EPIDEMIOLOGICAL AND CLINICAL FEATURES OF SPINAL-CORD LESIONS FROM MOTORCYCLE CRASHES

Jess F. Kraus, Ph.D., Charles E. Franti, Ph.D., Richard S. Riggins, M.D., Nemat O. Borhani, M.D., Department of Community Health, School of Medicine, University of California, Davis, California 95616 (USA)

INTRODUCTION

Injuries to the spinal cord can be devastating, often with tragic consequences to the survivor, his family, and society. Since present treatment offers little hope of restoring neurologic function, prevention of such injuries and limitation of sequelae is presently the best approach to combating this catastrophic injury. A significant proportion of spinal-cord injuries related to motor vehicles involve motorcycles. This report describes the epidemiologic features of motorcycle crashes that produce spinal-cord injury, and the severity, types, and pattern of spinal-cord and other injuries sustained.

METHODS AND MATERIALS

The methods used in ascertaining cases of traumatic spinal-cord lesions in 18 Northern California counties have been presented elsewhere (1). For completeness, this report recapitulates important methodologic considerations.

Definition of Spinal-Cord Injury and Incidence Criteria. For purposes of this study, a spinal-cord lesion was defined as an acute traumatic lesion of the spinal cord, including trauma to nerve roots, that results in sensory and/or motor deficit. The diagnosis of spinal-cord injury and description of resulting deficits were accepted as recorded by an attending physician in the hospital admission or discharge record, autopsy protocol, or other medical record. All information used was obtained from existing records, not by interview.

For inclusion as an incidence case, the injury must have occurred in 1970 or 1971 to a usual resident of 18 prespecified Northern California counties (regardless of place of occurrence or place of treatment of the injury). The years 1970 and 1971 were selected to utilize 1970 U.S. Census data as a denominator in deriving incidence rates according to sociodemographic factors.

Reference Population and Geographic Region. The population at risk was defined as the usual residents of the 18 Northern California counties, a population of slightly more than 5.8 million persons (29.1 per cent of the state's population). Figure 1 shows the area included. The 18 counties are Shasta, Tehama, Nevada, Placer, and El Dorado (mountain region); Butte, Yuba, Sutter, Yolo, Sacramento, San Joaquin, and Solano (central valley region); and Contra Costa, Alameda, Marin, San Francisco, San Mateo, and Santa Clara (coastal region).

FIGURE 1

California

18 County spinal cord study area

Method of Case Ascertainment. Case ascertainment involved a systematic, exhaustive review of records, files, and reports from all hospitals and coroner's offices in each county, plus records of the State of California Departments of Health (Crippled Children's Service), Rehabilitation, and Industrial Relations (Workmen's Compensation). There were three phases to case ascertainment: 1) review of all hospital admission records (the principal method of ascertainment); 2) examination of all autopsy protocols for evidence of spinal-cord lesions; and 3) 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 in the previous two phases.

Preliminary to case ascertainment, hospital admission indexing rubrics were examined to determine which could best identify hospital admission having a potential spinal-cord injury. All hospitals used either the International Classification of Diseases, Adapted (ICDA), the hospital adaptation of ICDA, or, to a lesser extent, the Standard Nomenclature of Diseases and Operations. Tests of potential rubrics at hospitals led to adoption of a final list of nine hospital admission/discharge rubrics (Table 1). The medical records of each potential case with one or more of these rubrics was examined to determine conformance with the definition of spinal-cord injury and whether the incidence criteria were met.

Case ascertainment was begun in October 1972 and completed in January 1974. Several months were devoted to case ascertainment outside the 18-county region to identify persons with a spinal-cord injury who were usual residents of the 18-county region but injured elsewhere. Examined for this purpose were admission records of major hospitals in counties on the periphery of the 18-county study region (i.e., the remainder of California, western Nevada, and southern Oregon). A complete search was made of the files of the State of California Crippled Children's Service, Department of Rehabilitation

and Workmen's Compensation, to identify all possible cases meeting the criteria of incidence. Autopsy protocols were reviewed from 30 of the most populous counties in California, western Nevada, and southern Oregon.

