / - / -	3 / 3 / 5	11 / 12 / 17	91 / 100 / 24	-
Paraparesis	- / - / -	- / -	-	37 / 79 / 58	2 / 4 / 3	7 / 15 / 13	1 / 2 / 2	47 / 100 / 12	-
Other Paralysis[a]	- / -	1 / 1 / 1	-	3 / 4 / 5	48 / 65 / 81	22 / 30 / 40	- / -	74 / 100 / 19	-
Other Deficit[b]	- / -	- / - / -	- / - / -	4 / 14 / 6	5 / 18 / 9	14 / 50 / 25	5 / 18 / 8	28 / 100 / 7	-
Total at Hospital Discharge	8 / 2 / 100	71 / 18 / 100	63 / 16 / 100	64 / 17 / 100	59 / 15 / 100	55 / 14 / 100	64 / 17 / 100	384 / 100 / 100	-
DOA	-	-	-	-	-	-	-	-	235

[a]Includes hemiplegia, monoplegia, central cord syndrome

[b]Includes transient paresis, or organ dysfunction

c % of row total

d % of column total

Functional impairment

Sixty-two per cent (384 persons) of those with a spinal cord injury were admitted to a hospital (a hospital admission rate of 32.2 per million population). Information on status of neuromuscular or organ impairment was available on all persons in this group. The remaining persons (38 per cent) were dead-on-arrival at the hospital or were taken directly to the morgue. For purposes of this report, six types of functional impairment at hospital admission and seven types of functional status at hospital discharge were developed. Admission impairment types included: quadriplegia,* quadriparesis,† paraplegia,‡ paraparesis,§ other paralysis,|| and other deficit.¶ Hospital discharge levels were similar but with the addition of a seventh type: in-hospital death. Data on concordance between admission and discharge diagnosis are given in Table 3, which shows 73 per cent concordance between admission and

*Paralysis of all four limbs (complete lesion at C3).

†Incomplete paralysis in all four limbs (complete or incomplete lesion C4-T1).

‡Paralysis of lower extremities (complete lesion T2-T9).

§Incomplete paralysis (lesion at L3-T2).

||Includes hemiplegia; Brown-Séquard syndrome (lesion to one side of spinal cord; monoplegia (nerve root avulsion); and central cord syndrome.

¶Other deficit (includes transient paresis, organ dysfunction).

discharge diagnosis (excluding deaths). Concordance was best for those with an admission diagnosis of paraparesis and poorest for those with hemiplegia, monoplegia, or central cord syndrome (other paralysis).

There were 64 in-hospital deaths. Case fatality rates were highest for quadriplegics (68 per cent) and quadriparesics (21 per cent).

Geographic distribution

Average annual incidence rates varied considerably, from a high of 89.4 per million population for Yuba County to a low of 40.4 per million population in Santa Clara County. In order to evaluate the relationship of incidence of spinal cord injury to geographic area, average annual county rates were grouped into low, medium, and high rate counties. The distribution of low, medium, and high tercile rates was not related significantly to geographic area (the association was not statistically significant possibly because of the small number of counties in each area). The apparent, but nonsignificant, aggregation of high rates for three of five mountain counties and low rates for four of six coastal counties could not be explained on the basis of differences in age distribution of the population among the three areas.

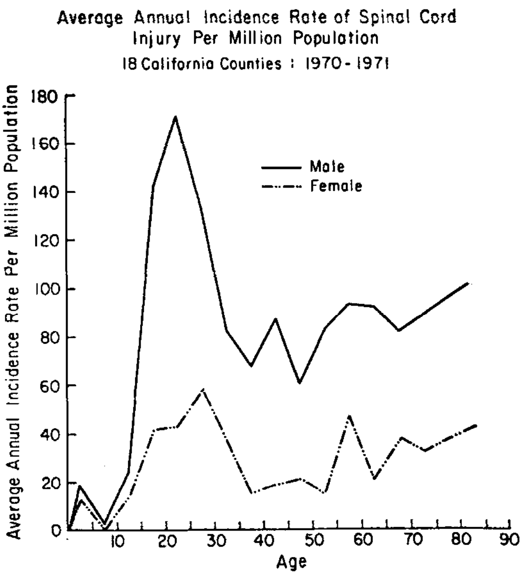

FIG. 3.

