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Aviation-Related Injury Morbidity and Mortality: Data from U.S. Health Information Systems

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Abstract

Introduction—Information about injuries sustained by survivors of airplane crashes is scant, although some information is available on fatal aviation-related injuries. Objectives of this study were to explore the patterns of aviation-related injuries admitted to U.S. hospitals and relate them to aviation deaths in the same period.

Methods—The Healthcare Cost and Utilization Project (HCUP) Nationwide Inpatient Sample (NIS) contains information for approximately 20% of all hospital admissions in the United States each year. We identified patients in the HCUP NIS who were hospitalized during 2000–2005 for aviation-related injuries based on the International Classification of Diseases, 9th Revision, codes E840–E844. Injury patterns were also examined in relation to information from multiple-cause-of-death public-use data files 2000–2005.

Results—Nationally, an estimated 6080 patients in 6 yr, or 1013 admissions annually (95% confidence interval 894–1133), were hospitalized for aviation-related injuries, based on 1246 patients in the sample. The average hospital stay was 6.3 d and 2% died in hospital. Occupants of noncommercial aircraft accounted for 32% of patients, parachutists for 29%; occupants of commercial aircraft and of unpowered aircraft each constituted 11%. Lower-limb fracture was the most common injury in each category, constituting 27% of the total, followed by head injury (11%), open wound (10%), upper extremity fracture, and internal injury (9%). Among fatalities, head injury (38%) was most prominent. An average of 753 deaths occurred annually; for each death there were 1.3 hospitalizations.

Conclusions—Aviation-related injuries result in approximately 1000 hospitalizations each year in the United States, with an in-hospital mortality rate of 2%. The most common injury sustained by aviation crash survivors is lower-limb fracture.

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Keywords

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Knowledge of injuries and the mechanisms of injuries sustained by victims of aviation mishaps are important for crash reconstruction, evaluation, and improvement of aircraft design and safety equipment, and resolution of medicolegal issues. Previous research, based primarily on autopsy or death certificate data, has revealed the predominant role of head injury caused by blunt trauma in aviation-related fatalities in both civil and military flights (8,12,15). Information about serious nonfatal injuries, however, has been lacking for civil aviation crashes because the National Transportation Safety Board (NTSB) and Federal Aviation Administration (FAA) do not systematically record injury data for crash survivors. Consequently, to find data on injuries to survivors of aircraft crashes or other aviation-related events, other data sources must be used. The present study was undertaken to determine the number and types of injuries present in hospitalized survivors of aviation crashes and non-crash events such as parachuting mishaps. Information on all fatally injured persons was also obtained in order to estimate the total injury burden associated with aviation.

METHODS

The Healthcare Cost and Utilization Project (HCUP) Nationwide Inpatient Sample (NIS) is a data system sponsored by the Agency for Healthcare Research and Quality that contains information for approximately 20% of all hospital admissions in the United States (1). Using the International Classification of Diseases, 9th edition, codes for air transport accidents (E840–E844), we identified patients in the NIS who were hospitalized through emergency or urgent admissions for aviation-related injuries during 2000–2005. Users of the hospitalization data are not permitted to publish numbers based upon fewer than 11 patients. Mortality data came from the National Center for Health Statistics' multiple-cause-of-death public-use data files for 2000–2005 (14). Aviation-related deaths were identified using International Classification of Diseases, 10th edition, codes for air transport accidents (V95.0-V95.3, V95.8, V95.9, V96, V97).

The estimated frequency distribution of aviation-related injuries in hospitalized patients was tabulated by victim type, discharge status, and length of stay. Frequencies were estimated based on weighted analysis of the HCUP NIS data. HCUP NIS discharge weights are equal to the number of universal discharges it represents in a stratum during that year (1). Injury- and victim-type-specific hospital case-fatality rates were estimated as the percentage of hospitalizations for aviation-related injuries that died in the hospital. Statistical analysis was performed using SAS version 9.2 (SAS Institute, Inc., Cary, NC). The study was based on publicly available data and was exempted from review.

RESULTS

Hospitalized Patients

During the 6-yr study period, an estimated 6080 patients were admitted to U.S. short-term hospitals with aviation-related injuries, based upon weighted analysis of the 1246 admissions captured by the HCUP NIS. The annual average number of patients was 1013 [95% confidence interval (CI) 894–1133]. The largest categories of patients were occupants of civilian, noncommercial, powered aircraft (primarily general aviation) (32%) and parachutists (29%). Occupants of commercial aircraft and unpowered aircraft each constituted 11% of the total. There were 17% of the patients coded as 'other', which included ground workers as well as passengers or crew injured outside the airplane.