TABLE 1. HOSPITAL ADMISSION INDEXING CODE NUMBERS AND RUBRICS USED FOR SPINAL-CORD INJURY CASE ASCERTAINMENT*

Rubric No.[a]	Rubric
349	Other diseases of spinal cord (mono-, hemi-, para-, quadriplegia)
725	Displacement of intervertebral disk
772.1	Birth injury without mention of cause
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

[a] International Classification of Diseases, Adapted (8th revision)

Official police reports were the source of information on the characteristics of the motorcycle involved and other features of the crash.

The 1976 version of the Abbreviated Injury Scale (2) (AIS) was used to assign numerical values to each injury identified from hospital records and/or coroner reports. The AIS codes and their descriptions are given in Table 2.

TABLE 2. ABBREVIATED INJURY SCALE CODE DESCRIPTIONS

Code	Description	Code	Description
0	No injury	5	Critical (survival uncertain)
1	Minor	6	Maximum (currently untreatable)
2	Moderate	9	Unknown
3	Severe (not life-threatening)		
4	Serious (life-threatening, survival probable)		

RESULTS

A total of 619 persons with a spinal-cord lesion were identified among the residents of the 18 county region: an average annual incidence rate of 53.4 per million population. There were, among the 619 cases, 314 deaths: 235 at the scene or dead-on-arrival at the hospital, 64 during hospitalization, and 15 from causes related to the spinal-cord injury in the four-to-five-year period following hospitalization. The case fatality rate was 50.6 per cent.

Figure 2 shows the percentage of spinal-cord injuries by category of external cause. Of the 619 cases, 346 (55.9 per cent) were from motor-vehicle collisions.

FIGURE 2

Percentage Distribution of Spinal Cord Injuries According to External Cause

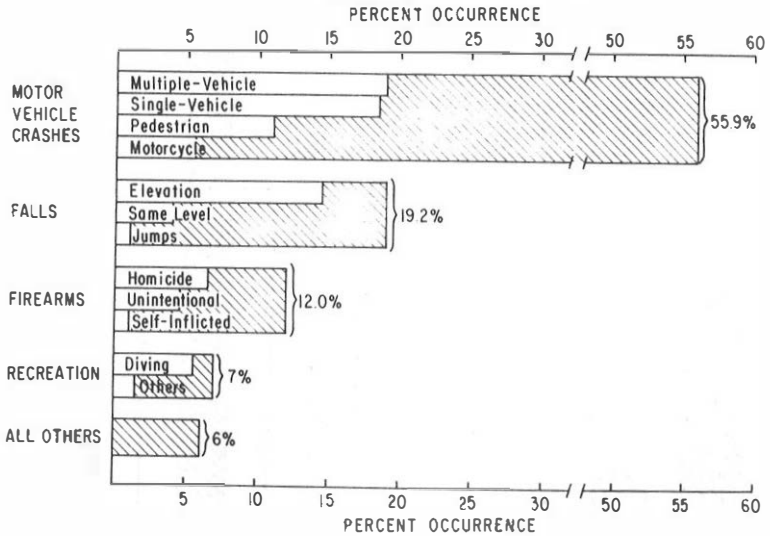


Figure 3 shows the percentage of injured persons by subcategory or motor-vehicle collisions, and the case fatality rate within each subcategory. Over 34 per cent of all motor-vehicle-related cases were from multiple-vehicle crashes, mostly involving two or more automobiles. Two-thirds of those cases died. Single-vehicle crashes accounted for 33 per cent of all cases, with a case fatality rate of 49 per cent. Pedestrian injuries accounted for slightly less than 20 per cent of the cases, but, of those, over 85 per cent died. Ten per cent of all injuries were among motorcyclists, and about one-third of those died. About four per cent were among bicyclists, and almost 70 per cent of those were fatalities.