Age and sex

The incidence rate of spinal cord injury was significantly higher for males than for females (80.1 vs 27.5 per million population, $p \ll 0.001$). The average (and median) age at time of injury for males was 34.4 yr, with a range in age of 2–87 yr. For females, the average age was 36.2 yr (median 36.4 yr), with a range in age from 1–88 yr. Figure 3 illustrates average annual incidence rates of spinal cord injury by age and sex. Peak age of incidence for males was 20–24 yr. Peak age of occurrence for females was 25–29 yr. Incidence of spinal cord injury among males increased drastically after age 15, declined after the age of 30, and tended to increase gradually through the latter decades of life. A slightly different pattern was observed for females. That is, peak incidence was about 5 yr later than for males, and there was no peaking in rate at age 35–44, as observed for males.

Although there was no significant difference in mean ages between injured males and females, age distributions were significantly different from the expected based on the proportionate age-sex distribution of the population in the 18 county area (for males $\chi^2_{(8)}=169.0$, $p \ll 0.0001$, for females $\chi^2_{(8)}=48.7$, $p<0.0001$).

Figure 4 depicts sex–age-specific death rates* per million population. As was the case for age–sex specific incidence rates, death rates for all ages were higher for males than for females. The distribution of death rates for males shows one peak at age 15–24 yr followed by a sharp decline and then a generally increasing death rate for persons over the age of 40. Although the death rates for females were lower in magnitude than for males, they were generally similar in pattern with the exception that the initial peak in death rate was 10 yr later for females than for males (25–34 yr of age). Lowest rates in both sexes occurred below the age of 15, with another low rate at about age 35–44 for females.

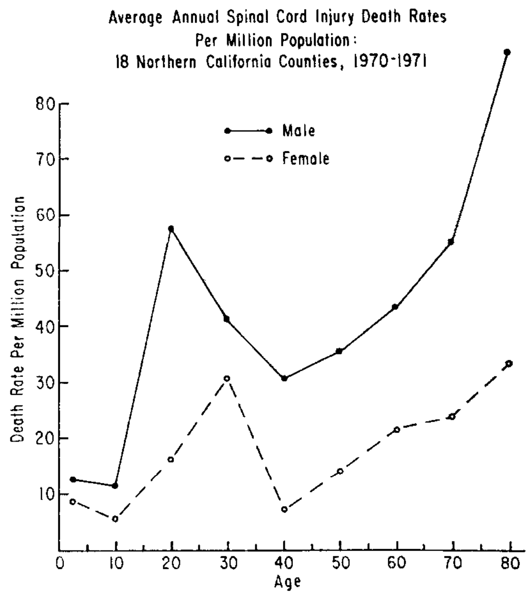

FIG. 4.

Highest fatality rates were seen for those less than 15 yr of age or older than 75 yr. The pattern of age-specific case fatality rates was not similar for males and females (Table 4). The case fatality rates were noticeably higher for females 25–34 and 45–64 yr of age than for males of the same age.

*Death rates include in the numerator any death which involved a spinal cord injury regardless if that injury was the immediate cause of death.

TABLE 4

CASE FATALITY RATES FOR PERSONS WITH A SPINAL CORD INJURY, BY AGE AND SEX: 18 NORTHERN CALIFORNIA COUNTIES, 1970-71

Age	MALES			FEMALES			BOTH SEXES		
	Persons Injured	Deaths	Case Fatality Rate (%)	Persons Injured	Deaths	Case Fatality Rate (%)	Persons Injured	Deaths	Case Fatality Rate (%)
<5	9	6	67	6	4	67	15	10	67
5-14	19	13	68	10	6	60	29	19	66
15-24	160	59	37	44	17	39	204	76	37
25-34	86	33	38	37	25	68	123	58	47
35-44	52	21	40	12	5	42	64	26	41
45-54	48	24	50	13	10	77	61	34	56
55-64	45	21	47	18	11	61	63	32	51
65-74	23	15	56	12	8	67	35	23	66
75+	15	13	87	10	8	80	25	21	84
ALL AGES	457	205	45	162	94	58	619	299	48

TABLE 5

AVERAGE ANNUAL INCIDENCE OF SPINAL CORD INJURIES ACCORDING TO RACE/ETHNIC GROUP AND SEX 18 NORTHERN CALIFORNIA COUNTIES, 1970-1971