A total of 9056 injuries (weighted number), averaging 1.5 diagnoses per patient, were listed on the hospital discharge records. It was possible to code as many as 19 diagnoses for any patient. Lower limb fractures were the most common injury and constituted 27% of all hospitalized injuries (Table I). Lower limb fractures were especially prevalent in parachutists, constituting 46% of their injuries. They were also the most common injury in each victim category: 28% of injuries to occupants of commercial aircraft, 22% of injuries to occupants of un-powered aircraft, and 17% of injuries to occupants of noncommercial aircraft. Head injuries were the second most common injury, constituting 11% of all injuries and 13% of injuries to occupants of noncommercial aircraft. Open wounds constituted 10% of all injuries, while upper-extremity fractures and internal injuries each constituted 9% of all injuries.

Of the estimated 6080 hospital patients, 1114 (18%) were transferred to facilities other than short-term hospitals. The mean length of stay for all 6080 patients was 6.3 (95% CI 5.8–6.8) d. Of the injured, 75% were male. In terms of age, 71% of patients were ages 20–59. The 40–49-yr age group was largest, with 22% of all patients. An estimated 120 patients (weighted number) died in the hospital, resulting in an inpatient case-fatality rate of 2%. Based upon the primary injury diagnosis, the highest case-fatality rates were for injuries to blood vessels, burns, and head injuries (39%, 13%, and 8%, respectively).

Fatality Data

Multiple-cause-of-death data for 2000–2005 revealed that 4517 aviation-related deaths occurred in the United States, an average of 753 per year. The ratio of hospitalized cases to total deaths was 1.3 (Table II). Analysis of the multiple-cause-of-death data by category of victim showed that 87% of persons who died were occupants of powered aircraft that were not categorized as commercial. Of fatally injured victims, 7% were occupants of commercial aircraft and 3% were parachutists. The patients with the highest ratio of hospital cases to deaths (i.e., the lowest risk of death) were parachutists and ‘ others ’. The patients with the highest risk of death were occupants of noncommercial aviation; these victims, with only half as many hospital admissions as deaths, were primarily those injured in general aviation crashes.

Comparison of the results of multiple-cause-of-death data analyses with mortality data from the NTSB for the same period (9) indicated close agreement in the total number of aviation deaths during 2000–2005. The NTSB reported 4555 deaths, less than 1% more than the number of deaths in the multiple-cause-of-death files. (A direct comparison, involving matching of individual cases, was not permitted under the terms of use of the multiple-cause-of-death data files.)

DISCUSSION

The present study is the first published analysis of aviation-related hospitalized injuries and deaths in the United States. The enumeration of all such deaths during the 6-yr 2000–2005 period plus a reliable estimate of hospitalized patients in the same years allows us to calculate a ratio of 1.3 hospital admissions for each death (the 2% overlap involving the in-hospital deaths has a negligible effect on this ratio). The annual number of deaths published by the NTSB agrees closely with our analyses of the multiple-cause-of-death data and, therefore, can be used in conjunction with this ratio; this possibility helps us to understand the magnitude of the problem of aviation deaths and injuries.

In New Zealand, Chalmers et al. (4) reported on 120 hospitalizations of aircraft occupants in a 6-yr period (1988–1993) and 104 deaths in 5 of those years. Adjusted to 5 yr, the ratio of 100 to 104 (0.96 to 1) is substantially lower than the U.S. ratio of 1.3 to 1 determined in our analysis. The lower ratio in New Zealand may result from the exclusion of parachutists, who on average are less seriously injured, in the Chalmers et al. study. Other factors that could have contributed to the lower injury-death ratio in New Zealand might be more stringent admission criteria and a larger proportion of general aviation flights among all aviation crashes.

Our results describing the injuries of hospital patients provide valuable information, not elsewhere available, on the kinds of injuries incurred in aviation-related events. The NTSB collects injury data on occupants in some fatal airline crashes and publishes the annual number of injuries in airline (Part 121) crashes (10). Otherwise, injury data are not published, nor are injury data available for other categories of aviation. Knowledge of the nature of injuries sustained, especially by aircraft occupants, is important for several reasons. First, data on injuries can inform crash reconstruction and help us to recognize needed changes in aircraft design. Most occupant injuries occur in general aviation crashes and some injuries could be prevented through changes in the designs of general aviation aircraft (7,15). The prominence of lower limb fractures in hospitalized patients in this study and in the fatality study reported by Wiegmann and Taneja (15) underscores the potential value of modifications to the various structures likely to be contacted by feet and legs when a crash occurs. In New Zealand, Chalmers et al. (4) also found that the most common injury in crashes of fixed-wing aircraft was to the lower extremities, while spinal injuries were more common in helicopter crashes.