Four categories of motorcycle crashes were formed to describe the general features of the collision that injured the spinal-cord of the driver and/or passenger. These categories included: collision with a stationary object; collision with a second vehicle; collision with a stationary object after the motorcycle had left the roadway; and motorcycle overturned on the road with-our secondary impact. Fifteen persons sustained a spinal-cord injury as a result of a crash with a second major vehicle (all passenger cars). Eleven injuries were caused by the motorcycle's leaving the road (at a curve in 9 of these 11 cases). Four injuries occurred when the driver lost control of the motorcycle and impacted with the roadway. Two cases resulted from a collision with a stationary object (both parked cars).

In Figure 4, the percentage of types of motorcycle crashes which resulted in one or more spinal-cord injuries is compared to that for a large group of motorcyclists seriously injured in crashes in Sacramento, California in 1970 (3). The data indicate that risk of spinal-cord injury from collision with roadside objects was twice that expected.

FIGURE 3

PERCENTAGE & CASE FATALITY RATES (CFR) FOR PERSONS WITH A SPINAL CORD INJURY BY CATEGORY OF MOTOR VEHICLE COLLISION

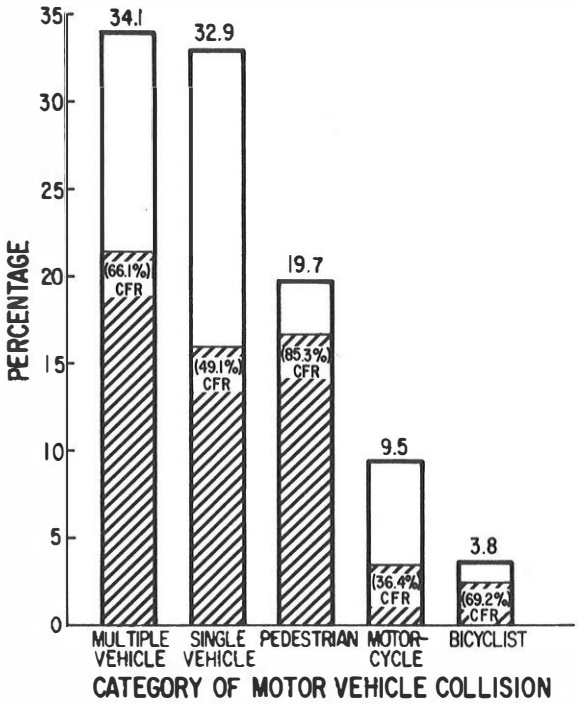
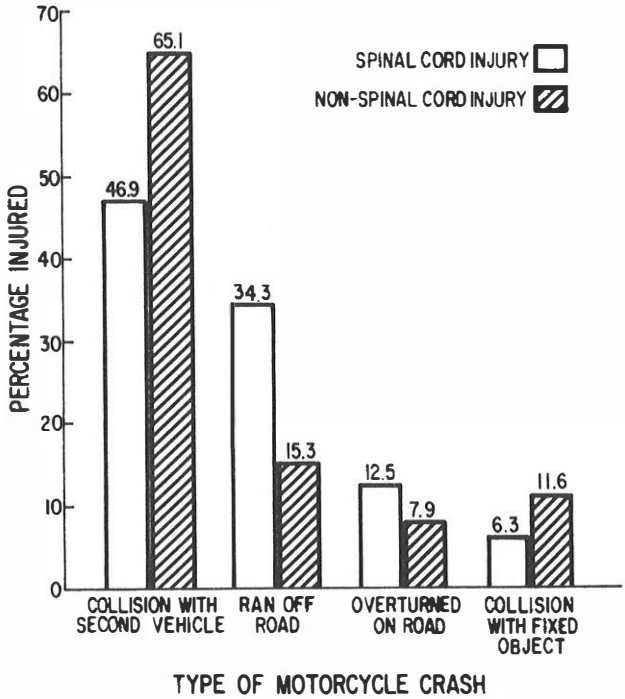


FIGURE 4

PERCENTAGE DISTRIBUTION OF SPINAL CORD & NON-SPINAL CORD INJURED MOTORCYCLISTS BY TYPE OF CRASH



Thirty-three motorcyclists had a spinal-cord injury--an incidence rate of 2.8 per million population. Their mean age was 23.9 years (range 14 to 41 years). This finding is consistent with data on age from a motorcycle-injury study conducted recently in Sacramento County, California (3). Table 3 shows that the age distribution of injured males was significantly different from the age distribution of males in the 18-county population. Two of the 33 injured persons were females (both passengers), and two of the 31 males were passengers. Type of crash was not related to age of the driver.