Race/ Ethnic	MALES				FEMALES				BOTH SEXES				
	Persons Injured	Number Population	Annual Injury Rate/ Million	Relative[1] Incidence	Persons Injured	Number Population	Annual Injury Rate/ Million	Relative Incidence	Persons Injured	Number Population	Race-Specific Annual Injury Rate/ Million	Age-Adjusted Race Specific Rate/ Million	Relative Incidence
White	328	2,123,381	77.2	1.0	132	2,214,497	29.8	1.0	460	4,337,878	53.0	52.5	1.0
Mexican-American	39	360,303	54.1	0.7	3	361,560	4.1	0.1	42	721,863	29.1	33.1	0.5
Black	69	208,123	165.8	2.1	19	215,204	44.1	1.5	88	423,327	103.9	110.9	2.0
Other[2]	7	161,490	21.7	0.3	7	156,392	22.4	0.8	14	317,882	22.0	23.9	0.4
All Groups	457[3]	2,853,297	80.1	-	162[3]	2,947,653	27.5	-	619[3]	5,800,950	53.4	-	1.0

$\chi^2_{(7)} = 240.6$, p << .0001

[1]Relative incidence is defined as the ratio of each race-specific rate to that for the white group which represents 75% of the total population.
[2]Includes Japanese, Chinese, American Indian, and Filipino.
[3]Includes 14 males and 1 female with unreported race/ethnic identification.

Race/ethnicity

Average annual race-specific incidence rates were highest for blacks and lowest for persons of 'other'* race/ethnic groups (Table 5). The incidence of spinal cord injury cases among the ethnic groups was significantly different from that expected, based on the percentage race/ethnic distribution of the general population in the 18 county area ($\chi^2_{(3)}=69.5$, $p\ll 0.0001$). Relative incidence of injury (the ratio of the rate for each race/ethnic group to that of the white group rate) for black males was twice that of

*Includes Japanese, Chinese, American Indian, and Filipino.

white males. The race specific injury rate for persons in the 'other' and Mexican–American race/ethnic group category was only about half the rate of persons in the white group. The rate of injury for Mexican–American females was only one-tenth the rate for white females, but it should be noted that the injury rate for the Mexican–American group was based on small numbers.

As shown by the age-adjusted race-specific incidence rates in Table 5, high injury rates for blacks (165.8 per million for males and 44.1 per million for females) could not be attributed to a disproportionately large representation of young persons in the black population.

The ratios of male to female incidence rates (relative incidence) differ for each of the race/ethnic groups. Risk of spinal cord injury for persons in the 'other' race/ethnic category was similar for both sexes. Risk of injury for Mexican–American males was considerably higher than for Mexican–American females. Among blacks, risk of injury was 3.7 times higher for males compared with females. The injury rate for white males was 2.6 times that for white females.

As shown in Table 6, average annual death rates were highest for blacks and lowest for persons in the Mexican–American or 'other' (largely Oriental) race/ethnic groups. This pattern was similar for both males and females although the rates were higher for males of each race/ethnic group (except for those in the predominantly Oriental group). With the exception of the Mexican–American group, case fatality rates were higher for females than for males for each of the remaining race/ethnic groups.

TABLE 6

AVERAGE ANNUAL DEATH RATES PER MILLION POPULATION AND CASE FATALITY RATES (PERCENT) ACCORDING TO RACE/ETHNIC GROUP AND SEX: 18 NORTHERN CALIFORNIA COUNTIES, 1970-71

Race/Ethnic Group	MALE			FEMALE			BOTH SEXES		
	Number of Deaths	Death Rate	Case Fatality Rate(%)	Number of Deaths	Death Rate	Case Fatality Rate(%)	Number of Deaths	Death Rate	Case Fatality Rate(%)
White	150	35.3	46	78	17.6	59	228	26.3	50
Mex-American	17	23.6	44	1	1.4	33	18	12.5	43
Black	36	86.5	52	12	27.9	63	48	56.7	55
Other	2	6.2	29	3	9.6	43	5	15.7	36
ALL GROUPS	205	35.9	45	94	15.9	58	299	25.8	48

Marital status

Average annual incidence rates of spinal cord injury by marital status for persons over 14 yr of age were highest for divorced, separated, and never married individuals and lowest for widowed and currently married persons (Table 7). The distribution of spinal cord injury cases was significantly different from that expected, based on the distribution of the 18 county population according to marital status ($\chi^2_{(4)}=51.6$, $p \ll 0.0001$). The incidence rate of injury for widowed males was almost four times that for widowed females, and the incidence rate was more than five times for separated males than for separated females. The influence of age on the difference in rate by marital state could not be evaluated in that the distributions of the 18 county area population by age and marital status was not available for analysis.