Occupant injuries to the head and internal organs of the chest and abdomen point to the need to consider changes in aircraft controls. Similar to the placement of an automobile steering wheel, the position of the wheel or stick immediately in front of the pilot's torso makes it a likely contributor to injury, even among restrained occupants (7,12). Military studies have shown that injury from aircraft controls accounted for approximately 5% of injury sources in survivable crashes for which sources of injury were identified (12); therefore, side-mounted controls have been recommended for both safety and comfort. This configuration is found in all Airbus aircraft and some military aircraft. Since forces are generally frontal, it make sense to eliminate, wherever feasible, hazards that are placed in front of pilots. Moreover, many general aviation aircraft still in use do not have upper torso restraints or have a detachable shoulder belt. As in autos, upper torso restraint should not be optional.

Our results are also pertinent to injured parachutists, whose lower-extremity fractures constituted almost half of all their injuries, suggesting the potential value of leg braces or other protection devices for the lower extremities as well as lower-velocity parachute canopies and, perhaps, modifications in landing fall procedures. Other studies of sports parachuting and military parachuting have produced similar findings of a high incidence of lower extremity injuries, particularly ankle injuries (2,5,6). The value of leg braces has been clearly demonstrated in studies of U.S. Army Airborne Rangers, where the use of an external ankle brace reduced the incidence of ankle injuries by 67% (13). Also, a controlled study of ankle brace use by students in airborne training showed that students who did not use the brace were almost two times as likely to suffer an ankle injury during a landing as their counterparts using the ankle brace (6).

Secondly, our results can provide hospitals with useful planning information on the spectrum of likely injuries when they are expected to receive victims of an aircraft crash. Extremity fractures, for example, are likely to be present in one-third of aviation-related injury patients, and head and internal injuries are each seen in about one-tenth of patients. Burns, while a major contributor to aviation deaths, were seen in only 2.5% of hospitalized patients. Nevertheless, hospitalized burn patients had a high case-fatality rate (13%), accounting for 17% of deaths among aviation victims. The case-fatality rate for hospital cases indicates the degree to which each type of injury is likely to be life threatening to patients admitted following aviation mishaps. The highest case-fatality rate, 39%, was in patients with injury to blood vessels, followed by burn patients (13%), and patients with head injury (8%).

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Finally, hospitalization data may help to reveal changes over time in the patterns of injuries in aviation mishaps. This can help to document the effectiveness, or lack thereof, of changes made to aircraft design, personal protective equipment, or regulations and procedures. For example, changes in the numbers of thermal injuries and their proportions among aviation injuries in recent decades have been difficult to assess due to questions as to whether burns occurred before or after death. Wiegmann and Taneja (15), studying autopsy data for general aviation pilots, reported that in 1996–1999, antemortem burns were present in 9% and postmortem burns in 24%. Li et al. (8), studying U.S. death certificates for all aviation-related fatalities in 1980 and 1990, found that burns were 4% and 3%, respectively, of the injuries recorded for aviation deaths in those years. They also noted a decrease in the annual number of fatalities with burn injuries, from 188 in 1980 to 90 in 1990. This suggests a decrease in burn injuries, although whether ante- and postmortem burns were consistently differentiated in those two periods is not known.

The limitations of this research include the lack of detailed information available from multiple-cause-of-death files and hospital data. Wiegmann and Taneja's (15) autopsy data, collected by the FAA at the Civil Aeromedical Institute for 44% of general aviation pilots killed during 1996–1999, contains valuable detail that was not available to us, who relied on multiple-cause-of-death files. Nevertheless, as noted by Wiegmann and Taneja (15), the fact that only 44% of pilot fatalities had autopsy data available limits researchers' ability to draw meaningful conclusions from the data. Comparisons between their study and ours are difficult because of the low autopsy rate in the Wiegmann and Taneja study and because their study was limited to general aviation. Ideally, all aviation deaths should result in autopsy and the findings should be part of the NTSB database.

Hospital data have limitations because coders are restricted to codes available in the ICD and because details of the crash, including airplane type, operational details, and circumstances, may not have been available in the medical record or may have been erroneous because hospital personnel have to rely on others for such information. Although it is unlikely that a person injured in an aviation mishap would not be coded with some form of aviation code (thus contributing to the likelihood that the total number would be close to correct), we do not know how accurate the specific coded data are. It is unlikely that hospital coders can correctly determine, for example, the type of operation in all cases.