TABLE 3. OBSERVED AND EXPECTED FREQUENCIES OF SPINAL CORD LESIONS FOR MALES FROM MOTORCYCLE CRASHES

Age	Number of Injured Persons		
	Observed	Expected[a]	Ratio O/E
10-14	1	5.8	0.2
15-19	9	5.2	1.7
20-24	11	5.0	2.2
25-29	6	4.4	1.4
30-45	4	10.5	0.4
	31	31.0	1.0

$X^2_{(1)} = 18.6$, $p = 0.001$

[a] Expected frequencies based on the age distribution of males 10-45 years of age in 18 Northern California Counties

Data on make and size of motorcycle were available for 31 of the 33 motorcycle injuries. Spinal-cord injury was not related to make of motorcycle (manufacturer). As Table 4 shows, the number of injuries related to an engine capacity of 501 cc or more was over twice the figure expected from the engine sizes for 22,433 registered motorcycles in Sacramento County, California in 1970. Engine size was not related to type of crash.

TABLE 4. OBSERVED AND EXPECTED FREQUENCIES OF SPINAL-CORD INJURY CRASHES BY ENGINE CAPACITY OF THE MOTORCYCLE

Engine Capacity of Motorcycle (in cc's)	Number of Spinal Cord Injury Crashes		
	Observed[a]	Expected[b]	Ratio O/E
< 126	5	14.1	0.4
126 - 500	15	9.9	1.5
501+	7	3.0	2.3
All Sizes	27	27.0	1.0

$\chi^2 = 13.32$, $p < 0.0001$

[a] Police report not located for 3 crashes; characteristics of the motorcycle were not recorded on 3 available reports.

[b] Expected values based on engine capacities for registered motorcycles, Sacramento County, California in 1970.

Information on estimated speed of the motorcycle at time of the crash was not recorded on 16 of the 31 available police reports. In addition, estimated speed recorded by the police officer investigating the injury-producing collision may be biased by the seriousness of the injuries involved.

Severity of the injuries (including the spinal-cord injury) was graded on the 1976 revision of the Abbreviated Injury Scale (AIS). Twelve of the 33 cases were fatalities (9 DOA's, and 3 in-hospital deaths). Table 5 shows injury severity for the most severe injury by type of motorcycle crash. Although the relationship between severity of injury and type of crash could not be tested statistically, it should be pointed out that 10 of 11 crashes from running off the road and 11 of 15 collisions with a second vehicle resulted in a fatality or an AIS grade of 5 (survival uncertain). Note that three of four cases from the motorcycle overturning on the roadway gave severe or serious injuries but survival was probable.

Information on helmet use is not routinely recorded by the investigating police officer on the standard report form.

Blood alcohol levels were determined for 10 of the 12 deaths. Of these, six persons had blood alcohol levels of 0.10 per cent by weight or higher.

TABLE 5. NUMBER OF INJURED MOTORCYCLISTS GRADED BY THE AIS BY TYPE OF MOTORCYCLE CRASH

Type of Motorcycle Crash	Number of Injured Persons				
	Abbreviated Injury Scale (AIS) Description				
	(6) Currently Untreatable	(5) Survival Uncertain	(4) Life-Threatening	(≤ 3) Not Life-Threatening	All Levels
Collision with Fixed Object	1	1	-	-	2
Ran off Roadway	3	7[a]	1	-	11
Overturned on Roadway	-	1	1	2	4
Collision with Second Vehicle	5	6[b]	4	-	15
All Types	9	15	6	2	32[c]

[a] Includes one in-hospital death. [b] Includes two in-hospital deaths.

[c] Excludes one person for whom type of crash was unknown.