TABLE 7

AVERAGE ANNUAL INCIDENCE OF SPINAL CORD INJURIES
ACCORDING TO MARITAL STATUS* AND SEX
18 NORTHERN CALIFORNIA COUNTIES, 1970-1971

Marital Status	MALES			FEMALES			BOTH SEXES		
	Persons Injured	Number Population	Injury Rate Per Million	Persons Injured	Number Population	Injury Rate Per Million	Persons Injured	Number Population	Injury Rate Per Million
Never Married	162	623,006	130.0	38	497,199	38.2	200	1,120,205	89.3
Currently Married (Not Separated)	194	1,310,347	74.0	70	1,305,112	26.8	264	2,615,459	50.5
Separated	11	34,227	161.2	3	49,848	30.1	14	84,075	83.3
Divorced	31	89,830	172.5	16	141,693	56.5	47	231,523	101.5
Widowed	11	49,587	110.9	14	235,428	29.7	25	285,015	43.9
All Marital States	409	2,106,997	97.1	141	2,229,280	34.8	585**	4,336,277	67.5

*Incidence includes persons 14 years of age or older
**Includes 35 persons with unrecorded martial status (28 males and 7 females)

Age–sex cause-specific incidence

Average annual cause-specific incidence rates for males are given in Fig. 5. Motor vehicle collisions accounted for the highest injury rates for all age groups. Injury rates for motor vehicle collisions as well as firearm and recreation-related causes were highest for persons 15–24 yr of age. Highest incidence of injury due to falls was observed for persons age 55 and older. Cause-specific incidence rates for females according to age are given in Fig. 6. Differences in the patterns and magnitude of cause-specific incidence rates between the sexes for the various age-groups were striking. For example, age-specific injury rates for all external causes were higher for males than for females. Also, peak age interval of incidence of injury due to motor vehicle collisions was 10 yr longer for females (age 15–34) than for males (age 15–24). In addition, peak age of injury due to firearms was 10 yr later for females than for males.

An association was found between race/ethnic group and external cause of injury ($\chi^2_{(12)}=65.5$, $p<0.001$). As can be seen in Table 8, blacks injured with firearms produced more than one-half of the total contribution to chi-square. For persons classified in the 'other' race/ethnic group, the frequency of falls exceeded expectation* about threefold. These results indicate an 'excess' of spinal cord injuries due to firearms among blacks and due to falls among Orientals (others).

*See Table 9 for derivation of expected frequencies.

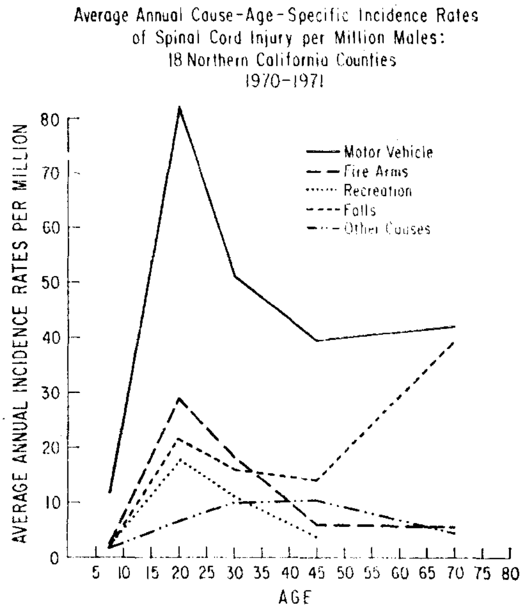

FIG. 5.

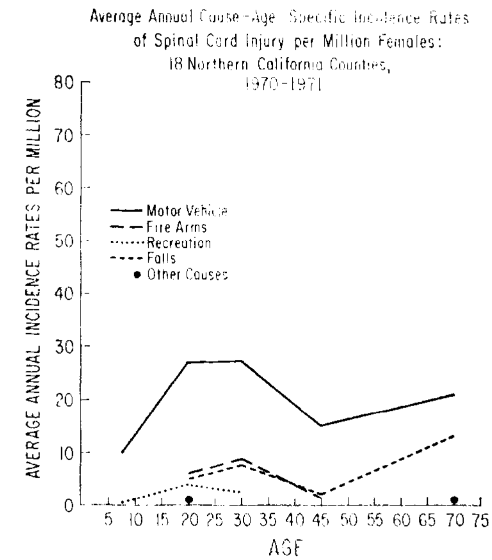

FIG. 6.

Case fatality rates were likewise related to external causes of the injury ($\chi^2_{(4)}=64.3$, $p\ll 0.0001$). The percentage case-fatality rates for motor vehicles, falls, firearms, recreational, and all remaining causes were 58.7, 30.3, 54.1, 4.7 and 48.6, respectively. The low case fatality rate for recreation-related causes of injury produced one-half of the contribution to chi-square, indicating that recreation-related spinal cord injuries were more often nonfatal than expected relative to case fatality experience due to other causes of spinal cord injury.