Because this paper examines fatal and nonfatal crashes, as well as aviation-related non-crashes and mishaps, many disparate categories of patients and operations are included. This makes it impossible to capitalize on all of the information that may be available on each case. On the other hand, this paper provides an overview of the myriad aspects of aviation and its resulting human damage.

The various military services have established highly effective surveillance and reporting systems for all aviation crashes and incidents, including the collection of detailed medical data, data concerning the use and performance of protective equipment, and detailed analysis of the crash forces and circumstances. These data have contributed significantly to improvements in crashworthiness of military aircraft over the years by providing detailed data on crash injuries and the incidence and causes of these injuries. These data identify where crash-worthiness problems exist and can be used to provide cost-benefit analyses of proposed improvements. The use of such data is probably best illustrated by the development and subsequent improvements to the Army's UH-60 Blackhawk helicopter (3,11). Unfortunately, a comparable system does not exist in the civil arena. Consequently, it is difficult for researchers to identify crashworthiness problems in particular aircraft or to estimate the magnitude of the problem or the technical and economic feasibility of proposed improvements. Recognizing the deficiency in available information, the Aerospace Medical Association passed a resolution in 2007 that

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standardized national databases be established "to record civil aircraft utilization and impact data, occupant exposure and injury data, and injury mechanism data; which should be made readily available to safety researchers" (16).

This study and others have documented the inadequacy of injury surveillance for civil aviation crashes in the United States and the consequences of the lack of such data. We strongly recommend that the NTSB and/or FAA establish a program similar to those of the military services or similar to the National Automotive Sampling System of the National Highway Traffic Safety Administration.

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TABLE I

AVIATION-RELATED INJURIES TREATED IN HOSPITALS, WEIGHTED ESTIMATES, BY VICTIM TYPE AND INJURY DIAGNOSIS, HEALTHCARE COST AND UTILIZATION PROJECT NATIONWIDE INPATIENT SAMPLE, UNITED STATES, 2000–2005.

Injury Diagnosis (ICD-9 Code)	Occupant of Commercial Aircraft (*N* = 643)	%	Occupant of Noncommercial Aircraft† (*N* = 1970)	%	Occupant of Unpowered Aircraft* (*N* = 665)	%	Parachutist* (*N* = 1756)	%	Other Person** (*N* = 1045)	%	Total (*N* = 6080)	%
Head Injury (800–804, 850–854)	56	7.5	486	12.9	85	9.5	185	7.8	161	12.5	973	10.7
Internal Injury (860–869)	19	2.6	406	10.8	127	14.2	181	7.6	97	7.6	830	9.2
Burns (940–949)	20	2.7	168	4.4	*	*	*	*	15	1.2	218	2.4
Injury to joint/muscle (840–848)	60	8.1	116	3.1	39	4.4	104	4.4	52	4.0	371	4.1
Lower-limb fracture (820–829)	211	28.4	647	17.2	197	22.0	1083	45.8	264	20.6	2402	26.5
Open wound (870–879)	55	7.4	590	15.6	51	5.7	73	3.1	135	10.5	904	10.0
Upper-limb fracture (810–819)	83	11.2	377	10.0	91	10.2	106	4.5	188	14.6	845	9.3
Other injury‡	238	32.1	980	26.0	293	32.8	630	26.6	372	29.0	2513	27.8
Total Injury Diagnoses§	742	100.0	3770	100.0	893	100.0	2367	100.0	1284	100.0	9056	100.0

* Represent fewer than 11 patients, unweighted; the numbers are included in the totals.

† Includes general aviation, military, and other powered aircraft.

§ Up to 19 diagnoses per patient were counted.

‡ Includes International Classification of Disease, Clinical Modification, 9th Edition (ICD-9), Nature of Injury Codes 850–900 that are not captured in any other category.

** Other person is defined by the 4th digit of the ICD-9 code.

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TABLE II

AVIATION-RELATED INJURY HOSPITALIZATIONS AND DEATHS AND RATIO OF HOSPITALIZATIONS TO DEATHS BY VICTIM TYPE, UNITED STATES, 2000–2005.

Type of Victim	Number of Hospitalizations	%	Number of Deaths	%	Hospitalization-to-Death Ratio
Occupant of commercial aircraft	643	10.6	333	7.4	1.9
Occupant of noncommercial aircraft	1970	32.4	3943	87.3	0.5
Occupant of unpowered aircraft	666	10.9	68	1.5	9.8
Parachutist	1756	28.9	145	3.2	12.1
Other	1045	17.2	28	0.6	37.3
Total	6080	100.0	4517	100.0	1.3