Injury Patterns and Clinical Features. Twelve of 33 persons with an injury to the spinal-cord from a motorcycle crash died. Of these, three were in-hospital deaths (one during emergency treatment within an hour of the crash, and, the others two hours and 76 hours after the crash).

Table 6 shows the distribution of injured motorcyclists by the AIS and survivorship status. All nine persons with at least one grade 6 injury died as well as three persons with at least a grade 5 injury. None died with an AIS grade of 4 or less. When the most severe injury graded by the AIS was the spinal-cord lesion, the distribution in AIS score and survivorship status are similar.

TABLE 6. DISTRIBUTION OF MOST SEVERE INJURY AND MOST SEVERE SPINAL-CORD INJURY GRADED BY THE AIS BY LIVING STATUS

AIS Grade	Injury Graded by AIS					
	Most Severe Injury--all Body Locations			Most Severe Spinal-Cord Injury		
	Died	Survived	Total	Died	Survived	Total
6 - Untreatable	9	-	9	8	-	8
5 - Survival Uncertain	3	12	15	4	12	16
4 - Serious (Life-Threatening)	-	7	7	-	5	5
3 - Severe (Not Life-Threatening)	-	2	2	-	4	4
TOTAL	12	21	33	12	21	33

Table 7 shows the distribution for the 33 cases according to the anatomic regions with the most severe injury. For 27 persons the spinal-cord lesion was the most severe injury. In three cases, the most severe injury was not the spinal-cord lesion. In three cases, the most severe injury was the spinal-cord or other body part.

TABLE 7. ANATOMIC REGION OF THE MOST SEVERE INJURY GRADED BY THE AIS

AIS Grade	Anatomic Region of Most Severe Injury Graded							
	Head	Neck	Chest		Abdomen		Extremities	Body Regions With Equal AIS Grades
		Cervical Spinal-Cord	Other Organ	Thoracic Spinal-Cord	Other Organ	Lumbar Spinal-Cord		
6-Untreatable	1	6	-	-	-	-	-	2[a]
5-Survival Certain	-	4	-	8	-	2	-	1[b]
4-Serious (Life-Threatening)	-	1	-	3	2	2	-	-
3-Severe (Not Life-Threatening)	-	1	-	-	-	-	-	-
All AIS Grades	1	12	-	11	2	4	-	3

[a] Head and cervical spinal cord injuries. [b] Cervical and thoracic spinal-cord injuries.

Among the fatalities, the mean number of AIS graded injuries per person was 7.9 (range 3-13 injuries), averaging 10 in those killed when the motorcycle ran off the roadway, and 7 in those killed in a crash with a second vehicle. Among survivors of crashes, injuries per person were 2.5 (range 1-8), averaging three when the vehicle ran off the road or collided with a second moving vehicle. When their vehicle overturned on the road, motorcyclists sustained only a single injury--the spinal-cord lesion.

Of the 33 motorcyclists, 15 sustained an injury to only one of the three major anatomic regions. As can be seen in Table 8 the region involved most commonly was the trunk. For those with injuries to two anatomic regions, the most common was to the head-neck and trunk. Nine motorcyclists had one or more injuries to all three anatomic regions and seven of those died.

Table 8. Distribution of Motorcycle Collision Injuries by Location of Anatomic Regions Involved

Anatomic Regions	Persons with Injuries (Fatalities)	
One Region		
Head-Neck	5	(2)
Trunk	10	(0)
Extremities	0	(0)
Two Regions		
Head-Neck and Trunk	5	(2)
Head-Neck and Extremities	2	(1)
Trunk and Extremities	2	(0)
All Three Regions	9	(7)
One or More Regions	33	(12)

Table 9 shows spinal-cord injuries by anatomic region and type of motorcycle crash. About 47 per cent were in the cervical region, and 34 per cent were located in the thoracic region. The distribution of cervical and thoracic-lumbar spinal-cord injuries was not related to type of crash.