TABLE 8

OBSERVED AND EXPECTED* FREQUENCIES
OF SPINAL CORD INJURIES ACCORDING TO RACE/ETHNIC
GROUP AND EXTERNAL CAUSE
18 NORTHERN CALIFORNIA COUNTIES, 1970-1971

External Cause	Number	Race/Ethnic Group			
		White	Black	Mexican-American	Other
Motor vehicle	Observed	270	40	25	3
	Expected	257.4	49.2	23.5	7.8
	Ratio Obs. to Exp.	1.0	0.8	1.1	0.4
Falls	Obs.	90	11	7	8
	Exp.	88.3	16.9	8.0	2.7
	O/E	1.0	0.7	0.9	3.0
Firearms	Obs.	36	30	7	1
	Exp.	56.4	10.8	5.1	1.7
	O/E	0.6	2.8	1.4	0.6
Recreation	Obs.	38	2	2	1
	Exp.	32.7	6.3	3.0	1.0
	O/E	1.2	0.3	0.7	1.0
Others	Obs.	26	5	1	1
	Exp.	25.1	4.8	2.3	0.8
	O/E	1.0	1.0	0.4	1.3

$X^2_{(12)} = 65.5,\ p < .001$

*Expectation was based on the marginal row total for each cause times the marginal column total for each race/ethnic group divided by the grand total (eg. the expected number of white persons injured from motor vehicle causes is (338)(460)/604 = 257.4)

Rates of impairment

Type or level of functional impairment changed during hospitalization for a substantial number of persons with a spinal cord injury (Table 3). For purposes of the analyses which follow, greatest functional impairment at admission OR discharge was used to evaluate impairment with respect to other factors. The exclusive use of discharge diagnosis as the basis for the evaluation of impairment resulted in two additional categories: death and no paralysis (or no deficit), neither of which adequately described the functional outcome of the injury.

The most frequent form of impairment among persons hospitalized with a spinal cord injury was quadriparesis (110 persons—a rate of 9.5 per million population). Incidence rates of paraplegia, other forms of paralysis, paraparesis, quadriplegia, and other deficits were 7.7, 6.5, 4.7, 3.2 and 1.6 per million, respectively. Incidence of all forms of impairment was 3.5–4.5 times higher for males than for females for all age groups except those less than 15 yr of age (male to female incidence ratio of 1.3 : 1.0).

Age-sex specific impairment rates show a pattern similar to those for over-all incidence rates. Relative incidence (RI) was 4–5 times higher for males as compared with females for quadriparesis (RI 5.0), paraplegia (RI 4.7), and other forms of paralysis (RI=4.4). For quadriplegia, paraparesis, and other deficits, the RI for males was twice that for females.

Age-specific rates for types of functional impairment for males and females are found in Fig. 7. Peak rates of quadriparesis, paraplegia, and other forms of paralysis for males occurred for those 15–24 yr of age. Incidences of quadriplegia (for males) and quadriparesis for males and females were bimodal, with peak occurrences at ages 15–35 and 55 and older. Peak incidence of paraparesis and for other paralysis were seen at age 15–24 yr for females. With the exception of quadriplegia and paraparesis, the pattern of incidence by age between males and females was similar.

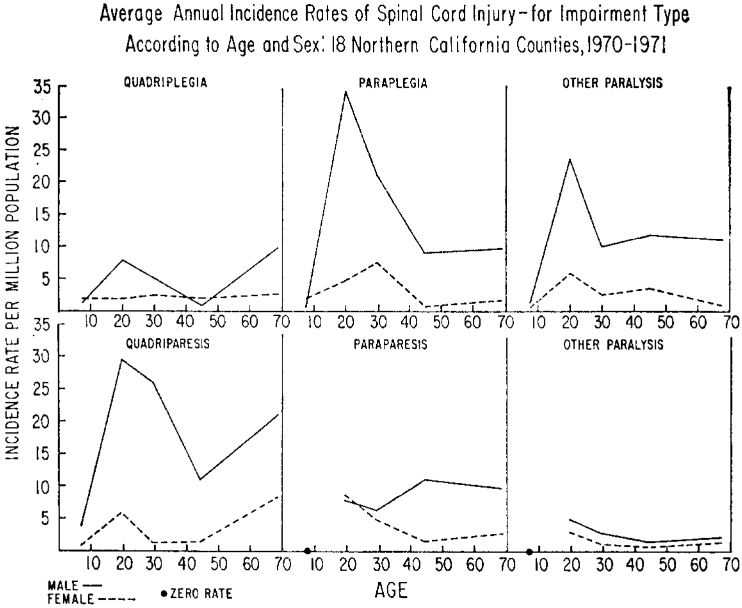

FIG. 7.

Type of impairment was not related to race/ethnic group.

Type of functional impairment was related significantly to external cause of spinal cord injury ($p \ll 0.0001$). Table 9 gives the observed and expected number of injured persons as well as risk ratios.* Risk of quadriparesis was highest for those injured in recreation-related activities (mostly diving injuries). The frequency of paraplegia among persons injured from firearms was 2.6 times that expected. These two impairment type-external cause groups contributed over 55 per cent of the magnitude of the chi-square statistics.

Quadriplegia resulted mainly from motor vehicle crashes, and quadriparesis resulted largely from motor vehicle crashes, falls, and from recreation-related injuries to the spinal cord. Paraplegia, likewise, was largely due to injuries resulting from

*Defined as the ratio of observed to expected cases with expectation based on row total times column total dividend by N=384.

motor vehicle crashes or firearms. Paraparesis and other paralysis occurred largely as a result of motor vehicle crashes and falls.

Motor vehicle crashes produced a significant number of all types of impairment and hospital admissions. Gunshot injuries to the spinal cord most often resulted in paraplegia.

TABLE 9

OBSERVED CASES, IN-HOSPITAL DEATHS AND EXPECTED* FREQUENCIES OF SPINAL CORD INJURIES FOR PERSONS ADMITTED TO A HOSPITAL: ACCORDING TO EXTERNAL CAUSE OF THE INJURY AND TYPE OF IMPAIRMENT--18 NORTHERN CALIFORNIA COUNTIES; 1970 - 1971

Type of Impairment	Number	External Cause										All Impairments	
		Motor Vehicle		Falls		Firearms		Recreation		All Others			
		No. Persons	No. Deaths	No. Persons	No. Deaths	No. Persons	No. Deaths	No. Persons	No. Deaths	No. Persons	No. Deaths	No. Persons	No. Death
Quadriplegia	Observed	21	[15]**	10	[7]	-		4	[1]	2	[2]	37	[25]
	Expected*	17.1		9.6		3.9		4.1		2.3			
	Ratio Obs. to Exp.	1.2		1.0		-		1.0		0.1			
Quadriparesis	Obs.	45	[10]	32	[8]	6	[2]	25	[1]	2	[1]	110	[22]
	Exp.	50.7		28.6		11.5		12.3		6.9			
	O/E	0.9		1.1		0.5		2.0		0.3			
Paraplegia	Obs.	43	[5]	15	[1]	24	[4]	-		7	[1]	89	[11]
	Exp.	41.0		23.2		9.3		10.1		5.6			
	O/E	1.0		0.6		2.6		-		1.3			
Paraparesis	Obs.	26	[0]	18	[1]	7	[-]	1	[-]	2	[-]	54	[1]
	Exp.	24.9		14.1		5.6		6.0		3.4			
	O/E	1.0		1.3		1.3		0.2		0.6			
Other Paralysis	Obs.	32	[-]	20	[-]	3	[-]	11	[-]	9	[-]	75	[0]
	Exp.	34.6		19.5		7.8		8.4		4.7			
	O/E	0.9		1.0		0.4		1.3		1.9			
Other Deficit	Obs.	10	[4]	5	[-]	-		2	[-]	2	[1]	19	[5]
	Exp.	8.8		4.9		2.0		2.1		1.2			
	O/E	1.1		1.0		-		1.0		1.7			
All Causes		177	[34]	100	[17]	40	[6]	43	[2]	24	[5]	**384**	**[64]**

* Number of expected cases are based on row total x column total ÷ N (384).
** [ ] Number died following admission to the hospital. $X^2_{(20)} = 78.6$, $p << .0001$.

The proportions of those surviving the acute period of hospitalization were generally similar for all external causes except recreation-related injuries (e.g. motor vehicles—81 per cent, falls—83 per cent, firearms—85 per cent, recreation—95 per cent. Survivorship with quadriplegia was poor regardless of external cause of the injury (i.e. motor vehicle—29 per cent, falls—30 per cent). No practical difference in the survival rate for persons with a diagnosis of quadriparesis was noted far those with a spinal cord injury from motor vehicle crashes (78 per cent) and those injured from falls (75 per cent). Ninety-six per cent of those with a diagnosis of quadriparesis from a firearm-inflicted injury survived.