TABLE 9. ANATOMIC REGION OF SPINAL CORD INJURY BY TYPE OF MOTORCYCLE CRASH

TYPE OF MOTORCYCLE CRASH	ANATOMIC REGION				
	CERVICAL (C_1 - C_7)	THORACIC (T_1 - T_{12})	LUMBAR (L_1 - L_5) & CAUDIA EQUINA	MULTIPLE LOCATIONS	ALL LOCATIONS
COLLISION WITH FIXED OBJECT	1/1[a]	0/1	-	-	1/2
RAN OFF ROADWAY	2/3	1/5	0/2	1/1	4/11
OVERTURNED ON ROADWAY	0/3	0/1	-	-	0/4
COLLISION WITH SECOND VEHICLE	6/8	0/4	0/2	1/1	7/15
ALL TYPES	9/15	1/11	0/4	2/2	12/32

[a] #/# = RATIO DEATHS/ALL INJURED PERSONS

Level of neurological impairment was diagnosed for 23 of the 33 injured motorcyclists. Of the nine DOA's, eight had destruction of the cervical spinal-cord which would have resulted in tetraplegia. One showed a transection of the thoracic spinal-cord that would have resulted in paraplegia. There were no survivors with a complete transection of the cervical cord. Nine of 20 survivors had a complete transection of the thoracic spinal-cord (Table 10). Level of neurological impairment was not related to type of motorcycle crash.

TABLE 10. TYPE OF NEUROLOGICAL IMPAIRMENT BY TYPE OF MOTORCYCLE CRASH

TYPE OF MOTORCYCLE CRASH	NEUROLOGICAL IMPAIRMENT				
	TETRAPLEGIA (ALL DEATHS)	TETRAPARESIS	PARAPLEGIA	PARAPARESIS & ALL OTHERS	TOTAL
COLLIDED WITH FIXED OBJECT OR RAN OFF ROADWAY	4	2	5[a]	2	13
OVERTURNED OR COLLIDED WITH SECOND VEHICLE ON ROADWAY	6[b]	2[c]	4	7	19
ALL TYPES	10	4	9	9	32

[a] INCLUDES ONE DOA, [b] INCLUDES 2 IN-HOSPITAL DEATHS, [c] INCLUDES ONE IN-HOSPITAL DEATH

SUMMARY - DISCUSSION

From our incidence data we estimate the number of persons in the United States with a spinal-cord injury from a motorcycle crash to be about 600 per year. About 64 per cent will survive, but most can expect a life with severe impairment. Almost two-thirds of male drivers involved in motorcycle crashes which produce spinal-cord injuries are 15 to 24 years old. No actuarial studies have been attempted of a cohort of persons with spinal-cord injuries.

Even so, persons aged 15 to 24 years with neurologic impairment can anticipate a life expectancy of about 48 years.

Four of five motorcyclists with spinal-cord injuries occurred in a collision with a second vehicle or a roadside object such as trees or bridge abutments. In addition, the spinal-cord injury or all injuries sustained in these crashes were graded mostly untreatable or having uncertain survivability.

One finding of this research was the excessive involvement of motorcycles having intermediate or large-displacement engines. These motorcycles with their greater horsepower and higher speed potential, can lead to a higher level of mechanical energy transfer and more injury to the motorcyclist.

Although no information was available on alcohol blood levels of non-spinal-cord injured motorcyclists, the 6 of 10 deaths with blood levels of 0.10 per cent alcohol by weight underscores the need for stronger measures to prevent the drinking driver from operating a vehicle.

The unprotected motorcyclist is equally vulnerable for cervical or thoracic spinal-cord injuries. Measures to prevent these injuries must focus not only on crash prevention but on minimizing the losses sustained in crashes. For example, our data emphasize not only the need to keep the drinking driver from operating a vehicle but environmental modifications to the roadway to keep motorcycles from leaving the road or striking unyielding objects. In its current configuration, the motorcycle offers little protection in the event of a crash. In almost all instances the driver/passenger was ejected over the front of the vehicle at the time of impact. While helmets have been shown to reduce the incidence of fatalities in motorcycle crashes, current technology offers little help in preventing severe neck, torso, or extremity injuries.

ACKNOWLEDGEMENT

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