DISCUSSION

Comments on methods

To our knowledge, a survey of this type has not been conducted previously. Thus, several points relating to the research design are pertinent to this report. In summary they are:

1. Survivors of spinal cord injury are frequently transferred to many different hospitals for various aspects of emergency, primary, and rehabilitative treatment.

Thus, record linkage must be an integral part of any effort to obtain complete medical data on persons hospitalized with a spinal cord lesion.

2. Autopsy protocols may, at times, be nonspecific with regard to spinal cord involvement. Many pathologists do not open the vertebral column to determine if a lesion has occurred but will make a judgment based on other postmortem findings (i.e. marked displacement of the vertebrae, crepitation of the skull on the atlas or axis), or diagnostic laboratory findings if the person was hospitalized prior to death. In this study, if there was doubt as to the presence or absence of a spinal cord lesion based on the information recorded on the autopsy report, the protocol was reviewed by a pathologist for a decision. If a clearcut decision on the presence of a spinal cord lesion could not be given, the case was excluded from further consideration.

3. Each hospital may list several (as many as 10) diagnostic rubrics for each person admitted with a spinal cord lesion. Those relevant to a spinal cord injury may not be the first ones listed in either the admission or discharge indexes.

4. Frequently, emergency room diagnosis mentions the *possibility* of a spinal cord lesion. Reliance on emergency room examination findings may lead to overestimation of negative cases. The most consistent source of information in terms of complete and authoritative description of the spinal cord injury was the hospital admission or discharge summary or a history sheet certified by the attending physician. The physician entry in the admission diagnosis, specialist evaluation sheet, or discharge summary sheet was the source of anatomic location and functional impairment data. Frequently, the admission diagnosis failed to mention a spinal cord lesion (or deficit) but anatomic and impairment data were recorded in the discharge summary. Occasionally, the reverse was true. Although information on the spinal cord lesion recorded at both admission and discharge was abstracted, the greatest level of functional deficit (impairment) was utilized for purposes of data analysis.

5. The extensive amount of time devoted to contacting the many agencies and organizations which might be interested in spinal cord injury research, thereby, obtaining their formal endorsement and support, was the single greatest factor in achieving 100 per cent access to all 184 hospitals and all the referral follow-up sources contacted.

6. Over 90 per cent of all incidence cases who were admitted to a hospital were identified from hospital admission/discharge indexes. The examination of Crippled Children's Service records as well as files of the State of California Departments of Health (Rehabilitation) and Industrial Relations (Workmen's Compensation) yielded less than 10 per cent of the total number of cases identified. Thirty-eight per cent of all cases were identified solely from county coroner reports. Although a significant proportion of deaths in nonhospitalized persons resulted from massive multiple trauma or causes not directly associated with injury to the spinal cord, it is noteworthy to point out that the underlying cause of death for almost two-thirds of the fatalities was a traumatic lesion(s) to the spinal cord. Incidence studies which do not incorporate a review of autopsy protocols will underestimate significantly the rate of occurrence of persons with spinal cord injuries. Reliance on death certificates to identify deaths from spinal cord injuries without matching autopsy records will grossly underestimate the incidence of such injuries.

Based on our data, we estimate the annual number of persons with a spinal cord injury to be about 11,200 in the United States. About 4200 of these will die before they reach a hospital for treatment. An additional 1150 will succumb during the period of hospitalization. The number of deaths due to late effects of spinal cord injury (i.e. after the initial period of hospitalization) is unknown. In this study, there was no practical way to determine deaths after initial hospitalization among those who sustained a spinal cord injury in 1970 or 1971. Long term follow-up studies to ascertain the full impact of spinal cord injury on mortality are lacking, and this subsequent impact should be the subject of future studies.

The average annual incidence rate and projected national annual estimate of new cases of spinal cord injury, based on data from this study, is substantially higher than that reported from previous studies [2–4]. Since definitions and methods of case ascertainment between our study and those in Arizona [3], Hawaii [2], and New England [4] differed substantially, comparisons are inappropriate. If the criteria of incidence, as defined in these three previous reports [2–4] (i.e. persons admitted to a hospital with paralysis due to a spinal cord injury), is applied to the data collected in this study, an incidence rate of about 32 per million population is found. This rate is similar to that reported for Arizona [3] and Hawaii [2] but is still three times higher than that found in New England [4]. It must be remembered, however, that use of only persons hospitalized with paralysis as a basis for enumeration will result in a gross underestimate of the total number of new cases of spinal cord injury occurring annually.

Injury rates for the external causes listed could not be derived due to the absence of exposure (denominator) information for the population. Future studies are needed to determine quantitative and qualitative indices of exposure to injury for the subgroups of causes presented. However, over one-half of all persons who sustained a traumatic lesion to the spinal cord were injured as a result of a motor vehicle crash. Motor vehicle crashes accounted for 45 per cent of all persons who survived the acute phase of a spinal cord injury and were discharged from the hospital. In addition, motor vehicle crashes are responsible for the major forms of impairment coincident with traumatic lesions to the spinal cord. Based on an average lifelong cost for care of $400,000 and an annual cost to the United States for support and treatment of all persons with a spinal cord injury of two billion dollars [14], it would appear logical to give high priority nationally to solutions of this problem. Any organized program to reduce the incidence of spinal cord injury and the tragic consequences of lifelong disability following such injuries must focus on the reduction of motor vehicle crashes and/or the severity of injuries sustained in them.

Males 15–34 yr of age accounted for the single largest category of persons with a spinal cord injury—most of whom were involved in motor vehicle crashes. Thus, survival following the acute period of injury most frequently will result in decades of disability or incapacitation. Almost three-quarters of those admitted to a hospital show some form of quadriplegia or paraplegia. Motor vehicle crashes contribute equally to all types of impairments from spinal cord injury, suggesting that the forces transmitted in such crashes are distributed broadly over the entire torso and not only to one segment of the spine. This pattern was not apparent for other external causes of injury. For example, among those admitted to a hospital with a gunshot injury to the spinal cord, the lesion most frequently resulted in paraplegia while recreation-related injuries (mostly diving) resulted in a complete or incomplete lesion in the lower part of the cervical spine. Survival rates* varied according to type of impairment and cause of the injury. Poorest survival rates were seen for quadriplegics regardless of external causes of the injury.

The reason for the higher case fatality rates for females age 25–34 yr compared with males of the same age is unclear. There were differences in spinal cord injury case fatality rates from motor vehicle crashes and firearms between the sexes within this age group, but not for males and females 15–24 or 35–44 yr of age. One possible explanation for the higher case fatality rates for 25–34 yr old females compared with males involved in motor vehicle crashes could be differential degrees of exposure, e.g. driver versus passenger status. Further research is needed to determine the reasons for the various discrepancies in case fatality rates between males and females for motor vehicle and firearm spinal cord injuries.

SUMMARY

The incidence of acute spinal cord lesions was studied in the population of 18 Northern California counties for the years 1970 and 1971. Case ascertainment included the complete review of all hospital admissions in these counties as well as the review of all death certificates, autopsy protocols, and records of the State of California Departments of Health (Crippled Children's Service), Rehabilitation, and Industrial Relations (Workmen's Compensation). The average annual incidence rate was 53.4 per million population, and the case fatality rate was 48 per cent. Almost 56 per cent of the spinal cord injuries were attributed to motor vehicle crashes. Incidence rates were three times higher for males 20–24 yr of age and females 25–29 yr of age. The pattern of case fatality rates were not similar for males and females. Age-adjusted incidence rates were highest for black males and lowest for males of Asian origin. Risk of spinal cord injury was highest for divorced or separated persons or those who have never been married.

The most frequent type of impairment among persons hospitalized with a spinal cord injury was quadriparesis. Functional impairment was related to the external cause of spinal cord injury.

The use of hospitalized persons as a basis for enumeration of spinal cord injuries will result in a gross underestimation of actual incidence.

Due to the extremely high costs for medical care of spinal cord injury survivors and the fact that over one-half of all persons who sustained a traumatic lesion to the spinal cord were injured as a result of a motor vehicle crash, any organized program to reduce the incidence of this tragic problem must focus on the reduction of motor vehicle crashes and/or the severity of injuries sustained in them.

Acknowledgement—A study of this scope could not have been possible without the generous cooperation of the northern California Hospital Association, California Hospital Association, Medical Record Librarian Associations, California Coroners and Public Administrators Association, and the State of California Departments of Health, Rehabilitation, and Industrial Relations. Without the cooperation of the California Highway Patrol and the many police and sheriff units, we would not

*Those that are discharged from the hospital alive compared to those admitted with a spinal cord injury.

have been able to gather information about the injury event. The cooperation given by all 184 hospitals contacted in the course of the study deserves very special recognition.

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